ASSOCIAZIONE ITALIANA
DI AGROMETEOROLOGIA
XX CONVEGNO NAZIONALE

UNIVERSITÀ
DEGLI STUDI
DI MILANO

DiSAA

SOCIETÀ ITALIANA
DI AGRONOMIA
XLVI CONVEGNO NAZIONALE

AIAM SIA MILANO 2017

STRATEGIE INTEGRATE PER AFFRONTARE LE SFIDE CLIMATICHE E AGRONOMICHE NELLA GESTIONE DEI SISTEMI AGROALIMENTARI

INTEGRATED STRATEGIES FOR AGRO-ECOSYSTEM MANAGEMENT TO ADDRESS CLIMATE CHANGE CHALLENGES

MILANO
12 - 14 SETTEMBRE 2017

A CURA DI
FRANCESCA VENTURA
GIOVANNA SEDDAIU
GABRIELE COLA

DIPARTIMENTO DI SCIENZE AGRARIE - UNIVERSITÀ DI BOLOGNA

AIAM SIA MILANO 2017

STRATEGIE INTEGRATE PER AFFRONTARE LE SFIDE CLIMATICHE
E AGRONOMICHE NELLA GESTIONE DEI SISTEMI AGROALIMENTARI

INTEGRATED STRATEGIES FOR AGRO-ECOSYSTEM MANAGEMENT TO
ADDRESS CLIMATE CHANGE CHALLENGES

XX CONVEGNO NAZIONALE DELL'ASSOCIAZIONE ITALIANA DI AGROMETEOROLOGIA (AIAM)

XLVI CONVEGNO NAZIONALE DELLA SOCIETÀ ITALIANA DI AGRONOMIA (SIA)

Strategie integrate per affrontare le sfide climatiche e agronomiche nella gestione dei sistemi agroalimentari

Integrated strategies for agro-ecosystem management to address climate change challenges

Milano
12 - 14 settembre 2017

a cura di
Francesca Ventura
Giovanna Seddaiu
Gabriele Cola

Dipartimento di Scienze Agrarie
Università di Bologna

ISBN 9788898010707
DOI 10.6092/unibo/amsacta/5692

COMITATO SCIENTIFICO
Francesca Ventura (Vicepresidente AIAM)
Giovanna Seddaiu
Gabriele Cola

COMITATO ORGANIZZATIVO
Luca Bechini
Stefano Bocchi
Gabriele Cola
Pietro Marino
Alessia Perego

SEGRETERIA ORGANIZZATIVA
Federico Spanna (Presidente AIAM)
Simone Falzoi
Tiziana La Iacona
Irene Vercellino

Grafica di copertina realizzata da Matteo Grandi

Bologna, 2017

INDICE

SESSION 1 "AGRO-ENVIRONMENTAL INNOVATIONS TO SUPPORT THE AGRICULTURAL POLICIES"
ORALI

POSTER

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

SESSIONE 2 " STRATEGIE DI PIANIFICAZIONE, GESTIONE E MONITORAGGIO DELL'AGROECOSISTEMA E DELLE FILIERE PRODUTTIVE"

ORALI

POSTER

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

DOI 10.6092/unibo/amsacta/5692

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

SESSIONE 3 "SOLUZIONI OPERATIVE E NUOVE TECNOLOGIE PER UN USO OTTIMALE DELLE RISORSE"

ORALI

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

POSTER

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

IS IT POSSIBLE TO COMBINE CONTRASTING AGRO-ENVIRONMENTAL OBJECTIVES? THE DILEMMA BETWEEN INCREASING SOIL ORGANIC CARBON AND MITIGATING METHANE EMISSIONS WITH RICE STRAW MANAGEMENT

È POSSIBILE COMBINARE OBIETTVI AGRO-AMBIENTALI CONTRASTANTI? IL DILEMMA TRA L'AUMENTO DELLA SOSTANZA ORGANICA DEL SUOLO E LA MITIGAZIONE DELL'EMISSIONE DI METANO NELLA GESTIONE DELLE PAGLIE IN RISAIA

Chiara Bertora[1*], Maria Alexandra Cucu[1], Cristina Lerda[1], Matteo Peyron[1], Daniel Said-Pullicino[1], Roberta Gorra[1], Laura Bardi[2], Luisella Celi[1], Carlo Grignani[1], Dario Sacco[1]

[1] Dipartimento di Scienze Agrarie, Forestali e Alimentari, Largo Braccini 2, 10095 Grugliasco (TO)
[2] CREA-IT, Area di Ricerca di Torino, Strada delle Cacce, 73, 10135 Torino
*chiara.bertora@unito.it

Abstract
Rice cultivation is the major source (11%) of global methane (CH_4) emissions. The main drivers of CH_4 fluxes are substrate availability and soil redox conditions, directly linked to straw and water management. Straw incorporation, that represents the most important source of C for paddy soils, may be framed within the measures of the rural development policy aimed at enhancing soil organic matter, particularly in Italian rice paddies that generally suffer from low organic matter contents. In the present study, we considered alternative options to the typical technique adopted in the Italian rice district that involves spring incorporation of straw and water seeding (SPR). These included autumn incorporation (AUT), straw removal (REM), and dry seeding (DRY). Treatments were monitored for CH_4 emissions and soil pore water DOC concentrations, along with changes in the methanogenic microbial abundances. All the considered alternative management options were effective, to various extents, in mitigating CH_4 emissions from rice paddies, with respect to the most widespread technique involving continuous flooding after spring incorporation of straw. Separating the moment of straw incorporation from the establishment of flooded conditions more than what happens for treatment SPR can, in fact, lead to a reduction in CH_4 emissions by 46% when straw is removed (treatment REM), by 48% in case of autumn incorporation (AUT), and up to 69% if rice is dry seeded (DRY).

Keywords: Greenhouse gas, Crop residue, Dissolved Organic Carbon, Methanogens.
Parole chiave: Gas a effetto serra. Residui colturali, Carbonio Organico Disciolto, Metanogeni.

Introduction
Rice cultivation is the major source (11%) of global methane (CH_4) emissions, one of the main greenhouse gases (Smith et al. 2014). Straw and water management practices influence the input of organic matter serving as substrate for methanogenic microorganisms, soil redox conditions and consequently the methanogenic activities that all influence CH_4 emissions. In the present study, we considered different options for the combined management of straw and water aiming at limiting substrate availability and methanogenesis therefore mitigating CH_4 emissions.

Materials and Methods
The field experiment was carried out within a long-term experimental platform located in the plain of the Po river (45°17′47″N, 8°25′51″E; Vercelli, NW Italy). Field treatments provided the comparison of four crop residue and/or water management systems, i.e. (a) tillage and crop residue incorporation in spring followed by water seeding, typical of the area (SPR); (b) tillage and crop residue incorporation in spring in combination with dry seeding and 1-month delayed flooding (DRY); (c) tillage and crop residue incorporation in autumn with water seeding in the following spring (AUT); (d) post-harvest straw removal, tillage in spring and water seeding (REM). Treatments were monitored for CH_4 emissions (Peyron et al. 2016), soil pore water DOC concentration (Said-Pullicino et al. 2016), methanogens abundances (Sharma et al., 2011).

Results and Discussion
Crop residue and water management significantly influenced the intensity and seasonal pattern of CH_4 emissions during the cropping cycle (Fig. 1). Major differences among treatments were observed during the early vegetative stage (from seeding to tillering) where SPR showed the highest fluxes, DRY the lowest, while AUT and REM intermediate values. Treatment SPR showed higher cumulative fluxes also during the late vegetative (from tillering to panicle initiation) and reproductive

(from panicle initiation to flowering) stages. In contrast, lowest cumulative emissions were registered for DRY in the late vegetative and ripening (from flowering to harvest) stages, while REM in the reproductive stage. Cumulative emissions over the whole cropping season showed that the most CH_4-emitting treatment was SPR, followed by REM, which was statistically lower than SPR and higher than DRY, then by AUT and finally by DRY (Fig. 2). We observed strong correlations between DOC concentrations in the topsoil and CH_4 fluxes in all treatments, except AUT, suggesting that DOC may generally be linked to substrate availability for CH_4 production and this is mainly true when crop residue incorporation in spring was presumably responsible for the presence of important amounts of more labile C after the onset of flooding. Among microbial abundances, a significant correlation with CH_4 emissions was found for methanogenic communities, showing a functional link between the presence of these communities and the net result (measured) of their activities (not measured).

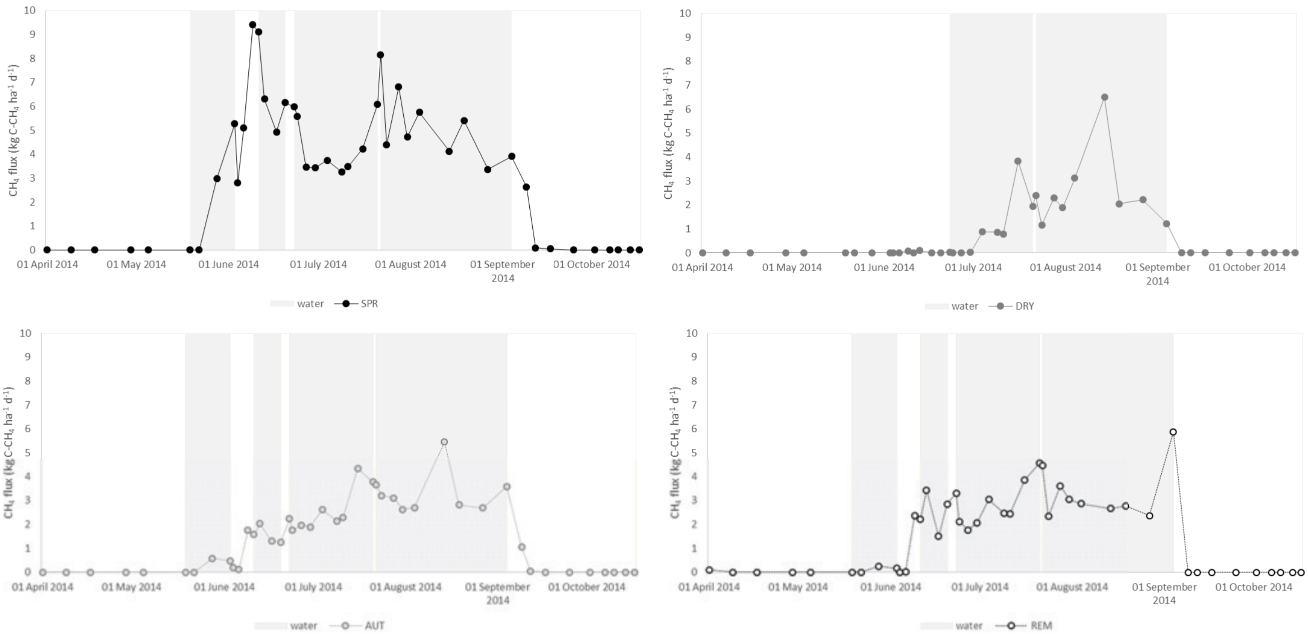


Fig. 1: Seasonal variations of CH_4 emission fluxes over the cropping seasons as a function of treatments of crop residue and water management practices involving spring incorporation (SPR), spring incorporation and dry seeding (DRY), autumn incorporation (AUT), and straw removal (REM).
Fig. 1: Andamento giornaliero delle emissioni di CH_4 durante il ciclo colturale del riso, in funzione dei trattamenti di gestione dei residui colturali e dell'acqua, che prevedono l'incorporazione primaverile della paglia (SPR), l'incorporazione primaverile associata alla semina in asciutta (DRY), l'incorporazione autunnale della paglia (AUT) e la rimozione della paglia (REM).

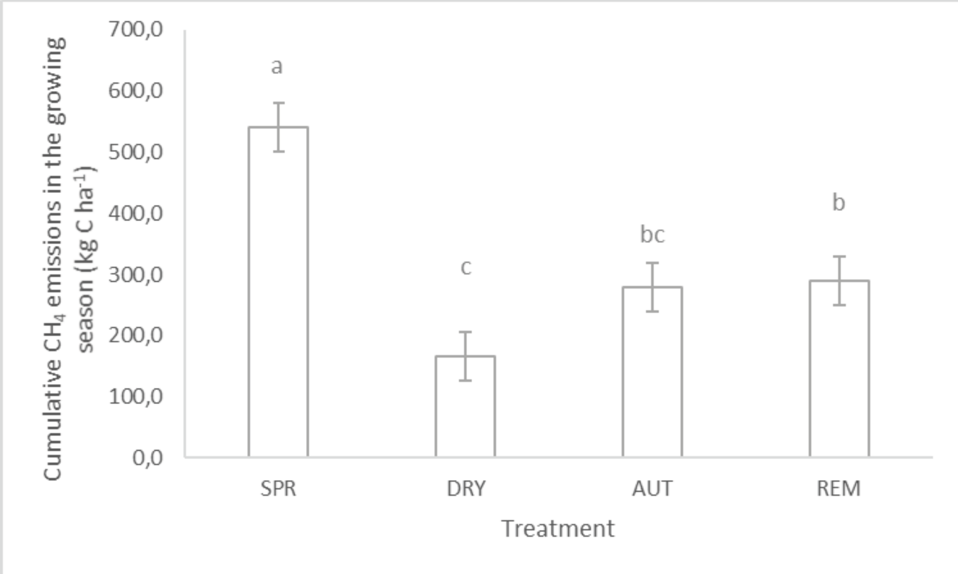


Fig. 2: Cumulative emissions of CH_4 during rice cropping cycle.
Fig. 2: Emissioni cumulate di CH_4 nel ciclo colturale del riso.

Conclusions

All the considered management options were effective, to various extents, in mitigating CH_4 emissions from rice paddies, with respect to the most widespread technique, involving continuous flooding after spring incorporation of straw. Separating the moment of straw incorporation from the establishment of flooded conditions can, in fact, lead to a reduction in CH_4 emissions by 46 up to 69% in the order straw removal < autumn incorporation < dry seeding. Therefore it is more valuable the proper timing of straw incorporation than its complete removal, thus preserving the role of crop residue in SOC safeguard and restoration.

References

M. Peyron, C. Bertora, S. Pelissetti, D. Said-Pullicino, L. Celi, E.F. Miniotti, M. Romani, D. Sacco 2016. Greenhouse gas emissions as affected by different water management practices in temperate rice paddies. Agric Ecosyst Environ 232:17-28.

D. Said-Pullicino, E.F. Miniotti, M. Sodano, C. Bertora, C. Lerda, E.A. Chiaradia, M. Romani, S. Cesari de Maria, D. Sacco, L. Celi 2016. Linking dissolved organic carbon cycling to organic carbon fluxes in rice paddies under different water management practices. Plant Soil 401: 273-290.

P. Smith, M. Bustamante, H. Ahammad, H. Clark, H. Dong, E.A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N.H. Ravindranath, C.W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling, F. Tubiello 2014 Agriculture, Forestry and Other Land Use. In: Edenhofer O, Pichs-Madruga R, Sokona Y, Farahani E, Kadner S, Seyboth K, Adler A, Baum I, Brunner S, Eickemeier P, Kriemann B, Savolainen J, Schlömer S, von Stechow C, Zwickel T, Minx JC (eds.) Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Sharma R., Ryan K., Hao X., Larney F. J., McAllister T. A., Topp E. (2011). Real-time quantification of mcrA, pmoA for methanogen, methanotroph estimations during composting. J. Environ. Qual. 40 199–205

INNOVATION PARTNERSHIP: INTEGRATED STRATEGIES TO ADDRESS AGRO-ENVIRONMENTAL-CLIMATE CHALLENGES IN THE RDPS 2014-2020
PARTENARIATI PER L'INNOVAZIONE: STRATEGIE INTEGRATE PER AFFRONTARE LE SFIDE AGRO-CLIMATICO-AMBIENTALI NEI PSR 2014-2020

Maria Valentina Lasorella[1], Federica Cisilino[2]

[1, 2] CREA, Council for Agricultural Research and Analysis of Agricultural Economics – Policies and Bioecomics Centre
Corresponding author e-mail: mvalentina.lasorella@crea.gov.it, federica.cisilino@crea.gov.it

Abstract

The common agricultural policy for the 2014-2020 period has four main objectives: ensuring efficient food production, ensuring sustainable management of natural resources, facing climate change and contributing to balanced territorial development. The realization of these goals requires the creation and application of new technologies, new products, new organizational models and a strengthened ability to cooperate and disseminate the acquired knowledge. This is taking place by adopting the multi-stakeholder approach and joint programming between Member States in research policy and introducing a specific tool to support innovative solutions, the so-called European Innovation Partnership (EIP). In Italy, the possibility of introducing innovative solutions in agriculture through the implementation of EIP-Agri was also of great interest with the planned training and funding of 625 GOs. Lazio with 165 operational groups expected and Emilia-Romagna with 116 are the leading Regions.

Keywords:. EIPs, Measure 16, Rural Development Policy, RDPs, stakeholders, agro-environmental-climate strategies
Parole chiave: Partenariati per l'innovazione, Misura 16, PSR, portatori d'interesse, strategie agro-climatico-ambientali

Introduction

One of the major innovation of the 2014-2020 programming is EIP-Agri: as well as increasing the chances of access to funding, this could be the most significant key for European agriculture's development process. EIP's activities on productivity and sustainability in agriculture are funded under the Second Pillar of the Common Agricultural Policy and the Horizon 2020 Framework Program. The purpose of the EIP-Agri is to facilitate the exchange between agricultural and research world and to assist Agricultural and forestry sectors to become more productive, more sustainable and capable of addressing the challenges posed by the market, as well as those related to environmental protection and climate change.

Networking could turn into an important success factor for the rural policy programming 2014-2020, increasing the chances of access to public funds and providing common socio-economic-environmental goods. Farmers can take advantage from a collective approach because they can adopt environmentally friendly farming practices on a larger scale and provide PG more effectively since their neighbouring farmers do the same (OECD, 2013). The EU gives priority to aggregation/integration of multiple actors operating in the same or in different sectors for the implementation of the RDPs, not only in a perspective of enhancing the production chain, but also as regards the environmental challenge to improve sustainability. Three are the main types of participants in collective actions: farmers (providing labour), non-farmers (providing expertise), Governments (providing policy measures - funds). Measure 16 Co-operation (art. 35 - 2 g Reg.EU 1305/2013) and 16.5 in particular, highlights the need to develop synergies in the provision of environmental services. The territorial dimension of environmental public goods, in fact, requires the adoption of collective approaches in the design and implementation of measures aimed at optimizing the production of environmental benefits like the adaptation to climate change and its mitigation, conservation and enhancement of the landscape, biodiversity preservation, sustainable management of water resources and soil protection, the rational use of renewable resources, with more effective results and consistent with those that can be achieved by operating individually. Considering P4 and P5 some other measures allow collective access to funds such as measures 10, 11, 4.4 (Vanni F, Cisilino F. 2017). In this study the attention is focused on measure 16.

EIPs act across the whole research and innovation chain, bringing together all relevant actors at EU, national and regional levels. The implementation of EIPs is based on an interactive model of innovation, encouraging collaboration between different categories of actors to make the best use of knowledge available in different fields (scientific knowledge, practices, managerial, organizational). Interactive innovation encourages the transformation of research results into practical applications and the creation of new ideas through interaction and exchange of knowledge between actors involved in a given project.

Materials and Methods
Information from Regional RDPs have been processed to evaluate the adopted strategis for each Region in Italy and the amount of budget allocated for the 16 measures under the priority 4 an 5 which are designed to encourage farmers to protect and enhance the environment on their farmland.
Operational Groups (OG) are funded nationally/regionally by RDPs and involve different types of actors and are designed to implement a specific project that addresses a practical problem or an opportunity that could lead to the introduction of an innovation. The implementation of the EIP-Agri is provided within the measure 16 cooperation of the RDPs, in particular sub-measure 16.1 "Support for the establishment and functioning of the IEP operational groups on the productivity and sustainability of agriculture", specifically addressed to the OG, and 16.2 "Support for pilot projects and the development of new products, practices, processes and technologies", which can be used to support actions carried out by OG, but also to fund projects not directly related to them. Most of the Italian Regions opted for the combination of the two subtypes 16.1 and 16.2. In order to understand the strategies adopted by Italian Regions to address agro-environmental-climate challenges, the financial plans of RDPs 2014-2020 (regional level) are taken into account in order to highlight the allocation of funds for these two sub-measures. In addition, a deep analysis on sub-measure 16.5. “Collective approaches to environmental projects/practices” have been carried out to evaluate which are the main problem/opportunity identified and to understand different interactions between the actors involved.

Results and Discussion
The analysis focus on the second Pillar of CAP: after a review the Reg. EU 1305/2013, the financial plans of Italian RDPs 2014-2020 (regional level) are taken into account in order to highlight the allocation of funds. This allows some remarks, revealing the strategy of the regions regarding a collaborative approach aimed at encouraging both innovative environmental projects and the development of PG. In Italy, the possibility of introducing innovative solutions in agriculture through the implementation of EIP-Agri is of great interest with the planned training and funding of 625 GOs. Lazio with 165 operational groups expected and Emilia-Romagna with 116 are the leading Regions.

Conclusions
The debate about public intervention through CAP is mainly based on the role – social and environmental – of agriculture. Farmers have a significant role in conserving natural resources. Moreover, sustainable agricultural activities can provide a large number of services relating to social, economic and environmental aspects and sustainability. One of the main benefits deriving from collaborative approaches is the geographical scale because this approach allow a tailored answer to well-known local specific needs (landscape, biodiversity). But there is also a reduction of costs as those related to the implementation of farm practices, or costs arising from the management of a complex task (as irrigation). Furthermore, the sharing of skills and information enhance farmers’ capacity and involve in this developing process different stakeholder and institution (increasing the chance for innovation). Through the analysis of measure 16 of Italian RDPs it is possible to understand the willing of local policies but only one step further, that of the implementation of the interventions, it will be possible to see what will be the effects on the environment and on climate change.

References
CREA-Rete Rurale Nazionale, 2016. Lo stato di avanzamento delle sottomisure 16.1 e 16.2 dei PSR 2014-2020, Mipaaf, Roma

OECD,2013. Providing agri-environmental public goods through collective action. OECD Publishing, Paris.

Vanni F., Cisilino F., 2017. I progetti agro-ambientali collettivi nella politica di sviluppo rurale 2014-2020, Rete Rurale Nazionale, Mipaaf, Roma

SERVICES FOR AGRICULTURE FROM COPERNICUS SPACE COMPONENT. THE SENSAGRI PROJECT

SERVIZI PER L'AGRICOLTURA DALLA COMPONENTE SPAZIALE COPERNICUS. IL PROGETTO SENSAGRI

Michele Rinaldi [1]*, Angelo Pio De Santis[1], Salvatore Antonio Colecchia[1], Carmela Riefolo[2], Alessandro Vittorio Vonella[2], Anna Balenzano[3], Sergio Ruggieri[2]

[1] *Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA) – Centro di Ricerca Cerealicoltura e Colture Industriali (CI) – S.S. 673, km 25,200 – 71122 Foggia, Italia*
[2] *Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA) – Centro di Ricerca Agricoltura e Ambiente (AA), Via Celso Ulpiani, 5 – 70125 Bari, Italia*
[3] *Consiglio Nazionale delle Ricerche (CNR), Istituto di Studi sui Sistemi Intelligenti per l'Automazione (ISSIA), via Amendola 123/D, Bari, 70126, Italy*
* michele.rinaldi@crea.gov.it

Abstract
In the emerging Copernicus Earth monitoring era, Europe provides Earth Observation (EO) data from Sentinel-1 (S1) and Sentinel-2 (S2) on a free and open data policy basis. In response of the EO Work programme "EO-3-2016: Evaluation of Copernicus Services", Sentinels Synergy for Agriculture (SENSAGRI) aims to exploit the synergy of optical and radar measurements to develop three prototype services capable of near real time operations: (1) surface soil moisture, (2) green and brown leaf area index and (3) crop type mapping. These prototypes shall provide a baseline for advanced services that can boost the competitiveness of the European agro-industrial sector. SENSAGRI proposes four advanced proof-of-concept services: (i) yield/biomass, (ii) tillage change, (iii) irrigation and (iv) advanced crop maps. The algorithms will be developed and validated in four European agricultural test areas in Spain, France, Italy and Poland and their usefulness demonstrated in other non-European countries. In order to refine the specifications of the products and to iteratively assess the services, actors of the agricultural sector will be involved using a Living Lab approach.

Keywords: Earth Observation, Sentinel-1, Sentinel-2, Land monitoring, Leaf Area Index, Surface Soil Moisture
Parole chiave: Osservazione della Terra, Sentinel-1, Sentinel-2, Monitoraggio del territorio, Indice di area fogliare, Umidità superficiale del suolo

Introduction

Earth observation is one of the most powerful tools available to assess the occurrence of the match between the production of sufficient food via plant and animal productivity and the preservation of a delicate environment and its services. In this context, it is essential to achieve a full understanding of the processes driving the current patterns of crops production and also the cropland carbon and water dynamics. The development of remotely-sensed products, which characterize the temporal and spatial heterogeneity of croplands, constitutes a valuable and indispensable tool for tackling these problems at different scales, from local to global extents. This concept is recognized in the Land Challenges identified by the science strategy within the Copernicus Land Monitoring Service and ESA Earth Observation Living Planet Program (ESA, 2015). The capabilities of Sentinel-1 (S1) and Sentinel-2 (S2) with short repeat frequency, large coverage and continuous provision of consistent datasets, present an unprecedented contribution to the global crop monitoring, for issues of global concern such as food security and strategies for climate change mitigations. Besides, the improved optical sensor of S2, and the improved radiometric quality of S1 with 2 polarizations, and its interferometric model, will allow covering the whole diversity of the agricultural landscapes (Tab. 1). When used alone either optical or radar sensors allow the mapping of crop types. However more robust, accurate, frequently updated and comprehensive crop maps are expected from the synergy of both types of measurements. The same holds when dealing with crop status, health and stresses. Experimental studies have demonstrated that fusion of optical and radar data opens up prospects for enhanced monitoring capabilities.
The "Evolution of Copernicus Services, Sentinels Synergy for Agriculture (SENSAGRI)" project, from 1st November 2016 to 30th October 2019, aims to exploit synergies of S1 and S2 data in order to develop an innovative portfolio of prototypes agricultural monitoring services that are so far unseen in existing EO products.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Tab. 1 - List of some Sentinel-1 and -2 satellite characteristics.
Tab. 1 - Descrizione di alcune caratteristiche dei satelliti Sentinel-1 e -2.

Parameter	**Sentinel-1**	**Sentinel-2**
Launch date	April 03, 2014 of S1-A April 25, 2016 of S1-B	June 23, 2015 of S2-A March 07, 2017 of S2-B
Repeat cycle	6 days	5 days
Orbital altitude	693 km	786 km
Sensor, Swath Width and spatial resolution	**C-SAR** (C-band Synthetic Aperture Radar): Stripmap (SM), 80km swath, 5 x 5 m spatial resolution Interferometric Wide swath (IW), 250km swath, 5 x 20 m spatial resolution Extra-Wide swath (EW), 400 km swath, 25 x 100 m spatial resolution Wave mode (WV), 20km x 20km, 5 x 20 m spatial resolution	**MSI** (Multi Spectral Instrument): 290km Swath four bands at 10 m: 490 nm, 560 nm, 665 nm, 842 nm six bands at 20 m: 705 nm, 740 nm, 783 nm, 865 nm, 1610 nm, 2190 nm three bands at 60 m: 443 nm, 945 nm and 1375 nm
Spacecraft mass	2300 kg	1100 kg
Spacecraft size	3.9 m x 2.6 m x 2.5 m	3.4 m x 1.8 m x 2.35 m

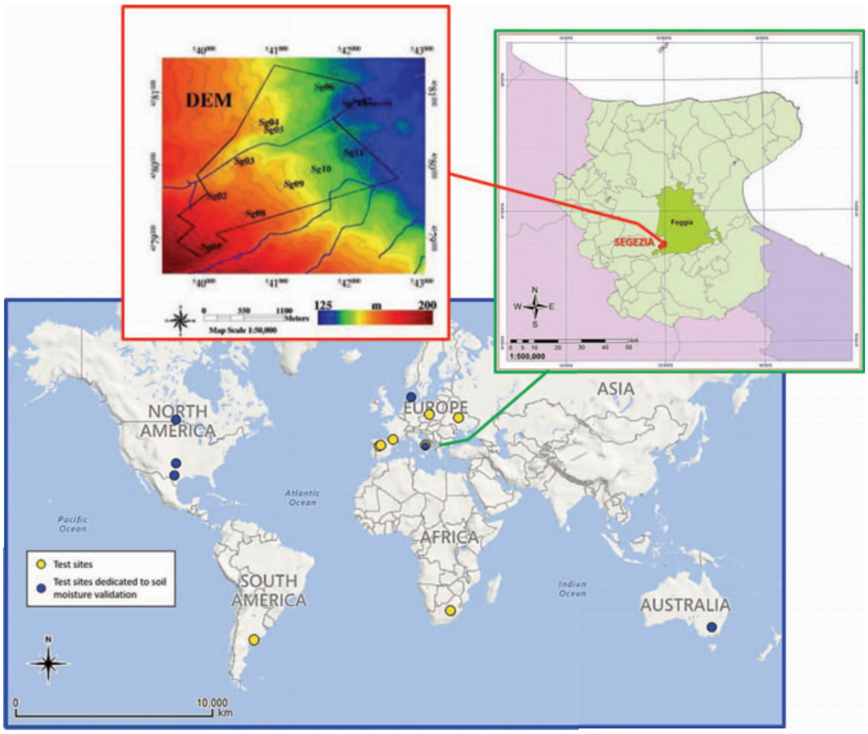


Fig. 1 - Overview of location of the test sites, in particular the test site of Segezia Hydrologic network (Apulia, Italy) dedicated to soil moisture validation.
Fig. 1 - Vista della localizzazione dei siti test, in particolare la rete idrologica di Segezia (Puglia, Italia) dedicata alla validazione dell'umidità del suolo.

Project structure and Methods

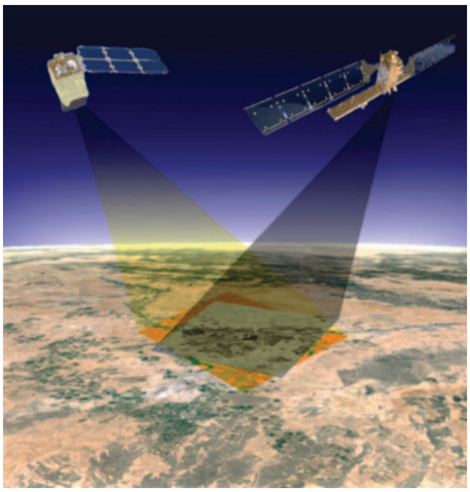
The SENSAGRI project, coordinated by the University of Valencia (Spain), with 6 other partners (Italy, Spain, France and Poland), includes the CREA (CI of Foggia and AA of Bari) and the CNR-ISSIA, for Italy (Tab. 2).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The project aims at developing an integrative use of S1 and S2 systems for advanced agricultural monitoring. An important aspect of this activity is the validation of the new SENSAGRI products that will be compared with in situ data collected over various test sites, which include EU (France, Spain, Italy, Poland) and non-EU (Ukraine, Argentina and South Africa) test sites, characterized by different climatic, geologic and agricultural conditions. In particular, Fig. 1 shows the hydrologic network located at the Segezia experimental farm in the Apulian Tavoliere site.
In addition, to strengthen the validation activity of the SENSAGRI soil moisture product, time series of soil moisture data collected over 5 additional sites, belonging to the International Soil Moisture Network will be included in the analysis.
SENSAGRI is structured around the development, validation and demonstration of crop monitoring services based on synergy of Copernicus S1- S2 data. The frequent coverage, combined with improved sensor spectral bands of optical sensor S2 (13 spectral bands), and the improved radiometric quality of S1 with 2 polarizations (Fig. 2), will be particularly featured to monitor cropland dynamics. Information on crop health and growth stage, e.g. with LAI from S2 and plant water content and biomass from S1, on soil moisture and tillage conditions with S1, will be essential for crop management, crop water requirements, irrigation water management, crop nutritional status, nitrogen fertilization, crop growth progress, yield and production modeling, and at regional level, for energy, water and carbon balance/budgets calculations.

Tab. 2 - The list of beneficiaries.
Tab. 2 - Lista dei beneficiari.

Name	**Short name**	**Country**
UNIVERSITAT DE VALENTIA	UVEG	Spain
CONSIGLIO NAZIONALE DELLE RICERCHE	CNR-ISSIA	Italy
UNIVERSITE PAUL SABATIER TOLOUSE III	UPS-CESBIO	France
CONSIGLIO PER LA RICERCA IN AGRICOLTURA E L'ANALISI DELL'ECONOMIA AGRARIA	CREA	Italy
ISTITUTO TECNOLOGICO AGRARIO DE CASTILLA Y LEON	ITACyL	Spain
ISTYTUT OCHRONY ROSLIN-PANSTWOWY INSTYTUT BADAWCZY	IPP	Poland



The project starts through setting up an S1-S2 data repository and associated pre-processing toolboxes (atmospheric correction, cloud screening) [WP 2]. WPs 2-5 have a strong technological focus and impact because in these WPs the potential of assimilation of S1 radar, S2 optical and in-situ data will be exploited for the delivery of new prototype services for crop health and crop area mapping. The main objective of WP 3 is to develop SSM maps retrieval algorithm based on S1 data and with support of S2 data. The algorithm will be based on the SSM retrieval algorithm (referred to as "Soil Moisture retrieval from multi-temporal SAR data", SMOSAR). Similarly, in WP 4 an improved LAI map will be developed whereby explicit distinction between *green* and *brown* LAI will be made. This will become possible thanks to the new S2 bands in the red-edge and in the SWIR. Latest machine learning regression algorithms (MLRAs) shall be evaluated and optimized. To close gaps due to cloud-cover, an interpolation synergy approach with S1 radar data is also proposed. A third prototype in WP 5 is the development of a seasonal crop mapping product by relying on synergistic S1-S2 data.

Fig. 2 - Conceptual example of S1 and S2 observing the same target.
Fig. 2 - Esempio di come i satelliti S1 e S2 osservano lo stesso punto.

It is foreseen that such synergy strategy will not only lead to higher classification accuracies, but also to maps with more detail. The primary prototype products prepared in WP 3-5 serves as the main input to advanced services in WP 6. This WP aims at developing new methods and improving existing algorithms, for which a demonstration exercise will be undertaken over different test sites.

These advanced products include derivation classification products (e.g. tillage and irrigation maps) and crop modelling products. WP 7 provides ground data collection and validation. This involves proof-of-concept testing of delivered product at four dedicated test sites. The validation will provide statistical goodness-of-fit indicators between retrieved variables from EO vs *in-situ* data or other types of benchmarking information that can be grouped in Taylor diagrams to visualize the results. After the testing and demonstration phase, WP 8 ensures that the services developed within SENSAGRI fit the needs of users and that their relevance and maturity are sufficient for proposing them as candidate for the evolution of Copernicus services. WP 8 further deals with the dissemination of the project results at the local, national and European scale in order to reach a wide public and all potential actors, by means of a "Living Labs" approach involving the potential users of the services. The coordination of all project activities is assured with the WP 1, for project management (Fig. 3).

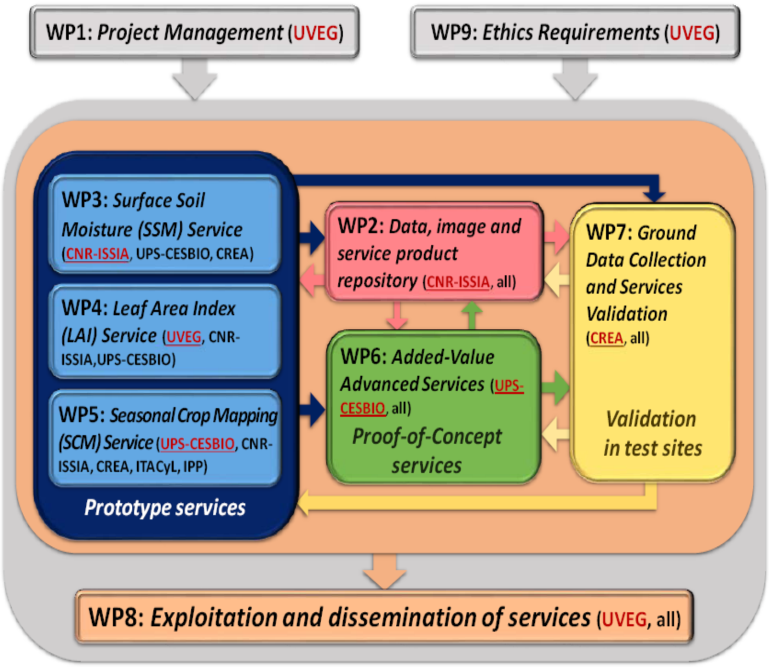


Fig. 3 - SENSAGRI work packages structure.
Fig. 3 - Struttura dei work packages in SENSAGRI.

Tab. 3 - Expected prototype services and their potential applications.
Tab. 3 - Servizi prototipali attesi e alcune potenziali applicazioni.

Prototype services	**Agricultural potential applications**
Surface Soil Moisture (SSM)	Drought monitoring, irrigation scheduling, actually irrigated fields soil erosion risk monitoring, detection illegal ground water extraction, field work practicability
Leaf Area Index (LAI)	Yield forecast, carbon budget, dynamic vegetation models, optimization of the application of crop protection products
Seasonal crop type mapping	Crop type, crop rotation, agricultural subsidies, precision farming, greening measures of agricultural common policy (PAC), crop rotations
Irrigated fields	Location of actual irrigated fields, detection of illegal ground water extraction
Tilled fields	Agricultural subsidies, soil erosion risk monitoring, no-tilled field and conventional tilled maps
Advanced crop type mapping	Detailed crop type maps, crop rotations, cover crops, intercropping, ecological focus areas

Expected Services

SENSAGRI proposes three primary prototype products (SSM, LAI, Crops) and four advanced proof-of-concept services: (i) yield/biomass, (ii) tillage change, (iii) irrigation and (iv) advanced crop maps (Tab. 3). The algorithms will be developed and validated in four European agricultural test areas in Spain, France, Italy and Poland, which are representative of the European crop diversity, and their usefulness demonstrated in at least two non-European countries.

Conclusions

The main SENSAGRI project goals are to:

1. Combine the Copernicus S1 radar with S2 optical and in-situ data in order to develop new applications and market opportunities for the European agricultural sector;

2. Develop prototype services of SSM, LAI and seasonal crop type mapping and use those for proof-of-concept services of advanced agricultural monitoring products;

3. Validate delivered services and establish service demonstration cases to show the large application potential of the new upstream data products;

4. Disseminate prototype and proof-of-concept services and interact services with the agricultural sector.

The services developed by SENSAGRI fit the needs of agricultural stakeholders and users and that their relevance and maturity are sufficient for proposing the evolution of Copernicus services. The proposed approach relies on the involvement of users from the early stage of the project to its end. This “Living Lab” approach we already experimented in order to involve actors of the agricultural sector, such as farmers, cooperative, research and technical institutes, public services, water managers and water authorities. In order to support the approach and possibly to reach more users, we will develop a geospatial web-portal (WebGIS) and a project web page (http://ipl.uv.es/sensagri/). The data produced by the Copernicus agricultural service will be freely available to everybody, on the contrary of commercial solutions, providing the software modules developed in the frame of the project under free and open source license.

Acknowledgement

The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement n. 730074 (coordinator Prof. J. Moreno, UVEG; scientific responsible for CREA dott. M. Rinaldi).

References

ESA (2015). ESA’s Living Planet Programme. Scientific achievements and future challenges – Scientific context of the Earth observation science strategy for ESa, ESA SP-1329/2 (2 volumes). ESA.

IMPACT OF AGRO-ENVIRONMENTAL MEASURES IN THE TUSCANY REGION. GEOGRAPHIC MULTI-CRITERIA ANALYSIS
L'IMPATTO DELLE MISURE AGROAMBIENTALI NELLA REGIONE TOSCANA. UN'ANALISI MULTICRITERIALE GEOGRAFICA

Emanuele Gabbrielli[1*]

[1] Department of Management of Agricultural, Food and Forestry Systems, University of Florence, Florence, Piazzale delle Cascine, 18, 50144, Firenze
*emanuele.gabbrielli@unifi.it

Abstract
Agro-environmental policies are taking increasing importance in community strategies and represent the main instrument for financing Rural Development Programs (RDP).
The difficulty of assessing the real environmental effectiveness is one of the elements characterizing the agro-environment measures. This difficulty is essentially related to the problem of identifying suitable parameters for evaluating farms according to their impact on the territory.
The research aimed at providing an analytical model suitable to different territorial situations.
Organic and integrated farms, financed by Tuscany region with Rural Development Plans 2007-2013, were evaluated through the use of Multi-criteria Geographical Analysis. Farms were classified according to their environmental impact, through multidimensional indicators. In particular, a simulation on economic and environmental effects of EU funding budget reductions, using geo-referenced data was conducted.
The implemented methodological approach was a helpful tool to assist Policy Makers in their own decisions, in ex-ante, interim, ex-post analysis, and also in the preparation of new measures on programming 2014-2020.

Keywords Rural Development Programme, Agri-environmental Payments, Measure 214, GIS, Multi-criteria Analysis.
Parole chiave: Piano di Sviluppo Rurale, Pagamenti Agroambientali, Misura 214, GIS, Analisi Multicriteriale Geografica

Introduction
Agri-environment measures support economically farmers in the protection, conservation and enhancement of environmental quality of their farmland.
Agri-environmental policies, included into the Rural Development Programmes (RDPs), play a major role within EU Policies. One element characterizing agri-environment measures, is the difficulty of assessing real environmental effectiveness. However, of agri-environmental assessment is a key point for the justification of such interventions that have granted significant financial resources.
The aim of this work is to develop a tool, adaptable to various local situations, able to analyze the distribution and impact of EU funding, and performing a classification of farms that receive funding from Rural Development Plan.
To this purpose a Spatial Multi- Criteria Analysis was used.

Materials and Methods
The case study includes all farm of Tuscany region that receive agri-environmental funds: payments are related to measure 214a1 (Organic Agriculture) and measure 214a2 (Integrated Agriculture) of RDP 2007-2013.
Spatial Multi-criteria Decision Analysis, that combines Multi-criteria Decision Analysis (MCDM) with Geographical Information System (GIS), was used.
Spatial Multi-criteria Analysis uses the potential of GIS to solve multi-criteria models in order to support decision-making in spatial planning processes and to get results that are easy to interpret (Malczewski 1999 and 2004). This methodology is appropriate for territorial analysis and is widely adopted in the literature (Joerin et al., 2001; Geneletti, 2010; Malczewski, 2006; Baja et al., 2007; Bell et al., 2007; Karnatak et al., 2007).The methodology allowing to choose the best alternative.
The quantification of organic and integrated farms in terms of economic and environmental aspect required an exam of Rural Development Plan's objectives (conservation of biodiversity in agro-ecosystem, reduction of exploitation and pollution of water resources, reduction of erosion and loss of soil fertility, conservation and landscape protection).
The aim was to define appropriate indicators able to express the degree of impact these farms have over the territory.
For this purpose the following indicators were selected: 1) runoff index; 2) index of distance from water bodies; 3) index of input of chemical elements; 4) ecosystem vulnerability index; 5) biodiversity index; 6) index of distance from protected areas; 7) value added index; 8) hydrogeological risk index.
To define a structure of multi-criteria analysis, Malczewski (Malczewski, 1999) proposes a model by which the decision problem (in this case represented by the identification of farms deserving of agri-environmental funds in plausible scenarios for future programming RDP), is analyzed through alternatives (all organic farms and integrated in Tuscany), evaluated

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

through economic and environmental objectives, and quantified by qualitative or quantitative indicators. Figure 1 shows the logical steps of the method adopted.

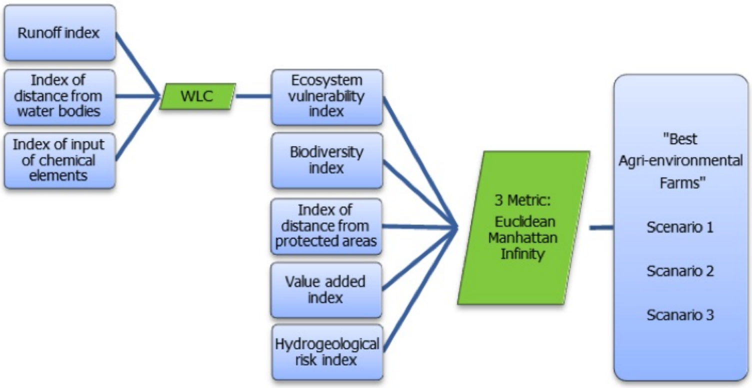


Fig. 1: Used indicators
Fig.1: Indicatori utilizzati

The ecosystem vulnerability map was found by applying simplest additive aggregation method of Weighted Linear Combination (WLC) (Malczewski, 1999). Runoff index, index of distance from water bodies and index of chemical input were used. Weighted Linear Combination (WLC) is one of methods allowing compensating and determining the value of each alternative, defined by pixels, as average value of each criterion multiplied by relevant constraints (Malczewski, 1999). This method allows the evaluation of the layers to be combined to determine a single layer formed by the union of the other ones.
Databases used to obtain an archive of raster maps, with resolution 100x100 meters:

- Database ARTEA including information of farms that receive agro-environmental funds (214a1 “Organic farm” and 214a2 “Integrated Farm”). This was elaborated relying on the extraction of data from the ARTEA Information System (SI), integrated with details on corporate structure and their technical and economical characteristics;
- Shapefile ARTEA. Maps of areas under agri-environmental commitments with geo-referenced details (individual cadastral particles).

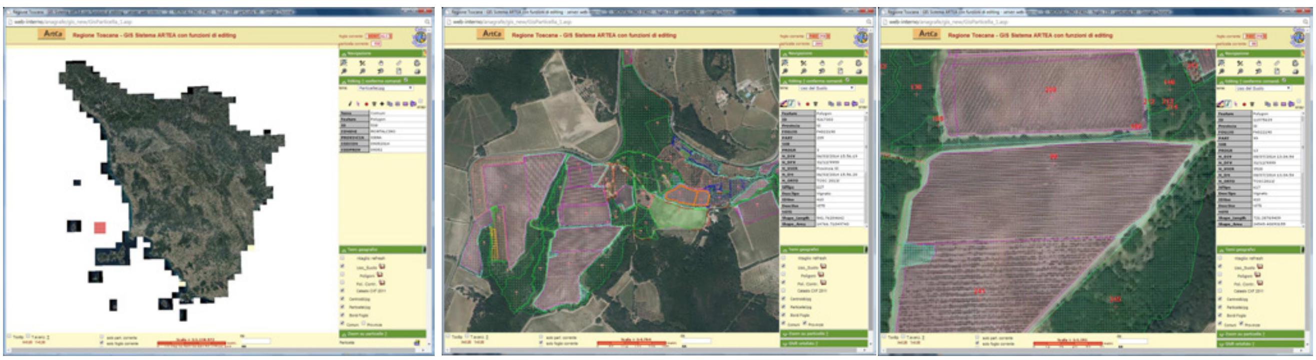


Fig. 2, 3, 4 : Orthophotos of Tuscany region - GIS ARTEA with land use (polygons). Database and Shapefile ARTEA
Fig. 2, 3, 4: Ortofoto Regione Toscana del GIS ARTEA con dettaglio usi del suolo (poligoni). Database e Shapefile ARTEA

For each indicator a raster cartography was produced (Figure 5, 6, 7, 8, 9, 10, 11, 12)

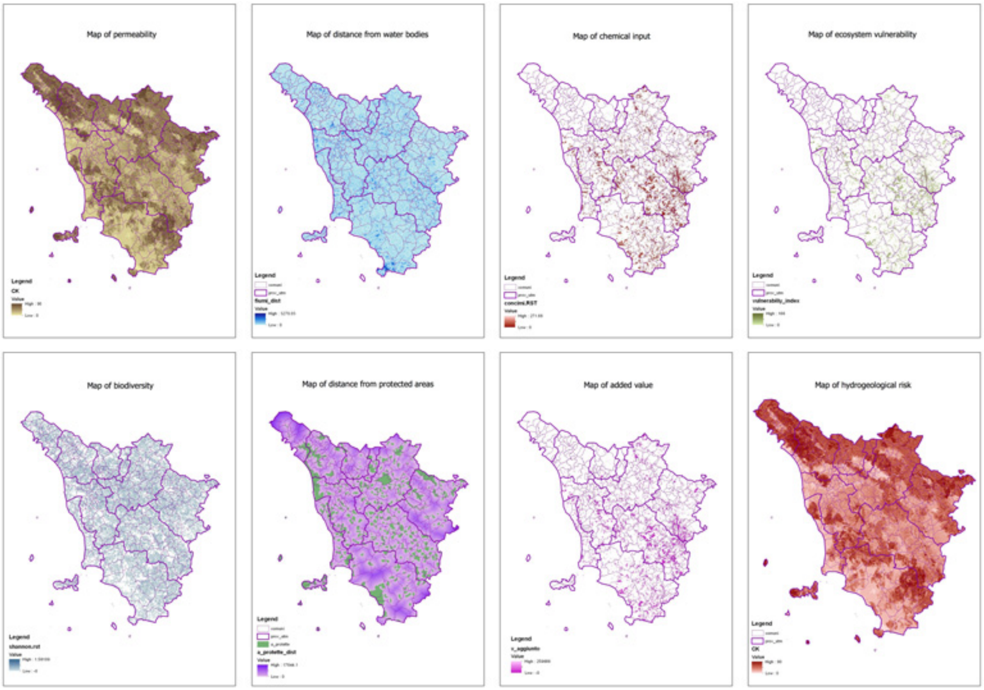


Fig. 5, 6, 7, 8, 9, 10, 11, 12: Map of: permeability, distance from water bodies, chemical input, ecosystem vulnerability, biodiversity, distance from protected areas, added value, hydrogeological risk.

Fig. 5, 6, 7, 8, 9, 10, 11, 12: Mappa della: permeabilità, distanza dai corpi idrici, apporto di elementi chimici, vulnerabilità ecosistemica, biodiversità, distanza dalle aree protette, valore aggiunto aziendale, rischio idrogeologico.

The aim is to create various thematic maps related to hypothetical scenarios of agri-environmental aids distribution in Tuscany, for future Community programs.
A possible scenario was created, where it was assumed a budget reduction of 50% of EU funding.
To define the "best agri-environmental farms" from environmental perspective, located in Tuscany, indices were aggregated with multi-criteria rules based on three metrics (Euclidean, City-block and Infinite), and depending on the distance from "ideal point" (Yu, 1973; Zeleny, 1974). Three hypothetical scenarios were created (fig. 12, 14, 15)

Risults and Discussion

The number of the initial beneficiaries (5,013) represented the total number of beneficiaries from agri-environmental funding of RDP 2007-2013 who have joined agri-environmental contracts over a period beginning in 2007, until 2014.
Subsequently thanks to ARTEA's database, each beneficiary identified by CUAA (Unique Code Farm), has been linked to an amount of payments received for measures 214a1 (Organic Agriculture) and 214a2 (Integrated Agriculture).
The hypothesis of financial budget reduction was considered for agri-environmental funding. It established in a 50% decrease of total amounts allocated, the number of beneficiaries identified for "Scenario 1" (Euclidean metric), going from 5,013 initial farms, to 2,308, with 84,558.86 hectares under agri-environment commitment (fig. 13).
In "Scenario 2", the number of beneficiaries identified using Manhattan's metric (city-block) was of 2,528 farms, with a total of 86,104.81 hectares of land under agri-environmental commitment (fig. 14).
The results obtained with the infinity metric, show a total of 2,140 beneficiaries with 86,619.99 hectares (fig. 15).
The maps (Figure 13, 14, 15) shows significant changes between farms that have been entitled to agri-environmental funding of RDP 2007-2013, highlighted in red, and those who remain supported after the hypothesis of EU budget reduction, highlighted in blue.

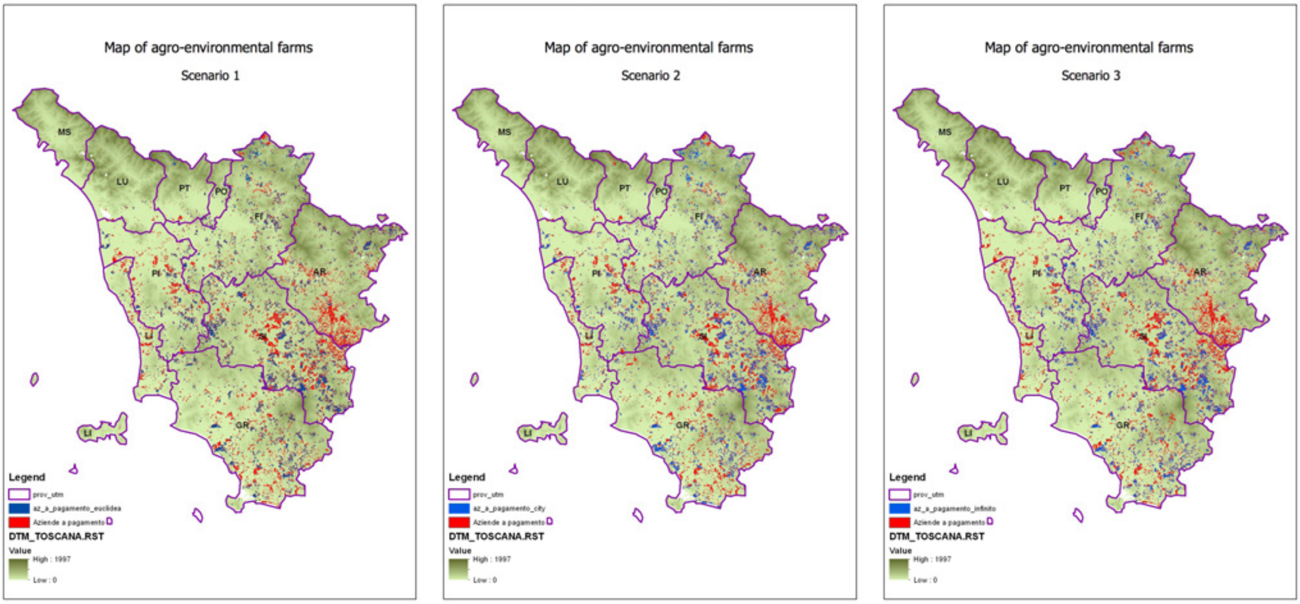


Fig.13, 14, 15: Maps of Agro-environmental farms. Scenario 1, Scenario 2, Scenario 3.
Fig.13, 14, 15: Mappa delle Aziende Agroambientali. Scenario 1, Scenario 2, Scenario 3.

The results for the Euclidean distance, show a scenario with blurred signals. The number of beneficiaries identified has a result that is in the middle between the other two distances (2,308). This means that using this method, a reduction from 2,000 to 2,500 hectares of land with agri-environmental commitments, compared to the use of other metrics can be hypothesized.
The second scenario (city-block distance) shows some interesting results. The result shows a significantly higher value for the number of beneficiaries who would still get funding, however, concerning the surface area, a maximum value of commitment (in hectares) would be maintained. Therefore, with these results we can assert that if Policy Maker, decide to use city-block distance, they might be able to fund, according to limits of hypothetical budget, a scenario formed by many farms with a small business size.
The results of the third scenario (infinite distance) show a very particular situation. The number of companies is the lower (2,140), but in contrast, the total areas under agri-environmental contract shows the greater value compared to all scenarios (86,619.99 hectares). This last scenario could hypothesize a decision by Policy Maker, to direct funding towards few large companies.

Conclusions
The purpose of the research was to provide an analytical model adaptable to various local situations. The model would also be able to analyze the distribution and the impact of EU funding for measures of Rural Development Plan which provide surface aid.
The research has defined a suitable tool for effective assessments, with rapid use and very high spatial detail. Currently, from the methodological point of view, the assessment of agricultural policies effects, is often carried out with aggregate values (municipal level), generating interpretations not particularly defined.
The analytical model used is a Multi-criteria Geographical Analysis, through which multiple economic systems can evaluate environmental and territorial factor that can direct distribution of EU funding in examined areas.
Beneficiaries of agri-environment measures are rewarded for engaging in farming practices that provide more environmental benefit compared to conventional practices. They are paid for income losses and additional costs resulting from practices beyond mandatory requirements. Therefore, the agri-environmental measures allow actions that provide a tangible improvement to environmental component in terms of agricultural quality. However, these are difficult to assess, especially for their real effectiveness, because being complex, they constantly need more and more flexible evaluation tools.
In fact, their assessment is a key point in the justification of these actions which have granted significant financial resources. Looking at the past, often, compared with substantial resources invested, the expected results have not always been achieved. By relying on GIS we have linked alphanumeric information of supported holdings, with geographic information relating to territory.

Companies adhering to agri-environmental contracts, frequently represent small farms located in marginal and hard lands, however that ensure a constant presence in territory. Geo-referenced information is a strategic data for decision-maker that can program specific actions to limit damages caused by a possible abandonment of territories.
The possibility of using information originating from administrative sources (ARTEA - Agenzia Regionale Toscana per le Erogazioni in Agricoltura) allowed a complete reliability of results, coupled with in depth details. Furthermore, using geo-referenced data referred to land-use of every farms represents also a high level of details.
Choosing companies "to be protected" by the Policy Maker, assumed in this work, allowed to select companies as the "best" in terms of achievement of some objectives (biodiversity, reduction of input chemicals, etc.) of RDP.
Assuming a possible financial budget reduction (-50% of amounts allocated for financing agri-environment), that might hypothetically occur in the next EU programming, three scenarios have been proposed in order to achieve a classification of agri-environmental farms.
Being able to make a targeted selection of beneficiaries in accordance with available resources, becomes very important when public resources are limited.
This study, with three types of metrics for resolution of multi-criteria matrix (Euclidean distance method, City-block distance method, Infinity distance method), showed significantly different results.
The values obtained are changed according to the number of companies and hectares of UAA that remained interested by agri-environmental funding, leaving to Policy Maker a discretionary decision to maintain funding towards few large farms or to many small farms. The methodology used will be a helpful tool to assist Policy Maker in their decisions during ex-ante, interim, and ex-post analysis, and also for new measures relating to the 2014-2020 EU program.

References

Baja S., Chapman D.M., Dragovich D. 2007. Spatial based compromise programming for multiple criteria decision making in land-use planning. Environ. Model. Assess. 12 (3), 171–184.

Bell N., Schuurman N., Hayes M.V. 2007. Using GIS-based methods of multicriteria analysis to construct socio-economic deprivation indices. Int. J. Health Geographics 6, 1–19.

Geneletti D. 2010. Combining stakeholder analysis and spatial multicriteria evaluation to select and rank inert landfill sites. Waste Management, 30 (2) 2010, pp. 328–337.

Joerin F., Theriault M., Musy A. 2001. Using GIS and outranking multicriteria analysis for land-use suitability assessment. Int. J. Geog. Inf. Sci. 15 (2), 153–174.

Karnatak H.C., Saran S., Bhatia K., Roy P.S. 2007. Multicriteria spatial decision analysis in web GIS environment. Geoinformatica, 11 (4), 407–429.

Malczewski J. 1999. Gis and multicriteria decision analysis. John Winley & Sons, Inc.

Malczewski J. 2004. Gis–based land-use suitability analysis: a critical overview. Elsevier.

Malczewski J. 2006. Ordered weighted averaging with fuzzy quantifiers: GIS-based multicriteria evaluation for land-use suitability analysis. Int. J. Appl. Earth Obs. Geoinf., 8 (4), 270–277.

Yu P.L. 1973. A class of solutions for group decision problems. Management Science, vol. 19, n.8.

Zeleny M. 1974. A concept of Compromise solutions and method of the displaced ideal. Computer and operations research, vol. 1, n.4.

DOI 10.6092/unibo/amsacta/5692

EFFECT OF ENVIRONMENTAL STRESS AND AGRONOMIC MANAGEMENT ON MORPHOLOGICAL, PHYSIOLOGICAL AND QUALITY TRAITS OF VEGETABLES

EFFETTO DEI FATTORI AGRONOMICI ED AMBIENTALI SULLE CARATTERISTICHE MORFOLOGICHE, FISIOLOGICHE E QUALITATIVE DI SPECIE ORTICOLE DI INTERESSE

PhD thesis candidate: Angelica Galieni[1,2] - *Tutor*: Michele Pisante[1] - *Co-tutor*: Fabio Stagnari[1]

[1] Faculty of Bioscience and Technologies for Food, Agriculture and Environment, Univ. Teramo, IT, mpisante@unite.it - fstagnari@unite.it
[2] Council for Agricultural Research and Economics, Vegetable and Ornamental Crops Research Centre, Monsampolo del Tronto, IT, angelica.galieni@crea.gov.it

Abstract

The chemical composition of vegetables depends on a number of factors, classified as genotype and growing conditions. Consequently, the characteristics of fresh vegetables could be improved trough cultivar selection, genetic modification, manipulation of environmental conditions and agronomic management.

The objective of this study was aimed at evaluating the effects of the manipulation of some environmental factors on morphological, physiological and quality traits of red beet and lettuce. The environmental factors were water, light, nitrogen and phosphorus.

The final work has been presented as a set of scientific publications obtained from the three-year results of 4 separate experimental designs, under controlled environment: 2 for red beet and 2 for lettuce. Results highlighted the effects of environmental factors, individually and/or in combination, on both species; important physiological traits at the leaf level were also identified as useful indicators of stressful conditions.

Keywords

Red beet - lettuce - manipulation of growing conditions - total polyphenols - antioxidant activity

Parole chiave

Barbabietola rossa - lattuga - controllo dei fattori produttivi - polifenoli totali - attività antiossidante

Introduction

Agricultural research and development in the past 50 years had primarily focused on increasing the productivity and minimizing food shortages. Besides, in the recent years the nutritional values and health effects of food crops became more and more important to face dietary issues. In addition, the relationship between food production and health is now as important as the environmental sustainability of production systems inside the consumer perception. Vegetables, in particular fresh vegetables, are important components of human diet, providing a range of nutrients and different bioactive compounds, including phytochemicals (phenolics and carotenoids), vitamins (vitamin C, folate and pro-vitamin A), minerals (potassium, calcium and magnesium), and fibres. Nevertheless, the chemical composition of vegetables and crops depends on a number of factors, classified as genotype and growing conditions. Consequently, the characteristics of fresh vegetables could be improved trough cultivar selection, genetic modification, manipulation of environmental conditions, agronomic management (i.e. nutrition) and elicitation (Ramakrishna and Ravishankar, 2011). Research should clarify the links between crop physiology with the development of plant-based foods, characterized by higher levels of important macro and micronutrients.

New management strategies are focusing on the manipulation of eco-physiological factors to enhance the intrinsic nutritive and health-promoting properties of vegetables, without reducing crop yields, i.e. inducing moderate environmental stress or manipulating the growing factors (Schreiner, 2005). Plants generally respond to environmental stress with numerous physiological changes: activation of the plant' defense system (Jahangir et al., 2009) which consequently lead to significant change in the plant metabolome with a number of signal pathways that can be pre-activated by salicylic acid (SA), jasmonic acid (JA), ethylene and abscisic acid pathways (Zhao, 2012). As consequence, a significant enhancement in the biosynthesis of some metabolites can be induced.

The objective of this study was aimed on the evaluation of the effects of the manipulation of water and light quantity and quality, as well as nitrogen and phosphorus nutrition on morphological, physiological and quality traits of two vegetable species: a root-vegetable crop (*Beta vulgaris* var. *conditiva* Alef.) and a leafy-vegetable crop (*Lactuca sativa* L.).

Red beet presents high nutritional and health potentials, and its relationships with abiotic stressful conditions have been poorly investigated. Lettuce is a leading component of an healthy diet, it tolerates and responds to a wide range of environmental conditions and it is harvested and consumed at a range of developmental stages.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA. Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Materials and Methods

Four different experiments have been carried out at the greenhouse of University of Teramo (42◦53′N and 13◦55′E, 15 m a.s.l.). Environmental conditions were constantly monitored during crop cycles using temperature, humidity and photosynthetically active radiation (PAR) sensors connected to a data logger (EM50 Data Collection System, Decagon Devices, USA).

Following a complete randomized block design with 3 replications, red beet has been subjected to: (i) three water regimes (100% of water holding capacity, WHC (W100); 50% of WHC (W50) and 30% of WHC (W30)), (ii) two modifications of the transmitted solar radiation (using two photoselective films i.e. Red and Green) plus a fully sunned Control, to understand crop adaption to unfavourable environments (dynamics of organs growth) as well as the mechanisms of accumulation of minerals (Ca, P, Mg, K, Fe, Mn, Zn) and molecules with putative biological activity (i.e. betalains, polyphenols) in storage organs. Some important morphological (i.e. *Leaf Area* (LA), *Specific Leaf Area* (SLA), *Leaf Mass Ratio* (LMR), *Leaf Area Ratio* (LAR)) and physiological (i.e. stomatal conductance (POR), leaf temperature (TIR), *Soil Plant Analysis Development* (SPAD), *Normalized Difference Vegetation Index* (NDVI), *Green Normalized Difference Vegetation Index* (GNDVI), *Water Index* (WI), Chlorophyll (Chl) content) leaf traits were also assessed, already at the very early stages of plant growth.

Lettuce plants have been primarily exposed to sixteen experimental treatments obtained by the combination of four nitrogen fertilization rates (0, 75, 150 and 300 kg N ha^{-1}) with calcium nitrate and four PAR availability levels (0, 50, 65 and 85% PAR reduction), following a split-plot design with 3 replications, in order to focus on biochemical properties (Chl content, total polyphenols content, minerals, dietary fibres) and safety (nitrate content) of harvested biomass. Besides, lettuce has been simultaneously subjected to two nutrient-deficiency (nitrogen and phosphorus limitations, i.e. 0 kg of N or P_20_5 ha^{-1}) and two abiotic stressful conditions (water deficit, i.e. 30% of WHC, and reduction of transmitted solar radiation, i.e. 85% of PAR reduction) with the aim to evaluate plant responses in terms of growth, phenolic compounds accumulation (total polyphenols content, identification and quantification of free and bound phenolic acids) and antiradical activity. During two consecutive crop growing cycles (i.e. spring-summer and autumn-winter), physiological (POR, TIR, SPAD; NDVI, GNDVI, WI) and morphological (LA, SLA, LMR, LAR) leaf traits have been recorded and calculated to compare the different limiting growing conditions and to identify which can reliably serve as representative stress indicators.

Results

Since the obtained results are very complex to present, a summary of the main ones is reported, please refers to the references for further explanations and information.

Red beet subjected to environmental stress resulted in a large set of parallel changes in morphological and physiological responses, favouring the plants capability to survive and grow. These changes match with the modification of storage roots' yield and quality. Water stress constrained root dry weight while favoured the concentration of phytochemicals (i.e. betalains and polyphenols) and some mineral elements (i.e. P, Mg, Fe and Zn). The severe reduction of PAR availability and red/far red (R/FR) ratio (achieved with Green photoselective film) strongly decreased biomass accumulation, but favoured the concentration of structural and non-structural carbohydrates and minerals.

Suitable selection indicators of early adaptive changes were LMR, WI for drought and SLA, LAR for modification of PAR transmittance.

In lettuce, the highest achievable dry biomass has been obtained with the optimal light/N combination of 0.9% PAR reduction and 185.4 kg N ha^{-1}; this combination induced a nitrate concentration far below the maximum limits set by the E.C. Regulation. Besides, a general trend for which the TPC and the antiradical activity were respectively enhanced and lowered by the N fertilization and PAR availability constraints was observed in lettuce leaves, regardless of cultivar and experimental conditions (autumn-winter and spring-summer growing cycles). Drought seems to improve the accumulation of some phenolic acids (i.e. caffeic, caftaric and chicoric acids) in their bound forms as well as TPC and antiradical activity of the same fractions.

N limitation and PAR reduction treatments were associated with both morphological and physiological stress-indicators; among which, those indirectly related to photosynthetic activity (LAR, SLA, LA, LMR, SPAD and POR) were more 'stable' across different climatic conditions. Moreover, SPAD, POR, TIR and WI were identified as good indicators of water stress conditions, although WI was less 'stable' across growing periods, i.e. easily influenced by variations in thermal and light conditions.

Discussion and Conclusions

As stated in the literature, the effects of the environmental stresses and management agricultural practices strongly depend on numerous physiological and experimental factors and sometimes appear to be contradictory, even if the same stress type and species were investigated. Despite this complexity, positive effects in terms of nutritional and health quality of vegetable-based foods were found. Thus, the manipulation of growing factors (i.e. solar radiation, water and nutrients availability) could be highly desirable for both environmental and social sustainability (improved human diet and health).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

In addition, the plants response in terms of morphological and, principally, physiological adaption to unfavourable environmental conditions should be taken into account in order to assess which traits (e.g. at leaf level) could be utilized in breeding programs as selection criteria at early stages. The selected genotypes could be advantageously cultivated in stressed environments or subjected to particular adjustments of agronomic techniques to obtain natural foods with high quality characteristics, without or slightly affecting yield performances.

Literature to be consulted for further information:

Galieni A., Stagnari F., Speca S., Pisante M., 2016. Leaf traits as indicators of limiting growing conditions for lettuce (*Lactuca sativa*). Annals of Applied Biology, 169: 342-356.

Stagnari F., *Galieni A*., Pisante M., 2015. Shading and nitrogen management affect quality, safety and yield of greenhouse-grown leaf lettuce. Scientia Horticulturae, 192: 70-79.

Galieni A., Di Mattia C., De Gregorio M., Speca S., Mastrocola D., Pisante M., Stagnari F., 2015. Effects of nutrient deficiency and abiotic environmental stresses on yield, phenolic compounds and antiradical activity in lettuce (*Lactuca sativa* L.). Scientia Horticulturae, 187: 93-101.

Stagnari F., *Galieni A*., Speca S., Cafiero G., Pisante M., 2014. Effect of light and water supply on morphological and physiological leaf traits of red beet. Agronomy Journal, 106: 459-468.

Stagnari F., *Galieni A*., Speca S., Pisante M., 2014. Water stress effects on growth, yield and quality traits of red beet. Scientia Horticulturae, 165: 13-22.

Stagnari F., *Galieni A*., Cafiero G., Pisante M., 2014. Application of photo-selective films to manipulate wavelength of transmitted radiation and photosynthate composition in red beet (*Beta vulgaris* var. *conditiva* Alef.). Journal of the Science of Food and Agriculture, 94: 713-720.

References

Jahangir M., Abdel-Farid I.B., Kim H.K., Choi Y.H., Verpoorte R., 2009. Healthy and unhealthy plants: the effect of stress on the metabolism of Brassicaceae. Environmental and Experimental Botany, 67: 23-33.

Ramakrishna A., Ravishankar G.A., 2011. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signaling and Behavior, 6: 1720-1731.

Schreiner M., 2005. Vegetable crop management strategies to increase the quantity of phytochemicals. European Journal of Nutrition, 44: 85-94.

Zhao Y., 2012. Auxin biosynthesis: a simple two-step pathway converts tryptophan to indole-3-acetic acid in plants. Molecular Plant, 5: 334-338.

EFFECT OF HIGH PLANT DENSITY ON YIELD AND MAIZE KERNEL QUALITY

EFFETTO DELL'ALTA DENSITA' SULLA RESA E QUALITA' DELLA GRANELLA DI MAIS

Giulio Testa[1], Massimo Blandino[2*], Amedeo Reyneri[2]

[1] Isagro S.p.A., Via Fauser, 28 Novara 28100 (NO).
[2] Dipartimento di Scienze Agrarie, Forestali e Alimentari, Università degli Studi di Torino, Largo Braccini 2, Grugliasco 10095 (TO).
[*] Massimo.blandino@unito.it

Abstract

Increasing the population density is an agronomical practice that has continuously been studied to increase yield. The present study compared different planting patterns and evaluated grain yield and kernel quality. It consisted on two experiments: the first one evaluated two row widths (traditional 0.75 m; narrow 0.50 m) combined with four planting densities, starting from 7.5 up to 12 plants m^{-2}. The second experiment was focused on 32 production situations (PS) in which standard planting pattern was compared to an innovative one. High planting density increased grain yield from 7.5 to 9.8% only on narrow inter-row. This result was confirmed on 90% of the PS where the narrow inter-row was combined with 10.5 plants m^{-2}. This system puts however the crop on more stressful conditions concerning higher mould development and lower kernel hardness. Therefore, stress control and commodity final destination should be considered before undertaking high plant density.

Keywords: Maize, planting density, yield, kernel quality
Parole chiave: Mais, densità colturale, resa colturale, qualità granella

Introduction

In the last decade the Italian maize yield index has progressively decreased, thus it is important to focus and develop agronomical tools that can support farmers to get the best advantages in terms of yield, offering a better breakthrough that can remove barriers and increase back again competitiveness. Increasing the population density of maize plants is indeed one of these strategies and it is the crop technique has evolved the most and will continue to evolve over the years (Tollenaar, 1992). After the introduction of the first maize hybrids, farmers started to steadily increase the plant density. In the US Corn Belt of the 1930s, the mean population density was 3 plants m^{-2}, while its average yield was around 2 t ha^{-1}. Nowadays the plant density is around 8 plants m^{-2} with proportional average yield increase (Duvick, 2005 and Li et al., 2015). The main purpose of increasing the number of plant per unit surface is to enhance maize yield in terms of grain or biomass, thus making the crop system more efficient and competitive per area unit. In fact, in case of absence or lenient biotic and abiotic stresses, grain yield is related to the amount of solar radiation intercepted by the crop, and the use of a high-density population, with an earlier canopy closure, can maximize the leaf area index (Cox and Cherney, 2001). Modern hybrids can generally withstand higher population densities, since they can bear a more stressful environment caused by a higher intra-specific competition more easily. However, in order to place the crop in the best growing conditions, planting pattern has to be re-thought with a reduction in the inter-row spacing that brings to a more balanced equidistance. Plants spaced more uniformly in fact compete minimally for the main growing factors, such as light, mineral nutrient uptake and water (Li et al., 2015).
Crop productivity however is not the only final aspect of yield agronomists are considering to sustain and guarantee maize competitiveness. Nowadays kernel quality features are becoming very important parameters for maize traders to suit to its best final destination. The two main quality aspects requested by the market trading maize are: low mycotoxins contamination for a healthy matter and good kernel technological properties, which for the dry-milling industry is related to the kernel endosperm hardness. These two quality features are indeed influenced by the field growing conditions, and it is supposed that high planting can play a key role on that.
The aim of this study was to evaluate the effects of different plant densities and sowing patterns on single plant and whole crop yield potential and on kernel qualitative traits in the concern of the food chain. The final objective was to understand whether high planting density can provide not only an increased yield but also maintain kernel quality for health and technological matters.

Materials and Methods

The study of the effect of different planting densities on the morphological development of plants, ears and kernels was performed over four growing seasons, from 2011 to 2014 (Testa et al., 2016). It involved two different experiments conducted in the agricultural area of North West of Italy in the Piedmont region.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The experiment number 1 consisted of two field trials conducted in 2013 and 2014 on which the compared treatments were a factorial combination of two inter-row spacings: 0.75 m wide, considered as the standard one for maize crop system (standard inter-row spacing: SIS), and 0.5 m, considered as the narrow one (NIS); four increasing planting densities, starting from the standard one of 7.5 plants m^{-2}, 9, 10.5 and 12 plants m^{-2}. Two hybrids were compared, characterized by a different ear development: with a stable (fix) or variable (flex) number of kernels set depending on the environmental conditions.
The second experiment consisted on the comparison of a standard planting system (StD), characterized by 7.5 plant m^{-2} planted in row 0.75 m apart with an average intra-row spacing of 0.18 m against an innovative high-density system (HiD) featuring 10.5 plant m^{-2} planted on 0.5 m wide rows and an intra-row distance of 0.19 m. The overall comparison of these two systems (StD vs HiD) was conducted considering 32 production situations spread in North West Italy, characterized all by equal fertilization levels among the two plant density regimes, all of them under irrigated conditions.
Ears were collected manually from each plot from a sub-area of 4.5 m^2. Ear weight, grain moisture, test weight, thousand kernels weight, kernel rows, kernel per row and kernel per square meter were assessed. A subsample of 1 kg was then used for further analysis concerning the kernel milling technologic aptitude, evaluated by the course/fine endosperm ratio, the milling energy test (Stenvert test, Blandino et al., 2010) and fumonisins and deoxynivalenol development.
The analysis of variance (ANOVA) was utilized to compare the effect of the planting density of experiment 1 on the recorded parameters. The average relative ratio (RR = HiD / StD) between the two planting systems was calculated for each measured parameter of all the production situations taken into account in the experiment 2.

Results and Discussion
A significant interaction between the hybrid ear development kind and inter-row spacing was reported on the experiment 1. A diminishing trend of the average number of kernels developed per row was observed for both types of hybrid as a consequence of the increasing planting density, from 7.5 to 12 plants m^{-2}. However, the effect was more consistent and significant on the flex hybrid, characterized by a variable kernel set number which, as expected, was influenced by the growing conditions occurred (fig. 1).

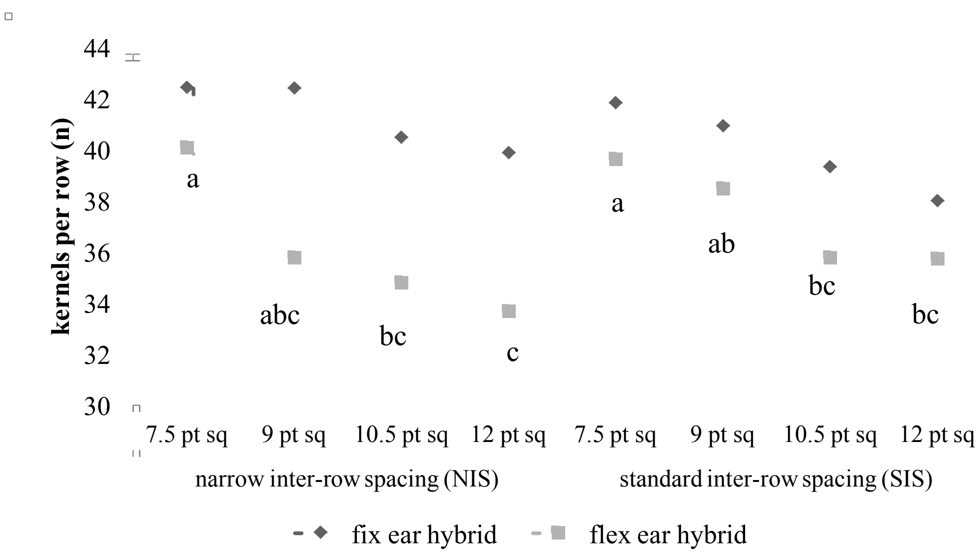


Fig. 1: Effect of inter-row spacing and planting density on the number of kernels per row developed on the fixed and flex ear hybrids. Means followed by different letters are significantly different (P<0.05).
Fig. 1: Effetto della distanza interfila e della densità colturale sul numero di cariossidi per rango sviluppate sull'ibrido a sviluppo "fix" e flex" della spiga. Valori medi seguiti da lettere diverse si differenziano in modo statistico (P<0.05).

Figure 2 shows the effect of different inter-row spacing and planting density on the final grain yield. As it is clearly shown, in the standard inter-row spacing (SIS), the grain yield did not increase by means of the higher planting density. On the other hand, the narrow inter-row system (NIS) showed a significant yield benefit when the plant population was increased from 7.5 to 10.5 plants m^{-2} (+7.4%). The highest yield peak (+9.8%) was obtained on 12 plants m^{-2} sowed on 0.5 m wide rows, however it was not significantly different from the lower density of 10.5 plants m^{-2}.

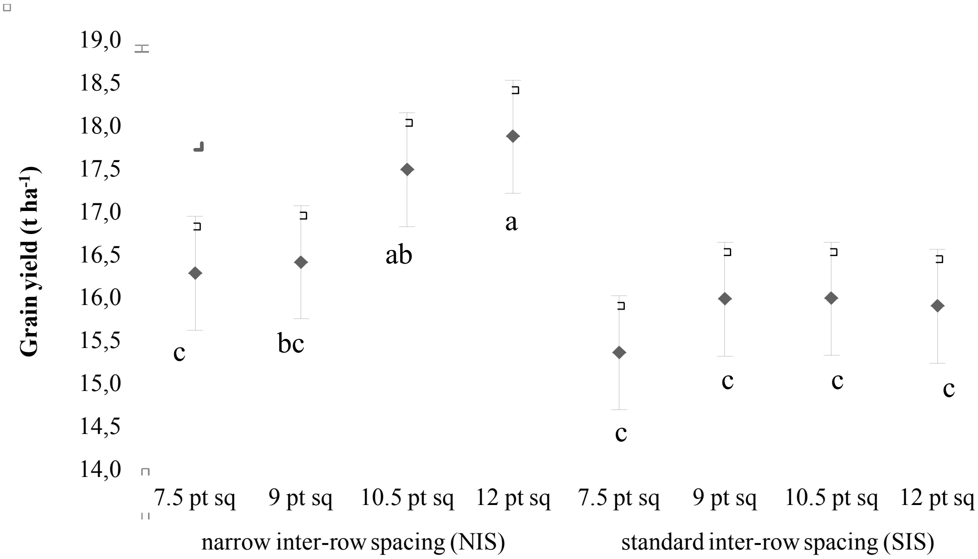


Fig. 2: Effect of inter-row spacing and planting density on grain yield. Mean values followed by different letters are significantly different (P<0.01).
Fig. 2: Effetto della distanza interfila e della densità colturale sulla resa in granella. Valori medi seguiti da lettere diverse si differenziano in modo statistico (P<0.05).

The comparison between the two agronomical systems conducted on the experiment n.2 (table 1), confirms the trend that a better grain yield is achieved when high planting density is applied, in fact the average yield gain was 11.4% and was achieved on 90% of the production situations. Parameters such as the grain moisture, test weight and the number of kernel rows, were not influenced. The high planting system showed to place the crop in a more sensible condition concerning the water consumption, especially from flowering to late ripening. The grain moisture in fact resulted to be lower generally in those production situations where a dry weather occurred prior to harvest. Vice versa, without drought conditions, the high plant population kept the canopy more humid, with more shade and less air flow, thus slowing down the kernel dry down phase. Other aspects related to the single plant yield potential were negatively influenced. For example a lower thousand kernel weight (-6%) was observed in the innovative system as well as the ear weight (-17.6%), since a lower number of kernel was present on each ear (-9%). However, since a higher number of ears were harvested per unit surface, an increase in the total number of kernels was observed (+23%).
Concerning the qualitative kernel trait, both the endosperm course/fine ratio, and grain protein content, were lower, indicating a reduced milling extraction capability on kernels belonging to the innovative system (HiD). In terms of health, the effect is not completely clear, since a higher severity of fungal rots was observed on ears, even though an average lower mycotoxin contamination was observed.

Conclusions
This work has proved that, for the cultivation of medium-late maturing hybrids in temperate areas and irrigated conditions, a high planting density of up to 10.5 plants m^{-2} can lead to a significant yield increase. This is true mainly when it is combined with narrow inter-row spacing (SIS), since by guaranteeing a better plant equidistance the single plant yield potential is more preserved. The high-density condition increases plant stresses, and modifies plant morphology and development to the detriment of the single plant yield. However, the lower yield per plant is fully compensated by the higher plant population. However, depending on which final use the harvest is aimed to, whether as livestock feed or human food, growers need to cautiously decide how to setup the crop system. This starts at planting, by choosing the most suitable hybrid that better responds to these requests, then by the correct planting density and planting pattern. If the main aim is yield and stress control allow it, a higher and intensive planting can drive to successful results. On the contrary, if the main objective is kernel quality, for the food chain, a standard planting density allows to obtain better grain in terms of kernel hardness for the milling industry with a lower mycotoxins content.

DOI 10.6092/unibo/amsacta/5692

Tab. 1: Comparison of the innovative planting density (HiD) and the standard density (StD) in different production situations on average grain yield, grain moisture, test weight, thousand kernel weight, ear weight, kernel rows, kernels harvested per square meter, course and fine endosperm ratio, grain protein content, severity of fungal rot development on ears, fumonisins and deoxynivalenol contamination.
Tab. 1: Confronto tra la densità colturale innovativa (HiD) e quella standard (StD) nelle differenti situazioni produttive sulla resa ad ettaro e l'umidità della granella, il peso ettolitrico, dei mille semi e della spiga intera, il numero di ranghi e di cariossidi raccolte per metro quadro. Il rapporto tra endosperma grossolano e fine, il contenuto in proteine nella granella, sviluppo fungino sulla spiga e contaminazione da fumonisine e deossinivalenolo.

Parameter	Unit	Mean HiD	Mean StD	Mean RR	Significance
grain yield	t ha^{-1}	18.1	16.2	1.117	***
grain moisture	%	25.4	25.0	1.013	NS
test weight	kg hL^{-1}	78.3	78.2	1.001	NS
thousand kernel weight	g	372	394	0.942	***
ear weight	g	260	317	0.824	***
kernel rows	n	16.5	16.3	1.013	NS
kernel per row	n	36.4	40.2	0.904	***
kernels per ear	n	597	653	0.913	***
kernels m^{-2}	n m^{-2}	5775	4690	1.233	***
course / fine endosperm ratio		0.887	0.917	0.962	***
grain protein content	g/100g	9.0	9.2	0.978	**
severity fungal rot	%	5.86	5.13	1.461	**
fumonisins	ppb	2644	2869	1.862	*
deoxynivalenol	ppb	3057	3946	1.785	NS

References

Blandino, M., Mancini, M.C., Peila, A., Rolle, L., Vanara, F., Reyneri, A. 2010. Determination of maize kernel hardness: comparison of different laboratory tests to predict dry-milling performance. J. Sci Food Agric. 90: 1870-1878.

Blandino, M., Reyneri, A., Vanara, F., 2008. Effect of plant density on toxigenic fungal infection and mycotoxin contamination of maize kernels. Field Crops Res. 106: 234–241.

Boomsma CR, Santini JB, Tollenaar M, Vyn TJ. 2009. Maize morphophysiological responses to intense crowding and low nitrogen availability: An analysis and review. *Agron J.* 101(6): 1426-1452.

Cox, W.J., Cherney, J.R., 2001. Row spacing, plant density, and nitrogen effects on corn silage. Agron. J. 93, 597–602.

Duvick, D.N., 2005. Genetic progress in yield of United States maize (Zea mays L.). Maydica 50: 193–202.

Li, J., Xie, R.Z., Wang, K.R., Ming, B., Guo, Y.Q., Zhang, G.Q., Li, S.K., 2015. Variations in maize dry matter, harvest index, and grain yield with plant density. Agron. J. 107: 829.

Liu T, Gu L, Dong S, Zhang J, Liu P, Zhao B. 2015. Optimum leaf removal increases canopy apparent photosynthesis, 13C-photosynthate distribution and grain yield of maize crops grown at high density. *F Crop Res.*: 170:32-39.

Sangoi L. 2000. Understanding plant density effect on maize growth and development: an important issue to maximize grain yield. *Ciência Rural*. 31(1): 159-168.

Testa, G., Reyneri A., Blandino, M. 2016. Maize grain yield enhancement through high plant density cultivation with different inter-row and intra-row spacings. European J. of Agronomy 72: 28-37.

Tollenaar, M, 1992. Is low plant plant population a stress in maize? Maydica, 37: 305-311.

AGRO-ENVIRONMENTAL-CLIMATE PAYMENT: A KEY MEASURE TO ADDRESS THE CLIMATIC AND AGRONOMIC CHALLENGES IN THE NEW RDPS

PAGAMENTI AGRO-CLIMATICO-AMBIENTALI: UNA MISURA CHIAVE PER AFFRONTARE LE SFIDE CLIMATICHE ED AGRONOMICHE NEI NUOVI PSR

Maria Valentina Lasorella[1], Danilo Marandola[2], Antonio Papaleo[2], Alessandro Monteleone[2]

[1] Council for Agricultural Research and Analysis of Agricultural Economics –Politics and Bioecomics, Via di Corticella 133, 40127, Bologna
[2] Council for Agricultural Research and Analysis of Agricultural Economics –Politics and Bioecomics Via Po, 14, Roma

corresponding author e-mail: *mvalentina.lasorella@crea.gov.it

Abstract
Europe's countryside is facing huge challenges today. In many member states soil erosion is increasing, wildlife is declining, water quality and availability is still a great cause for concern, and many farming systems continue to contribute significantly more to greenhouse gas emissions. In some areas in EU more traditional farming systems, which has delivered benefits for society for generations, are changing in response to poor market returns. People in these areas are abandoning more sustainable traditional practices, with more intensive agricultural practices, with serious consequences for local communities and the wildlife dependent on their farming systems. To address this problems the new Common Agricultural Policy is facing new challenges, in particular the reduction of greenhouse gas emissions by 20% by 2020. In this context new RDPs addressing high percentage of its budget to agro-environmental-climate focus areas and related measures. The amount of funding allocated agro-environmental-climatic focus areas (P4 and P5) is a clear confirmation of the important role that agriculture plays in our economy and thus the contribution to face the problems connected with GHG emissions. A top down approach, starting from the European level to the Regional ones underline which strategies have been adopted in terms of measure funded to take action to prevent and mitigate the impacts of climate change from agriculture.

Keywords: Agro-environmental climate payments, RDPs, policy, sustainability measures, , pilot projects
Parole chiave: pagamenti agro-climatico-ambientali, PSR, politiche, misure sulla sostenibilità, progetti pilota

Introduction
Among the innovations of the 2014-2020 Common Agricultural Policy there is a strong emphasis on the challenges of environmental sustainability and the fight against climate change affecting agriculture and rural areas. To meet the 2020 targets, the European Union asks farmers higher sustainability target in the 1st Pillar (e.g. greening) and offers strengthened support on the Second Pillar with the adoption of more sustainable agronomic practices to address the climatic and agronomic challenges. The second Pillar of the CAP (RDPs), is designed to specifically address these challenges of greater agri-environmental sustainability. In order to reach the goals of Europe 2020, the 2014-2020 PSRs are geared towards achieving six strategic priorities of interest for agro-forestry and rural areas. Priorities 4 and 5, are those reserved for the environmental and climatic sustainability of agriculture. The allocation of the financial resources of the Italian RDPs among the different priorities highlights the particular importance reserved for the "green" themes under the new programming period 2014-2020 (EAFRD 2013). In fact, resources are mainly focused on Priority 4 (restoring, preserving and enhancing ecosystems related to agriculture and forestry) with around 34% of the resources allocated. Noteworthy is also the financial funding programmed for Priority 5 (promoting resource efficiency and supporting the shift toward a low-carbon and climate-resilient economy in the agriculture, food and forestry sectors) dedicated to measures relevant for resource efficiency and climate change.
The new Rural Development Programmes (RDPs) 2014-2020 offer numerous opportunities to advance agro-environmental-climate activities in each MS. For the programming period 2014 to 2020, In Italy, the total resources allocated by the RDPs for the achievement of Priority 4 are about 7 billion euros and around 8.5 billion euros if the resources allocated to Priority 5 are added. Italian RDPs used the FEASR to fund operations such as those related to renewable energy, energy efficiency, afforestation and forest fire prevention, irrigation, improved nitrogen-use efficiency and manure management, and grassland management. In this context, Italy represents the second Member State, after France, with the highest funding allocation to agro-environmental-climate priorities (AECs) in the EU and with an amount of rural best practice which have been very successful at European level in particular best practice examples on the following measures: agro-environment-climate, investments in physical assets, knowledge transfer and integrated and organic farming which will be discussed (Vanni, 2013).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Materials and Methods

The analysis on Agri-environment climate (AEC) priorities and measures have been developed at European, National and Regional level. Information on RDPs have been extrapoleted for the analysis of adopted strategis for each single MS, with a focus on the Italian situation. The amount of budget allocated for the AEC measures, which are designed to encourage farmers to protect and enhance the environment on their farmland, have been discussed (Frelih-Larsen et al., 2014).

A series of best practice examples on the implementation of measure to address the climatic and agronomic challenges in the new RDPs have been written which seek to explain how some key "new and innovative" measures work, and how they are integrated into the current RDP operations. By "new and innovative" we mean actions either not commonly implemented in the past RDPs (but which have significant climatic and agronomic potential), or actions which have already been commonly implemented in RDPs but which have significant additional agro-environmental-climate potential. In order to provide actions that target a wide range of farm systems, GHG emission sources and adaptation in RDPs.

Results and Discussion

Several PSR measures contribute to achieving Priorities 4 and 5. Among them, a measure of strategic importance is certainly the measure 10Agro-environmental-climate payment (AEC). AEC Measure (Article 28, Reg. 1305/2013) aims to promote the necessary changes in agricultural practices between farmers and land managers to reduce the pressure on natural resources and the climate, enhancing the positive role that farming activities can have on the soil protection, water resources management, increase organic matter content, protect biodiversity, mitigate and adapt to climate change. It is such a strategic measure that Community regulations prescribe mandatory inclusion in rural development programs. For this reason, the Measure 10 is one of the measures with the widest geographical coverage and is also one of the measures with greater financial resources. The AEC measure consists of two sub-measures (which in turn provide for a diverse range of specific interventions/operations): sub-measure 10.1 "Payments for environmental agri-climate commitments" and sub-measure 10.2 "Support for conservation, use and Sustainable development of genetic resources in agriculture ". Sub-measure 10.1 aims at the sustainable development of rural areas and the fulfilment of the growing demand for environmental services required for agriculture by society. It intends to encourage farmers and other land managers to provide environmental services to the benefit of the entire society, with the introduction of extensive agricultural production methods and compatible with the protection and improvement of the environment landscape and its natural characteristics.

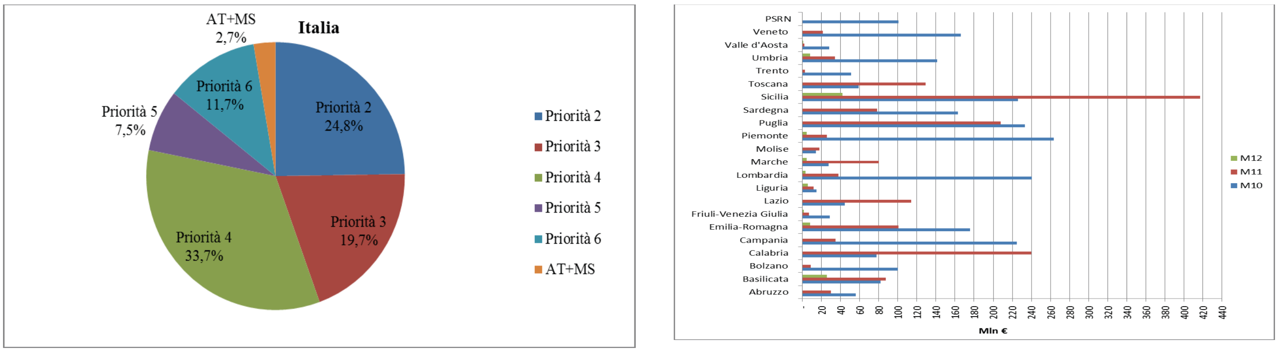


Fig. 1: a) Percentage of budget in Italy for Focus area; b) amount of budget allocated for agro-environmental climate measures between Italian Regions (Rete Rurale Nazionale on RDPs data).

Fig. 1: a) Percentuale del bilancio in Italia per Focus area; b) importo del bilancio destinato alle misure climatiche ambientali tra le regioni italiane (Rete Rurale Nazionale sui dati dei RDP).

AEC measure represents the "richest" in the EU framework, with almost 17% of total programmed spending, second only to the size of corporate investment, which weighs 23% on the budget. The same situation occurs in the Italian context of the 21 rural development programs, which allocate a total of around 2.5 billion euros to Measure 10, a budget of 12% of the total public expenditure programmed by the Italian programs for the whole of the seventh, second Of importance only to that for Measure 4 "Investments". In absolute terms, the Regions that plan the largest public spending on Measure 10 are, in order, Piedmont, Lombardy, Apulia, Campania and Sicily, with grants exceeding € 200 million for the entire period. The same trend can be seen when considering the proportion of the budget allocated to this Measure in relation to the total expenditure envisaged by the Programs. Beyond Bolzano and Valle d'Aosta, which are programs with lower total budgets, only Piedmont and Lombardy devote to Measure 10 more than 20% of the entire programmed budget. In March 2017 Italian PSRs opened calls for measures of 10 for 101 of the 134 planned interventions. The total of banned resources was about 950 million euros. Some PSRs have already report important results in terms of impact of this measures on the agro-

DOI 10.6092/unibo/amsacta/5692

environmental-climate measure in particular related to integrated and conservative agriculture where the amount of application and current beneficiaries highlight the importance of such measure and strategy for the agricultural activities.

Conclusions

Sustainable agricultural activities can provide a large number of services relating to social, economic and environmental aspects and sustainability. For this reason the implementation at European, National and Regional level of measures and actions promoting the efficient use of resources, biodiversity and soil protection, a better water management and the integration of technical innovation at farm level is a crucial aspect for our agriculture and economy. One of the main benefits deriving from the application of agro-environmental-climate measure is related not only to the environment and the quality and safety for the products, but our activity have demonstrate the increase interest from famers to produce in a more sustainable way, saving money and with a less impact on natural resources. Through the analysis of measure 10 at European, National and Regional level it is possible to understand the willing of local policies with the analysis of the numbers of application received at Regional level supporting the agro-environmental strategies. Through these preliminary results, it will be possible to see what will be the effects on the environment and on climate change.

References

Frelih-Larsen A., MacLeod M., Osterburg B., Eory, A. V., Dooley, E, Kätsch S., Naumann, Povellato, A., Bochu, J.L., Lasorella, M.V., Longhitano,D. 2014. "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

EAFRD Regulation, 2013. Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005. Official Journal of the European Union L 347/520.

Vanni, F., 2013. The provision of agri-environmental public goods through collective action: Evidence from case studies in Italy. Istituto Nazionale di Economia Agraria.

FIRST SUGGESTIONS FOR AN UPGRADED COMPARATIVE EVALUATION OF THE MODIFICATION OF FOUR ALPINE VALLEYS DURING THE LAST CENTURY

SUGGERIMENTI PER UNA VALUTAZIONE COMPARATIVA AVANZATA DELLE MODIFICAZIONI DI QUATTRO VALLATE ALPINE NELL'ULTIMO SECOLO

Vittorio Ingegnoli*[1], Stefano Bocchi[1]

[1]Department of Environmental Science and Policy, University of Milan. 2, via Celoria 20133 Milano
*vittorio.ingegnoli@unimi.it

Abstract
In the last 100 years the Alpine Valleys passed through strong transformations, mainly due to the increase of tourism economy. Being the landscape/territory a complex system, an upgraded comparative evaluation of the Valleys is made possible following the new discipline of Landscape Bionomics, because the traditional ecology is not sufficient. We considered four Valleys: small and wide at low altitude (Gresta and Fiemme, Trentino), small and wide at high altitude (Cuneaz and Ayas, Aosta). During the last century, the forest cover has grown nearly by 10-15 %, while cultivated areas have sharply decreased, with the exception of Gresta. Tourists permanence have enlarged local populations, leading in some cases to the heterotrophy of a landscape unit, e.g. Cavalese. At high altitudes the exceptional bionomics state of prairies and pastures and their economic contributions tend to limit the forest re-growing, as in Cuneaz.

Keywords: Alpine valley, Bionomics, Biological Territorial Capacity of vegetation, Standard Habitat x capita, Human Habitat, Bionomics Functionality
Parole chiave: Vallate Alpine, Bionomia, Biopotenzialità della vegetazione, Habitat Standard x capita, Habitat umano, Funzionalità bionomica

Introduction
In the last century Alpine Valleys passed through strong transformations, mainly due to the increasing of touristic economy and to the abandonment of cultivated land. Their study cannot be limited to a reductionist approach, that is geographical frame, ecological description, land use/land cover measures and socio-economics considerations, because the landscape/territory is a complex system and, thus, it needs a change in the scientific theoretic *corpus* of reference: that means a passage from reductionism to holism, to a systemic theory and approach, which in add show the limits of many branches of biology, mainly genetics, ecology and medicine. The discipline of General Ecology or *"Speech on our House"* is necessary, but not sufficient: we require also the Bionomics, that is the new "*Doctrine of the Laws of Life Organization on the Earth*" (Ingegnoli, 2015), within which the landscape is recognised as a proper biological organisation level (Maffe and Carrol, 1997, Ingegnoli, 2001, 2002, 2011), characterised by a wide exchange of information between man and his territory (Waddington, 1961; O'Neil et al, 1986; Ingegnoli & Pignatti, 2007; Bottaccioli, 2014; Ingegnoli, Bocchi, Giglio, 2017). This new theoretic *corpus* inevitably leads to significant changes on how to investigate and manage the environment.

Materials and Methods: LANDSCAPE BIONOMICS APPLICATIONS
Landscape Bionomics (Ingegnoli, 2015) (a) recognizes 'ecological units' of territory as living entities, composed by a complex integration of natural and human systems and (b) studies their physiology and pathology through a quali-quantitative clinical-diagnostic approach (Ingegnoli, 2011, 2012, 2015;Ingegnoli, Bocchi, Giglio, 2017).
The identification of the structure of Landscape Units (LU) requires new principles: the concept of *ecocoenotope* replaces that of ecosystem, the concept of *ecotissue* replaces the one of ecomosaico, the concept of *landscape apparatus* identifies functional systems of ecocoenotopes forming specific configurations within the ecotissue (Ingegnoli, 2002, 2015). Between all, three main systemic functions arise: the SH*, *Theoretical Minimum Standard Habitat* per capita (Ingegnoli, 2001, 2002); the BTC, *Biological Territorial Capacity of vegetation* (Ingegnoli, 1999; Ingegnoli & Giglio, 1999) and the HH, *Human Habitat*, allowing to evaluate the *Bionomic Functionality* (BF) of the examined landscape unit, reaching from normality (1.00-0.85) to quite complete absence (around 0.1-0.3). These principles bring to new proper methodologies (see Ingegnoli, 2015, for a deepen treatment of them).
The SH* represents the theoretical vital area per capita [m^2/inhab] needed by an organism: it is divisible in all its components, biological and relational, derived from the systemic functions of landscape apparatuses[1]. The SH, Standard Habitat per capita, represents the surveyed vital area per capita [m^2/inhab] available for an organism, estimated on the bases of the multiple functions of each tessera of the land use mosaic of the landscape. The ratio SH/SH*, known as Carrying Capacity of a LU, is a method to evaluate the autotrophy or heterotrophy of a landscape unit. If SH/SH* < 1 the LU presents heterotrophy. Moreover, the application of this methodology permits to control the distribution of the Human Habitat and Natural H. per each main landscape apparatus.
The BTC of vegetation is a bio-systemic function able to measure the level of order and metastability reached by a phytocoenosis (natural or anthropic), as a negentropic flows of energy related to its metabolic functions [Mcal/m^2/yr]: values for grass and fields range between 1.20 and 2.40, while vines, shrubs, plantations and gardens from 2.40 to 4.00, adult/mature forest from 6.00 to 9.50. HH is the percentage evaluation of the human capacity to affect and limit the self-regulation capability of natural systems: it is a component of landscape multifunctional apparatuses (Ingegnoli, 2002). Its evident correlation with BTC in landscape units of

[1] e.g. PRD = productive (i.e. agricultural ecocoenotopes), PRT = protective, RNT = resistant (i.e. forest), RSD = residential (i.e. houses), etc.,

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

different landscape types brought to the model HH/BTC. As shown in Fig. 1, the function of correlation HH/BTC[2], derived from the analysis of 45 landscape units in North Italy and Central EU, can be used as a model and allows us to define the most frequent thresholds of characterisation of the main types of landscape.

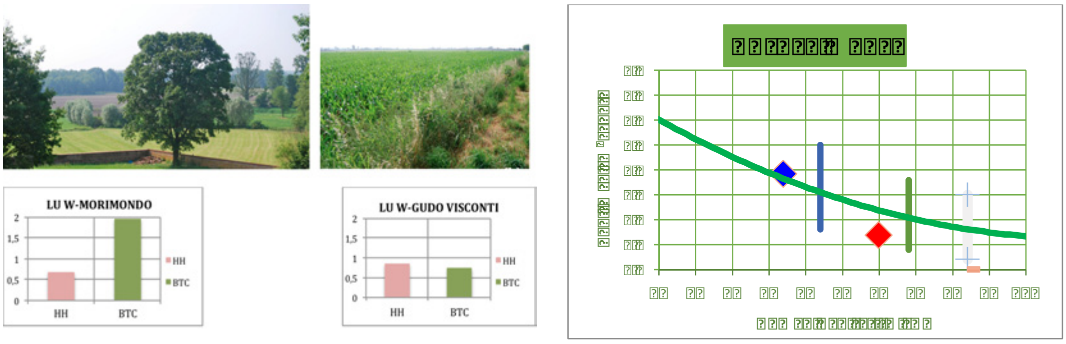


Fig. 1. Comparison between two agricultural landscapes units in Lombardy (Italy): near Morimondo Abbey, with an acceptable level of BTC (Mcal/m^2/yr) and near Gudo Visconti with a worst level of its BTC. Note their different position in the HH/BTC model (left), where the green curve represents normality, the blue line defines the threshold protective agricultural/productive agricultural LU, the green line the threshold productive agricultural/suburban LU .
Fig.1. Confronto fra BTC e HH in paesaggi agrari nel Milanese. A sinistra, la loro posizione nel modello HH/BTC.

The surveys of vegetation were made following the LaBiSV methodology. This methodology (Landscape Bionomics Survey of Vegetation) has been proposed to respond to the bionomics assertions. The LaBiSV method (Ingegnoli, 2002; Ingegnoli & Giglio, 2005; Ingegnoli & Pignatti, 2007) may be synthetized in a *frame protocol*, articulated in 12 main phases and linked to a development model per each phytocoenosis type (so even anthropic vegetation), based on an exponential and logarithmic function BTC/Years. Other new systemic functions and indexes, such as the CBSt (the Efficiency of Vegetation Index) and the bQ (the Bionomic Quality), permit to deepen our studies (see Ingegnoli, 2015).
We considered four Valleys, wide and small at low altitude (Fiemme V. and Gresta V., Trentino), wide and small at high altitude (Ayas V. and Cuneaz V., Aosta). In Fig. 2 we can see the two most important: Fiemme and Ayas. The study proceeded since 2009 and finished in 2015.

Fig.2. Fiemme Valley, 41,570ha, with Lagorai Mts. (2600-2750m a.s.l.); Ayas High Valley, 12,985ha, with Breithorn (4250m).
Fig.2. Val di Fiemme, 41.570ha, con M.ti Lagorai (2600-2750m slm); Alta val d'Ayas, 12.985ha, con cime Breithorn (4250m).

Results and discussion
As we can see, the main measured variables are divided into geographical and bionomics (Tab. 1). The most important difference between low and high valleys today is in sterile areas, snow and ice, growing exponentially with altitude, followed by the ratio forest/pastures near inverted from low to high valleys. Obviously, human habitat is dependent on previous variables, resulting HH = 1.5 wider in lower valleys. The ecological density of population (*sensu* Odum 1971, 1983) is 4.5 times more elevated in lower than in higher valleys. Less dependent is the Biological Territorial Capacity, i.e. the ratio Forest area/BTC which is equal to 0.0723 in lower valleys, whereas it has a value of 0.1015 in higher ones.
The historical dynamics of the last century shows interesting trends.
GRESTA, a small valley at mean altitude of 800 m a.s.l., shows a crop & meadow decrease limited to –22.8%, one of the most moderate of the entire Alps and an increase of 6.9% in forest cover. Population remained near constant, +2.1%, even counting the tourist permanence. The HH and the SH are decreasing (-14.5%), the BTC of the LU is in a slow increase, +5.4%.
FIEMME, a wide valley at mean altitude of 1000 m a.s.l., presents two major dynamics: a strong increase of population, +46.8%, and a strong decrease of agriculture, -77.6%. The increase of forest is +9% and still more for pasture +27%, both giving an increase also in BTC, +7.3%, while the HH has a small contraction, -3.6%. The decrease of SH is notable: the valley is near the limits of population pressure.
AYAS, with the valley floor lying between 1500 and 1750 m a.s.l. and still 10% of glaciers (13 km^2, from 4250 to about 2900m),

[2] HH/BTC function: $y = 0.0007x^2\ 0.1518x + 8.85$ [$R^2 = 0.95$]

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

is delimited by many hanging valleys (one of which is Cuneaz), thus the most part of it is sterile (41%). The comparison shows an increase of forest similar to that of Fiemme, +8.3%, while the proportion of land cover is less than a half of it. The decrease of agriculture is more moderate, from 770 to 500 ha, mainly meadows. The population is in decline, -5.4%, notwithstanding the tourism of the well known Monte Rosa Ski plants of Champoluc. The bionomics functionality BF shows a slow increase, but it remains very far from the normality (48 Vs 85).
CUNEAZ, the small valley having two of the most elevated villages in the Alps (Cuneaz, 2050m, and Crest, 1950m a.s.l.), today interested by a ski runs, has lost the majority of its inhabitants, from 105 to 10, becoming 32 if we consider the tourist mean permanence. Anyway, the increase of forest cover is good, +13.2%, but with a measured BTC increase of +4.6%. The agriculture presents the disappearance of crop fields, but still numerous semi-natural meadows (*Triseteta*), pastures and cow herds.

Tab. 1. Main variables comparing last century changes in Alpine valleys
Tab. 1. Variabili principali di confronto dei cambiamenti delle vallate alpine nell'ultimo secolo

	1900		2010		Δ%	Δ%	1910		2010		Δ%	Δ%
Variables	**Gresta**	**Fiemme**	**Gresta**	**Fiemme**	**Gresta**	**Fiemme**	**Ayas**	**Cuneaz**	**Ayas**	**Cuneaz**	**Ayas**	**Cuneaz**
Mean Altitude m a.s.l.	*800*	*1000*	*800*	*1000*	-	-	*1600*	*2000*	*1600*	*2000*	-	-
Surface ha	*3052*	*41570*	*3057*	*41714*			*12990*	*895*	*12985*	*895*		
Population (inhab/1000)	1.91	15.6	1.95	22.9	+2.1	+46.8	1.84	0.11	1.74	0.03	-5.4	-72.7
Steril %	6	11.4	5.5	11.0	-8.3	-3.5	41.6	38	41	37	-1.4	-2.6
Forest %	56.8	52.3	60.6	57.0	+6.9	+9.1	18.1	12.9	19.6	14.6	+8.3	+13.2
Pastures & shrubs %	5.1	18.9	7	24.0	+37.3	+27	33.6	45.5	32	44.5	-4.8	-2.2
Crops & Meadows %	31.1	17.9	24	4	-22.8	-77.6	6	3.6	4.4	3.3	-33.3	-10.8
Human Habitat HH %	33.9	19.7	29	19	-14.5	-3.6	17.1	17	18.5	16.6	+8.2	-2.9
L. Unit BTC (Mcal/m²/yr)	3.7	4.24	3.9	4.55	+5.4	+7.3	1.73	1.51	1.8	1.58	+4.1	+4.6
Standard Habitat SH (ha/ab)	0.54	0.52	0.46	0.30	-14.8	-42.3	1.22	1.45	1.36	4.65	+11.5	+320
L. Unit state, BF	**0.82**	**0.78**	**0.79**	**0.75**	**-3.6**	-3.9	**0.45**	**0.38**	**0.48**	**0.37**	**+6.7**	-2.6

In Tab. 2 we synthetized the results of the vegetation survey, made following the LaBiSV method. Low and high altitude valleys are sharply different. Forests present a very high plant biomass volume in Fiemme, about 45% more than Ayas, being the canopy height 30 m Vs. 24 m and a BTC = 8.05 Vs. 6.88. But the prairies are better in Ayas, with a BTC = 0.82 Vs. 0.77 and the CBSt (Concise Bionomic State) = 30.78 Vs. 26.16.

Tab. 2. Comparison between Ayas and Fiemme Vegetation Surveys, LaBiSV Method.
Tab.2. Comparazione fra i rilievi di vegetazione in Ayas e Fiemme, metodo LaBiSV.

	Altitude	Plant Species tot.	*Hc*	*v FM*	*T*	Soil (R X N)	*BTC*	bQ	M-Th	CBSt
AYAS and CUNEAZ	m a.s.l.	n°	*m*	*m³/ha*	*Pignatti (2005)*	*Pignatti (2005)*	*Mcal/m²/yr*	%	%	%
FORESTS, Mean	*1782*	*37*	*24.06*	*603.8*	*3.12*	*8.91*	***6.88***	*66.40*	*46.36*	***30.94***
Prairie & pasture, Mean	*1954*	*37*	*0.75*		*3.49*	*18.02*	***0.82***	*58.17*	*48.98*	***30.78***
FIEMME										
FORESTS, Mean	*1598*	*35*	*30,04*	*877.4*	*3.35*	*8.43*	***8.05***	*73.99*	*62.23*	***47.32***
Prairie & pasture, Mean	*1462*	*31*	*0.72*		*3.7*	*20*	***0.77***	*56.78*	*34.26*	***26.16***
Hc = canopy height, vFM = volume of Fitomass, T = temperature, RxN = humus efficiency, bQ= bionomics quality, CBSt = concise bionomics state, M-Th= Maturity level of Phytocoenosis;										

The collapse of agriculture seen in Table 1 can be explained by Tab. 3, in which four main touristic municipalities related with the examined valleys are analysed. Their human habitats (HH) are proportional with the dimensions of the valleys. We have evaluated the total population, composed by the local inhabitants and the tourist-equivalents. In Trentino they reach a very conspicuous number, therefore the standard habitat per capita (SH) in Ayas and Cuneaz result near incomparable. We must note that the territory of Cavalese, presenting a SH/SH*= 0.75, shows a condition of heterotrophy.

Tab. 3. Population, tourism and Carrying Capacity of the most important Municipalities of the four valleys.
Tab. 3. Popolazione, turismo e Capacità Portante Bionomica dei più importanti Comuni delle quattro valli.

Municipality	**area**	**HH**	**HH**	**Residents**	**Tourists**	**added inhab.**	**Population**	**SH**	**SH***	**Carrying cap.**
Locality (altitude): valley	km²	%	km²	Inhab.	Inhab.	%	tot inhab.	ha/ab	ha/ab	SH/SH*
Cavalese (1000 m asl): Fiemme	45	21	9.45	4,150	1,827	44	**5,977**	0.16	0.21	**0.75**
Ronzo-Chienis (1000 m asl): Gresta	13.8	30.2	4.16	1,020	260	26	**1,280**	0.32	0.21	**1.55**
Champoluc (1580 m asl): Ayas	45	19	8.55	450	166	37	**616**	1.39	0.29	**4.78**
Cuneaz (2050 m asl): Cuneaz	8.95	16.6	1.49	10	22	220	**32**	4.64	0.35	**13.27**

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The most unknown result of this study is the ecological state of the examined Alpine valleys: BF values are very low, so these landscapes are not in a true healthy state. Anyway, future may lead to some new hope. Among the main strategies of innovation in agriculture, the agro-ecological one seem to be the best, as it follows a systemic approach (Bocchi, 2015). Therefore, tourism today can be systemically integrated with agriculture returning to Alpine cereals and other local seed cultivations (e.g. medical herbs, as *Digitalis purpurea*, or *Artemisia genipi* etc.). Remember that in the last century the agrarian production increased about 4 times (Gliessman, 2014; Ingegnoli, 2015). This is true even in the Alpine environment, as proved in Ayas (Fig. 3), where an experimental field of wheat and barley produced near 4.8 ton/ha, at the altitude of 1,660 m a.sl.

Fig.3. Experimental fields of wheat and barley in Ayas valley, Antagnod, 1,660 m of altitude.
Fig. 3. Campi sperimentali di frumento e di orzo in val d'Ayas, ad Antagnod, quota 1660m.

Conclusion

Being each landscape/territory a complex system, an upgraded comparative evaluation of it is made possible following the new discipline of Landscape Bionomics, because the traditional ecology is not sufficient. Agroecology is shifting in this direction: more interesting results will arrive.

References

Bocchi S (2015) Zolle, storie di tuberi, graminacee e terre coltivate. R. Cortina Editore, Milano.

Bottaccioli F (2014) Epigenetica e Psiconeuro- endocrinoimmunologia; le due facce della Rivoluzione in corso nelle scienze della vita. Edra Spa, Milano, pp. XI+176

Gliessman SR (2014) Agroecology: the ecology of sustainable food systems. CRC Press. USA

Ingegnoli V (1999) Definition and Evaluation of the BTC (Biological Territorial Capacity) as an Indicator for Landscape Ecological Studies on Vegetation. In Sustainable Landuse Management: The Challenge of Ecosystem Protection. EcoSys: Beitrage zur Oekosystemforschung, Suppl Bd 28:109-118

Ingegnoli V (2001) Landscape Ecology. In: Baltimore D, Dulbecco R, Jacob F, Levi-Montalcini R (eds.) Frontiers of Life. vol IV, Academic Press, Boston, pp 489-508.

Ingegnoli V (2002) Landscape Ecology: A Widening Foundation. Berlin, New York. Springer, pp. XXIII+357

Ingegnoli, V. (2011). Bionomia del paesaggio. L'ecologia del paesaggio biologico-integrata per la formazione di un "medico" dei sistemi ecologici. Springer-Verlag, Milano, pp. XX+340.

Ingegnoli, V. (2012). Valutazione bionomica delle componenti naturali del paesaggio e conseguenti criteri di progettazione ecologica. Pp. 64-72. in A.M. Ippolito Il progetto di paesaggio come strumento di ricomposizione dei conflitti. Franco Angeli, Saggi, Milano.

Ingegnoli V (2015) Landscape Bionomics. Biological-Integrated Landscape Ecology. Springer, Heidelberg, Milan, New York. Pp. XXIV + 431

Ingegnoli V, Giglio E (1999) Proposal of a synthetic indicator to control ecological dynamics at an ecological mosaic scale. Annali di Botanica LVII: 181-190

Ingegnoli V, Giglio E (2005) Ecologia del Paesaggio: manuale per conservare, gestire e pianificare l'ambiente. Sistemi editoriali SE, Napoli, pp. 685+XVI

Ingegnoli V, Bocchi, S, Giglio, E (2017) Landscape Bionomics: a systemic approach to understand and govern territorial development. WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT, pp.189-196

Ingegnoli V, Pignatti S (2007) The impact of the widened Landscape Ecology on Vegetation Science: towards the new paradigm. Springer Link: Rendiconti Lincei Scienze Fisiche e Naturali, s.IX, vol.XVIII, pp. 89-122

Meffe G.K., Carroll C.R. (1997), *Principles of conservation biology*. Sunderland, Massachusetts, Sinauer Associates, Inc Publ.

Odum E.P. (1971), Fundamentals of ecology. 3rd ed, WB. Philadelphia, Saunders. Pp. XIV+574

Odum E.P. (1983), Basic Ecology. CBS College Publ. USA, pp. XI+544

O'Neill RV, De Angelis DL, Waide JB, Allen TFH (1986) A hierarchical concept of ecosyestems. Princeton Univ. press, Princeton, NY

Pignatti S. (2005), Valori di bioindicazione delle piante vascolari della flora italiana. Braun-Blanquetia 39:1-97

Waddington CH (1961) The nature of life. Atheneum, New York

MONITORING EROSION IN SLOPING VINEYARDS: EFFECTIVENESS OF GRASS COVERING IN DIFFERENT PERIODS

IL CONTROLLO DELL'EROSIONE NEI VIGNETI IN PENDENZA: EFFICACIA DELL'INERBIMENTO IN DIVERSI PERIODI STORICI

Giorgia Bagagiolo[1*], Danilo Rabino[1], Marcella Biddoccu[1], Eugenio Cavallo[1]

[1] CNR-IMAMOTER, Strada delle Cacce, 73, 10135 Torino (TO)
*g.bagagiolo@ima.to.cnr.it

Abstract

Under projected climate changes, runoff and soil erosion processes are likely to become more severe due to the intensification of extreme precipitation events. In consequence of the expected increase of rainfall intensity and erosivity, grass cover is acknowledged as the most effective soil management practice adopted to reduce soil loss by runoff. The aim of this study was to verify the effectiveness of grass cover (GC) in preventing runoff and soil erosion in sloping vineyards with respect to conventional tillage (CT) and to seasonal pattern. Rainfall, runoff and soil loss from experimental farm of Vezzolano (NW-Italy) were recorded in two different periods.

Results confirmed the effectiveness of GC, especially when high erosive events occurred in summer, while soil protective effect considerably decreased in autumn, thus pointing out the need to improve appropriate agronomic strategies to achieve better water and soil protection throughout seasons.

Keywords: run-off; soil erosion; climate change; sloping vineyards; soil management

Parole chiave: ruscellamento; erosione del suolo; cambiamento climatico; vigneti in pendenza; gestione del suolo

Introduction

Climate change projections suggest that the Mediterranean area in the next years will be subjected to increasingly warmer conditions, with a pronounced decrease in precipitation, especially in the warm season. In Italy, particularly in the North-West and in the Alpine Region, mean annual temperatures increased by more than 1°C in the last fifty years and an increase of extreme precipitation events related to global warming is expected for the next decades (Corti et al., 2009).

The climate changes in rainfall intensity and precipitation pattern have a considerable impact on runoff and soil erosion in hilly vineyards since rainfall erosivity is strongly related to rainfall intensity (Biddoccu et al. 2013; Biddoccu et al. 2014). Moreover, in sloping conditions, the erosional processes are highly affected by seasonal climatic fluctuations (Cerdà, 2002) and soil management practices (Tropeano 1984; Ramos and Martinez-Casasnovas 2006; Blavet et al. 2009).

In order to prevent the negative impacts on soil erosion of future climate change and predicted increase of rainfall intensity and erosivity, proper protection measures should be taken (Li and Fang, 2016). The use of controlled grass cover in the inter-rows is one of the most common and effective soil management practices adopted in order to reduce runoff and soil erosion in vineyards (Blavet et al., 2009), nevertheless, the protective effect of grass cover may decrease according to seasonal pattern (eg. extraordinary meteorological events or insufficient soil covering).

For this reason, previous studies (Biddoccu et al., 2014, Biddoccu et al., 2016) stressed the importance of investigating the actual effectiveness of conservation measures and stated the need of elaborating appropriate soil management practices to achieve better water and soil protection throughout the seasons.

Since 1980, the Institute for Agricultural and Earthmoving Machines (IMAMOTER) of the National Research Council of Italy (CNR) have been carrying out studies on the effect of soil management on runoff and erosion in sloping vineyard. The results presented in this paper refer to soil erosion monitoring activity carried out during 90's and in last two years in the Experimental Farm of Vezzolano (45°08'N, 7°96'E, 426 m asl), located in Piedmont (north-western Italy) in the Basso Monferrato hilly vine production area.

The study aimed to assess, in the framework of climate changes and more frequent extreme precipitation events, the effectiveness of grass covering in preventing runoff and soil erosion in sloping vineyards. The analysis was performed for two different time-periods, at micro-plot scale, in order to evaluate: (1) the efficacy of grass covering versus conventional tillage inter-row soil management; (2) the impact of seasonal pattern variation on runoff/soil losses in grass-covered inter-rows.

Materials and Methods

EXPERIMENTAL AREA

The climate of the experimental site is characterized by dry summer and cold winter with snowfall events.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Rainfall was recorded with mechanical weather station in the period 1962-2004 (mean annual precipitation 845.8 mm) and with an electronic station in the period 2005-2017 (mean annual precipitation 958.3 mm). Precipitation events mainly concentrated in May, October and November. The driest month was July.
Mean annual air temperature measured at the experimental site was 11.8°C in the period 1962-2004 and 13.3°C in the period 2005-2017.
The soil texture is clay loam (28% clay), resting over marls (Middle Miocene).
The experiment was conducted in two different vineyards in Vezzolano Farm and during two different periods:

- plots on a hillslope cultivated along contour lines with SE aspect and average 15% slope (in the 90's);
- plots on a hillslope partly cultivated along contour lines, partly aligned along the slope, with SO aspect and average 21% slope (experiment currently in progress).

DATA COLLECTION IN 90'S

In Vezzolano's catchment, controls were carried out from 1993 to 1997, in a vineyard with rows across the slope (15%) and SE aspect.
Two plots were monitored, with 0.52 ha area, managed with i) conventional tillage (CT): autumn ploughing, summer hoeing; ii) control grass cover (GC): mowing and chopping of herb three times per years. The plots were hydraulically isolated and supplied with: water capture outlet, slowing tanks, measurement devices. Runoff was measured (and sampled) by means of two balancing buckets with click counter, and an overflow meter when water overflows the decantation tank.
The rainfall events were considered when the runoff exceeded 300 l ha^{-1}.

DATA COLLECTION IN 2015-2017

In order to evaluate the runoff and soil losses after rainfall events in a grassed vineyard, n. 3 micro-plots were placed in non-contiguous rows and away from the edge of the vineyard to avoid the edge effect. The 3 micro-plots have dimensions 6 m x 2.70 m; each one is located in a different row, in order to provide independent measures.
The runoff collection system in each micro-plot consists of a collection tank of 20 liters capacity, partially buried, equipped with a sedimentation area and a septum for retaining suspended parts. In case of small rainfall events, any runoff is collected and contained within the collection tank. The volume of water at the end of the event is finally measured, the sediment is collected, dried and weighed, so as to obtain the runoff and soil losses values in the sample area.

Results and Discussion

MONITORING ACTIVITY IN 90'S

Tab. 1 – Annual rainfall, runoff and soil losses measured in years 1993-1997 in two vineyard plots in Vezzolano catchment.
Tab. 1 – Dati di precipitazione annuale, ruscellamento e perdita di suolo misurati negli anni 1993-1997 nei due vigneti di Vezzolano.

Year	Annual rainfall (mm)	N. of events with		Rainfall (mm) with		Runoff coeff. (%) (runoff events)		Runoff coeff. (%) (erosive events)		Erosion (kg/ha)	
		runoff	erosion	runoff	erosion	CT	GC	CT	GC	CT	GC
1993	973.8	20	20	801.8	801.8	2.93	1.32	2.93	1.32	13,521.1	2,354.8
1994	984.4	15	12	797.0	637.4	0.61	1.26	0.77	1.57	21.0	19.3
1995	798.4	15	12	596.0	504.4	0.61	0.57	0.72	0.67	138.2	20.0
1996	1,054.2	19	14	806.6	585.0	0.78	0.60	1.08	0.83	1,171.8	88.7
1997	1,334.5	5	3	250.7	153.7	0.71	0.73	1.16	1.19	119.5	109.9
Avg.	**1,029.1**	**-**	**-**	**650.4**	**536.5**	**1.13**	**0.90**	**1.33**	**1.12**	**2,994.3**	**518.5**

In the period 1993-1997 (Tab. 1) runoff coefficient measured from the 0.52 ha-plots were lower than 3%. The orientation of rows along contour lines had a primary role in reducing runoff also in the CT plot, if compared with other studies on similar slope in NW-Italy (Biddoccu et al., 2015). Annual runoff was not always reduced in the GC plot, with respect to CT. When runoff was higher in GC than in CT, soil losses were only slightly lower in the grassed plot than in the tilled one. On the contrary, runoff was reduced up to 55% by the grass cover in years where soil losses were more relevant in CT. There were no significant differences in average annual runoff and soil losses, that were analyzed using paired *t*-test (for runoff) and Mann-Whitney rank sum test (for soil losses), although there were large annual variations in erosion. The use of grass cover reduced the mean annual soil losses by 83%, which is better result than in other studies in vineyards (Biddoccu et al., 2016; Novara et al., 2011; Ruiz-Colmenero et al., 2011). The best protection was shown when high erosive events occurred in summer. Indeed, in 1993 the highest erosion was measured in both the plots, mainly due to a single summer storm (maximum hourly rainfall intensity was 148.8 mm h^{-1}), which causes erosion of 12,306 kg ha^{-1} and 2,183 kg ha^{-1} in CT and GC, respectively. In 1996 GC was able to reduce the annual soil loss by 92%, compared to CT, and most of erosion was due to some summer storms occurred in August.

MONITORING ACTIVITY IN 2015-2017

Tab. 2 – Annual rainfall, rainfall erosivity, mean runoff and soil losses measured in micro-plots in a grassed vineyard in the Vezzolano catchment, from May 2015 to April 2017. Runoff and soil losses are average of values measured in the three micro-plots.

Tab.2 – Dati di precipitazione annuale, erosività della pioggia, ruscellamento medio e perdita di suolo misurati da maggio 2015 ad aprile 2017 nei micro-plot di vigneto inerbito siti a Vezzolano. I valori di ruscellamento e perdita di suolo corrispondono alla media dei valori misurati nei tre micro-plot.

	Annual rainfall (mm)	**Rainfall (mm) with erosion**	**Erosivity-EI30 (MJ mm/ha h)**	**Runoff * (mm)**	**Runoff coeff. (erosive events) (%)**	**Soil loss * (kg/ha)**
May 2015-April 2016	682.0	508.6	552.2	4.1	3.59	21.4
May 2016-April 2017	852.8	583.6	1309.8	4.8	4.40	52.4
Averages	**767.4**	**546.1**	**931.0**	**4.5**	**3.99**	**36.9**

During the most recent monitoring activity (from May, 2015 to April 2017) runoff and soil erosion was measured by means of micro-plots in a grassed vineyard, with rows along the slope (Tab. 2). The mean runoff coefficient resulted 0.81%, thus it was lower than in the previous monitoring period, and higher than the runoff coefficient observed by Ruiz-Colmenero et al. (2011) in micro-plots in a vineyard with spontaneous vegetation. Mean annual soil losses were in the range of those observed in the period 1993-1997 and by other authors in vineyards with different cover crops (Novara et al., 2011; Ruiz-Colmenero et al., 2011). The seasonal pattern of soil losses was similar to runoff (Fig. 1): the highest runoff and soil losses were measured in autumn (44.5 kg ha^{-1} of soil lost in two years), that was the season with the highest amount of precipitation. The lowest precipitation, runoff and soil erosion (3.2 kg ha^{-1}) were measured in winter. In summer rainfall showed the highest erosivity, nevertheless soil losses were limited to 11.6 kg ha^{-1}. The grass cover was especially effective in reducing soil losses in GC during summer months, but its protective effect decreased in autumn, as was also observed in Monferrato vineyards by Biddoccu et al. (2016) and in an olive farm by Gomez et al. (2014).

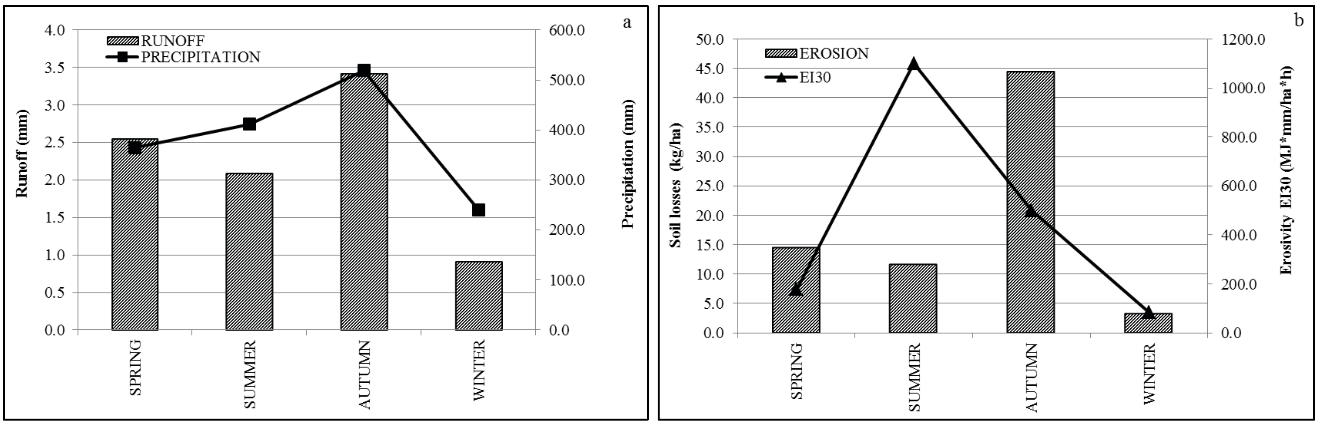


Fig. 1 – (a) Amount of precipitation and consequent runoff,, and (b) rainfall erosivity (EI30) and soil losses measured at Vezzolano by micro-plots in the period May 2015 – April 2017.

Fig. 1 - (a) Quantità di precipitazione e conseguente ruscellamento e (b) erosività della pioggia (EI30) e perdita di suolo misurate dai micro-plot di Vezzolano nel periodo maggio2015 - aprile 2017.

Conclusions

Climate change is expected to impact on soil erosion, since frequency of extreme events with high precipitation will increase the potential of rainfall erosivity. In sloping vineyards, the adoption of grass cover in the inter-rows is one of the most common techniques suggested in literature, nevertheless the efficacy of this technique in protecting soil from water erosion may vary with vineyard management and seasonal pattern.

Even though annual runoff was not always reduced in GC plot with respect to CT, the present study confirmed the effectiveness of grass-cover in preventing soil losses in vineyards, especially when relevant erosive events occur (e.g. during high-intensity summer storms). Moreover results of the study proved the role of orientation of rows along contour lines in preventing runoff also when conventional tillage is adopted.

With regard to seasonal pattern, results suggest that the grass cover was particularly effective in reducing soil losses in GC during summer months although summer rainfall showed the highest erosivity values. On the opposite, during autumn months the protective effect of GC decreased considerably and this must be mainly due to the low vegetation cover.
Taking into account predicted climate changes and the consequent climatic fluctuation throughout seasons, improvement of integrated agronomic strategies will become more and more relevant. Consequently, further studies are needed to identify the appropriate green cover variety and management in order to improve effectiveness of conservation measures in reducing soil losses when extraordinary meteorological occurs, even during autumn.

References

Biddoccu, M., Ferraris, S., Cavallo, E., Opsi, F., Previati, M., Canone, D., 2013. Hillslope Vineyard rainfall-runoff measurements in relation to soil infiltration and water content. *Procedia Environmental Sciences*, *19*, 351-360.

Biddoccu, M., Opsi, F., Cavallo, E., 2014. Relationship between runoff and soil losses with rainfall characteristics and long-term soil management practices in a hilly vineyard (Piedmont, NW Italy). *Soil science and plant nutrition*, *60*(1), 92-99.

Biddoccu, M., Ferraris, S., Opsi, F., Cavallo, E., 2015. Effects of Soil Management on Long-Term Runoff and Soil Erosion Rates in Sloping Vineyards. G. Lollino et al. (eds.), Engineering Geology for Society and Territory – Volume 1, DOI: 10.1007/978-3-319-09300-0_30

Biddoccu, M., Ferraris, S., Opsi, F., Cavallo, E., 2016. Long-term monitoring of soil management effects on runoff and soil erosion in sloping vineyards in Alto Monferrato (North–West Italy). *Soil and Tillage Research*, *155*, 176-189.

Blavet, D., De Noni, G., Le Bissonnais, Y., Leonard, M., Maillo, L., Laurent, J. Y., Roose, E., 2009. Effect of land use and management on the early stages of soil water erosion in French Mediterranean vineyards. *Soil and Tillage Research*, *106*(1), 124-136.

Cerda, A., 2002. The effect of season and parent material on water erosion on highly eroded soils in eastern Spain. *Journal of Arid Environments*, *52*(3), 319-337.

Corti, S., Decesari, S., Fierli, F., Fuzzi, S., Provenzale, A., Sabbioni, C., Santoleri, R., Vitale V., 2009. Clima, cambiamenti climatici globali e loro impatto sul territorio nazionale - Quaderni dell'ISAC, volume 1. ISAC-CNR, Bologna, pp. 64.

Lisa, L., Parena, S., Lisa, L., 2001. Erosione dei vigneti collinari lavorati o inerbiti. Controlli svolti a Vezzolano dal 1992 al 1998 – Rapporto Interno 01.04. IMA-CNR, Torino, 10-25.

Gomez, J.A., Vanwallenghem, T., De Hoces, A., Taguas, E.V., 2014. Hydrological and erosive response of a small catchement under olive cultivation in a vertic soil during a five-year period: implications for sustainability. Agric. Ecosyst. Environ. 188, 229–244.

Li, Z., Fang, H., 2016. Impacts of climate change on water erosion: A review. *Earth-Science Reviews*, *163*, 94-117.

Novara, A., Gristina, L., Saladino, S. S., Santoro, A., Cerdà, A., 2011. Soil erosion assessment on tillage and alternative soil managements in a Sicilian vineyard. *Soil and Tillage Research*, *117*, 140-147.

Ramos, M. C., Martinez-Casasnovas, J. A., 2006. Nutrient losses by runoff in vineyards of the Mediterranean Alt Penedès region (NE Spain). *Agriculture, ecosystems & environment*, *113*(1), 356-363.

Ruiz-Colmenero, M., Bienes, R., & Marques, M. J., 2011. Soil and water conservation dilemmas associated with the use of green cover in steep vineyards. *Soil and Tillage Research*, *117*, 211-223.

Tropeano D., 1984. Rate of soil erosion processes on vineyards in Central Piedmont (NW Italy). *Earth Surface Processes and Landforms*, *9*(3), 253-266.

SOIL GHGs EMISSIONS IN A VEGETABLE CROP ROTATION UNDER INTEGRATED, ORGANIC AND CONSERVATION ORGANIC MANAGEMENT
EMISSIONI DI GAS SERRA DAL SUOLO IN UNA ROTAZIONE ORTIVA INTEGRATA, BIOLOGICA E BIOLOGICA CONSERVATIVA

Iride Volpi[1], Jonathan Trabucco[1], Daniele Antichi[2], Christian Frasconi[2], Cristiano Tozzini[1], Simona Bosco[1*]

[1]Institute of Life Sciences, Scuola Superiore Sant'Anna, via S. Cecilia, 3, 56127, Pisa
[2] Dipartimento di Scienze Agrarie, Alimentari, e Agro-Alimentari, Università di Pisa, Via del Borghetto 80, 56124 Pisa
*s.bosco@santannapisa.it

Abstract
The integration of organic and conservation agriculture may help in improving soil quality, while reducing the use of agrochemicals. However, the impact of these practices on the emissions of greenhouse gases (GHGs) is not well defined, particularly in Mediterranean climates. A field-experiment was conducted to evaluate the effect of three systems, i.e. Integrated (INT), Organic (ORG) and Conservation Organic (ORG+), on a 2-year vegetable crop rotation (fennel, summer lettuce, cabbage, spring lettuce), on carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) emissions. The monitoring of soil GHGs emissions was performed from October 2014 to July 2016, using an innovative instrument equipped with laser analyzers. Main results were that only CO_2 emissions were affected by system management, while no differences were observed in N_2O and in CH_4 emissions among treatments.

Keywords: soil flux; nitrous oxide; carbon dioxide; methane; no-till
Parole chiave: flussi dal suolo; protossido di azoto, anidride carbonica, metano, non lavorazione

Introduction
Agricultural management practices affect the production of greenhouse gases (GHGs) from soil, especially nitrous oxide (N_2O) and methane (CH_4), which have global warming potentials, respectively, 265 and 28 times higher (without inclusion of climate-carbon feedbacks) than carbon dioxide (CO_2) (Myhre et al., 2013). Agricultural soils emit approximately 10.3–12.8 Tg N_2O-N year^{-1} (Butterbach-Bahl et al., 2013), as a result of two main biological processes, i.e. nitrification and denitrification. CH_4 is mainly consumed by methanotrophic bacteria in aerobic soil condition, while it may be produced by methanogenic bacteria in anaerobic conditions (Hütsch, 1998). CO_2 emissions from soils are mainly related to the decomposition of soil organic matter (SOM), thus all the practices that increase soil C stock may mitigate CO_2 emissions (Paustian et al., 1997).
Conservation agriculture includes reduced tillage practices such as no tillage (NT) or minimum tillage (MT) and it may help in preserving or increasing SOM in soil (Holland et al., 2004). Moreover, conservation agriculture directly affects N_2O soil production even if with highly variable rate (Rochette et al., 2008). Organic/integrated farming systems are considered not compatible with conservation tillage mainly because of the reliance of conservative systems on herbicides to control increasing weed pressure in absence of inversion tillage, and on mineral fertilizers, to obtain satisfactory yields with a reduced mineralization rate (Peigné et al., 2007).
To achieve the integration of organic or integrated systems with conservative systems two major issues need to be addressed: the availability of specific machines for mechanical cover-crop management and physical weed control, and for sod-seeding/planting; and the optimization of cropping systems to improve nutrient cycling and minimize the development of weeds. Agricultural practices, such as N fertilization, tillage practices and cover cropping may enhance or mitigate GHGs emissions from soil, dependently on soil characteristics and environmental conditions (Smith et al., 2008). However, information on GHGs emissions from crop rotation under conservative agriculture is scarce and contradictory results were reported (Tellez-Rio et al., 2017).
The "Smart Management of Organic Conservative Agriculture" (SMOCA) project (2014-2017) aimed at: i) designing an innovative cropping systems able to integrate organic agriculture and conservative agriculture; ii) developing innovative machines; iii) comparing three systems; integrated (INT), organic (ORG) and a conservative organic (ORG+) systems; considering the agronomic performances, the environmental impacts and economic point of view. In particular, the aim of this paper is to present the effect of the three management systems on CO_2, CH_4 and N_2O.

Materials and Methods
The study was conducted in the Pisa coastal plain (43° 40' N Lat; 10° 19' E Long; 1 m a.s.l and 0% slope), at the “Enrico Avanzi” Centre for Agro-Environmental Research of the University of Pisa. The climate is typical Mediterranean, characterized by a long-term average annual rainfall of about 900 mm and a mean annual temperature of 15°C (1986-2013). The field trials consisted in a 2-year vegetable crop rotation, cultivated under three different management systems

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

managed according to: integrated farming recommendations with conventional tillage practices and mineral fertilization (INT); organic farming regulations with conventional tillage practices, organic fertilizers, green manures and mechanical weed management (ORG); organic farming regulations integrated with conservative practices including no-tillage, organic fertilizers and physical weed management (ORG+). The rotation was replicated both in space and time, thus each crop was present every year. The crops included in the rotation were: savoy cabbage (*Brassica oleracea* var. sabauda L. cv. Famosa), spring lettuce (*Lactuca sativa* L. cv. Justine), fennel (*Foeniculum vulgare* Mill. Cv. Montebianco) and summer lettuce (cv. Ballerina). ORG included a spring green manure mixture incorporated into the soil before transplanting of summer lettuce, composed by field pea (*Pisum sativum* L.) and faba bean (*Vicia faba* subsp. *minor* L.), and a summer green manure mixture, incorporated into the soil before fennel transplanting, composed by red cowpea (*Vigna unguiculata* L.), buckwheat (*Fagopyrum esculentum* L.), millet (*Panicum miliaceum* L.) and foxtail millet (*Setaria italica* L.). ORG+ included a summer green manure, terminated as dead mulch by roller crimper and flaming before transplanting of fennel, composed by the same plants used in the spring green manure of ORG, and a red clover (*Trifolium pratense* L.) directly seeded and established as a living mulch for summer lettuce and cabbage.

	N fertilizer rate (kg N ha^{-1})			
	Fennel	Summer lettuce	Cabbage	Spring lettuce
INT	122	46	108	27
ORG	77	0	59	20
ORG+	28	0	28	0

Tab. 1: N fertilizer rate in the three systems for each crop included in the rotation.
Tab. 1: Dose di azoto distribuita con la fertilizzazione nei tre sistemi per ogni coltura inserita nella rotazione.

The rotation was replicated in two adjacent fields and for each field the three systems were randomized with three replicates each.
The monitoring of soil GHGs emissions was performed from October 2014 to July 2016, using an innovative instrument developed within the LIFE+ project "Improved flux Prototypes for N_2O emission from Agriculture" (IPNOA, www.ipnoa.eu) and though the flow-through non-steady state chamber. The instrument was a light tracked vehicle that can be operated by remote control and equipped with an Ultraportable Greenhouse Gas Analyser (UGGA) to measure CO_2, CH_4 and water vapour, and a N_2O, carbon monoxide (CO) and water vapour detector that uses off-axis integrated cavity output spectroscopy (ICOS), both provided by Los Gatos Research (LGR) Inc. (Mountain View, CA, USA). Output gas concentrations are given with a scan rate of 1 s. Measured data were recorded by a smartphone connected via Bluetooth®. Technical details on the instrument and its validation are reported by Bosco et al. (2015) and Laville et al. (2015). A PVC collar (15 cm height, 30 cm ø) was inserted to 5 cm soil depth in each plot within plant rows. Daily flux of each GHG was calculated from the slope of the linear increment of the gas concentration within the chamber plus collar volume during the chamber deployment time (2-3 minutes), considering the mean daily atmospheric pressure, mean daily temperature and the ratio headspace volume/area of the chamber.

Results and Discussion

CUMULATIVE GHGS EMISSIONS

Cumulative CO_2 emissions in the two years resulted to be significantly lower in INT (30 ±2 t CO_2-C ha^{-1}) than in ORG and ORG+ (37 ±2 t CO_2-C ha^{-1} and 41 ±2 t CO_2-C ha^{-1}, respectively). The higher soil respiration in ORG could be explained with more frequent field operations for weed management and higher organic inputs (green manure) that might have enhanced soil carbon mineralization (Sanz-Cobena et al., 2014). The highest level for ORG+ may be due to the mineralization of higher organic inputs. However, a partition of soil respiration in autotrophic and heterotrophic component would be necessary to understand the main sources of CO_2 from soil.
No differences were observed among the three systems for cumulative N_2O emissions, considering the whole monitoring period (crop growing periods and fallow periods) and they were on average 10 ±3 kg N_2O-N ha^{-1}. Surprisingly, the lower nitrogen fertilization in ORG and ORG+ did not achieve to reduce N_2O emissions. This could be explained by an increment in N_2O emissions due to green manure mineralization (Sanz-Cobena et al., 2014), especially considering legume crops, both in ORG and ORG+ systems and a progressive increase in water filled pore space (WFPS) that can promote N_2O production (Smith et al., 2008).
Similarly, cumulative CH_4 emissions were not different among the three systems and they were on average equal to -0.7 ±0.2 kg CH_4-C ha^{-1}. Thus, cumulative CH_4 emissions resulted in a net uptake in the three systems, in agreement with what reported by some authors in Mediterranean environment (Sanz-Cobena, et al. 2014; Tellez-Rio et al., 2017), even if other studies reported that an increased tillage intensity or N fertilizer rate may decrease CH_4 uptake in soil (Le Mer and Roger, 2001; Ussiri et al., 2009).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

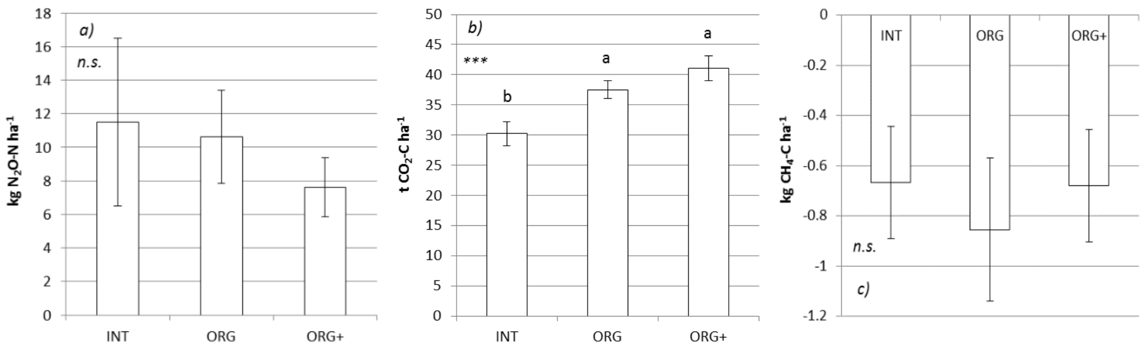


Fig. 1: Average cumulative a) N_2O (kg N_2O-N ha^{-1}), b) CO_2 (t CO_2-C ha^{-1}) and c) CH_4 (kg CH_4-C ha^{-1}) emissions in the three systems, along the whole monitoring period (642 days).
Fig. 1: Media delle emissioni cumulate di a) N_2O (kg N_2O-N ha^{-1}), b) CO_2 (t CO_2-C ha^{-1}) e c) CH_4 (kg CH_4-C ha^{-1}) nei tre sistemi, considerando l'intero periodo di monitoraggio (642 giorni).

Conclusions

The comparison of integrated, organic and conservation organic was tested in a vegetable rotation on GHG emissions from soil. The results from the first two years showed that nor ORG nor ORG+ achieve to mitigate N_2O flux from soil, while they showed higher CO_2 flux than INT. However, only a part of this flux can be related to carbon mineralization, indeed a CO_2 flux partition study would be needed to evaluate the different sources of CO_2. However, all the three systems were identified as net sinks of methane. Long-term studies are needed to verified the effect of the tested systems on GHGs flux from soil.

Acknowledgments

This research was funded by the Ministry of Education, University and Research - MIUR, FIRB 2013. Project title: Smart Management of Organic Conservative Agriculture - SMOCA (2014-2017) (http://smoca.agr.unipi.it/). The authors would like to acknowledge Fabio Taccini for the support in conducting the field trials.

References

S. Bosco, I. Volpi, N. Nassi o Di Nasso, F. Triana, N. Roncucci, C. Tozzini, R. Villani, P. Laville, S. Neri, F. Mattei, G. Virgili, S. Nuvoli, L. Fabbrini, E. Bonari, 2015. LIFE+IPNOA mobile prototype for the monitoring of soil N_2O emissions from arable crops: first-year results on durum wheat. Ital J Agron 10:669.

K. Butterbach-Bahl, E.M. Baggs, M. Dannenmann, R. Kiese, S. Zechmeister-Boltenstern, 2013. Nitrous oxide emissions from soils: how well do we understand the processes and their controls? Philos. Trans. R. Soc. Lond. B. Biol. Sci. 368, 20130122.

J.M. Holland, 2004. The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence. Agric. Ecosyst. Environ. 103, 1–25.

B.W. Hutsch, 1998. Tillage and land use effects on methane oxydation rates and their vertical profiles in soil, Biol. Fert. Soils 27, 284–292.

P. Laville, S. Neri, D. Continanza, L.F. Vero, S. Bosco, G. Virgili, 2015. Cross-Validation of a Mobile N_2O Flux Prototype (IPNOA) Using Micrometeorological and Chamber Methods. Journal of Energy and Power Engineering. 9:375–385.

G. Myhre, D. Shindell, F.M Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura, H. Zhan, 2013. Anthropogenic and Natural Radiative Forcing: In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press. Cambridge, United Kingdom New York, NY, USA 659–740.

K. Paustian, O. Andrén, H.H. Janzen, R. Lal, P. Smith, G. Tian, H. Tiessen, M. Van Noordwijk, P.L. Woomer, 1997. Agricultural soils as a sink to mitigate CO_2 emissions. Soil Use Manag. 13, 230–244.

J. Peigné, B.C. Ball, J. Roger-Estrade, C. David, 2007. Is conservation tillage suitable for organic farming? A review. Soil Use Manag. 23, 129–144.

P. Rochette, 2008. No-till only increases N_2O emissions in poorly-aerated soils. Soil and Tillage Research, 101 (1-2), pp. 97-100.

A. Sanz-Cobena, S. García-Marco, M. Quemada, J.L. Gabriel, P. Almendros, A. Vallejo, 2014. Do cover crops enhance N_2O, CO_2 or CH_4 emissions from soil in Mediterranean arable systems? Science of the Total Environment, 466-467, pp. 164-174.

P. Smith, D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, M. Howden, T. McAllister, G. Pan, V. Romanenkov, U. Schneider, S. Towprayoon, M. Wattenbach, J. Smith, 2008. Greenhouse gas mitigation in agriculture. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 363, 789–813.

A. Tellez-Rio, A. Vallejo, S. García-Marco, D. Martin-Lammerding, J.L. Tenorio, R.M. Rees, G. Guardia, 2017. Conservation Agriculture practices reduce the global warming potential of rainfed low N input semi-arid agriculture. Eur. J. Agron. 84, 95–104.

A SURVEY ON REGIONAL AGROMETEOROLOGICAL NETWORKS IN ITALY
INDAGINE SULLE RETI AGROMETEOROLOGICHE REGIONALI IN ITALIA

Maria Carmen Beltrano[1*], Flora De Natale[1], Stanislao Esposito[1], Barbara Parisse[1]

[1] Consiglio per la Ricerca in agricoltura e l'analisi dell'Economia Agraria - CREA, Centro di ricerca Agricoltura e Ambiente, Via della Navicella 2-4, 00184, Roma
*mariacarmen.beltrano@crea.gov.it

Abstract
The agrometeorology plays a primary role in building DSS – decision support systems - to face the challenges derived from climate changes, as stressed also by the recent *Common Agricultural Policy* (CAP 2014-2020). The AGROMETEORE project aims at improving and widening the resources on agrometeorology, available at NUTS2 level (administrative regions, in Italy), through the institution of a National Task-Force (NTF), focused on stimulating the resource sharing among the different NUTS2 Agrometeorogical Services (ASs) and their interoperability. As a first step in this process, a questionnaire on the main features of station networks and on data flows, processing and divulgation has been administered to each regional representative of the NTF. The survey has highlighted a great heterogeneity among the different services: some of these are fully operative, while others are in a reorganization phase. An important information derived from the survey is the encouraging value of the overall station density, referred to the Utilized Agricultural Area (UAA), which is comparable with the main European agricultural districts. The paper provides a preliminary overview of the state of the ASs in Italy. Some further results will be derived from the next activities of the NTF.

Keywords: agrometeorology, agrometeorological services, agrometeorological bulletins, meteorological network, weather stations.
Parole chiave: agrometeorologia, servizi agrometeorologici, bollettini agrometeorologici, rete meteorologica, stazioni meteorologiche.

Introduction
The agrometeorology plays a primary role in building DSS – decision support systems - to face the challenges derived from climate changes. The recent *Common Agricultural Policy* (CAP 2014-2020) has stressed the need to use agrometeorological applications in the field of Integrated Production and Organic Farming. Moreover, in order to implement the Directive 2009/128/CE on sustainable use of pesticides, each Country has to adopt a National Action Plan. The Italian plan (*Piano d'Azione Nazionale per l'uso sostenibile dei prodotti fitosanitari*) binds also the administrative regions to provide adequate agrometeorological services as support for farmers. Within the framework of the National Rural Network, the AGROMETEORE project has been designed with the aims at improving and widening the resources on agrometeorology, available at national and regional level, also through the institution of a National Task-Force (NTF) with representatives of all Italian administrative regions (and autonomous provinces, henceforth named "regions"). The NTF activities focus on stimulating the resource sharing among the different regional services and their interoperability.
As a first step in this process, a questionnaire has been administered to each regional representative of the NTF. The questions were related to the main features of station networks and to data flows, processing and divulgation at regional level. A similar investigation was already carried out in 2000 (Micale, 2000), when most Agrometeorogical Services (ASs) had been already developed (the first ones started in 1985) or were being developed. A more recent survey, mainly focused on the status of agrometeorological data networks, was accomplished by Marletto (2016). The results were based on regional reports on the sustainable use of pesticides (Dir. 2009/128/EC) and on information available on regional websites.
In this paper an updated overview of regional agrometeorological networks and of the status of provided services is presented and discussed.

Materials and Methods
The survey has been based on a questionnaire, administered to each regional representative of the NTF. The questionnaire has been implemented as a web form using Google Forms; it mainly consisted of closed-ended questions in order to ensure standardized responses to facilitate the filling out. In addition, a guideline document has been provided to the respondents.
The questionnaire has been structured in the following sections: (a) respondent's general data; (b) detailed information on agrometeorological network; (c) synergies among different meteo networks; (d) measured variables; (f) data flow; (g) climatology; (h) dissemination and communication; (i) critical issues.
The forms were administered in July 2016 and they were completely filled-out by most regions within October 2016. Only Umbria and Bolzano representatives returned a partially completed form. Data collected have been processed also by using ArcGIS® software by Esri to provide some statistics and maps useful to define a framework of the ASs in Italy.
Data on geographical distribution of agrometeorological sensors have been derived by computing regional station densities

in relation to the Utilized Agricultural Area (UAA) estimates drawn by the Italian National Institute of Statistics (Istat, 2010).
Other data sources used in order to compare the Italian results with the main European Countries, are the WAMIS report of the World Meteorological Organization (WMO, 2009) and EUROSTAT statistics on European UAA (European Commission Eurostat, 2010)

Results and Discussion

The results obtained are quite representative of the current state of the ASs in Italy, as the non-response rate is very low (only 2 of 21 respondents sent partially completed forms).
The first information collected relates to the organization of the ASs in the different administrative regions. As showed in figure 1(a), the local office engaged in this field depends on different institutions. The reference office is a service (agrometeorological or phytosanitary) of the regional Department of Agriculture in 7 regions, it is a local Agency for the Agricultural Development in 6 cases, while in 4 regions the office is a Regional Agency for the Protection of the Environment. Finally, 4 regions engage an external company.

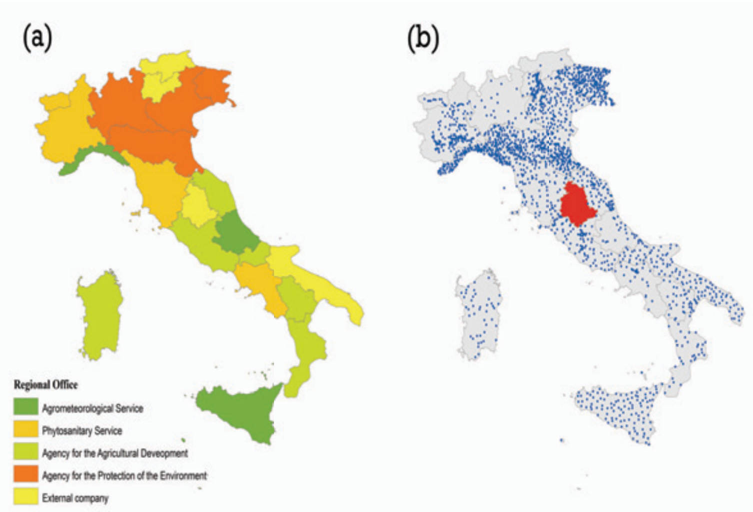


*Fig. 1: Reference institutions for the agrometeorology in the Italian administrative regions (**a**); geographical distribution of the automatic weather stations used by the ASs; red color indicates no data (**b**).*
*Fig. 1: Istituzioni responsabili dei servizi agrometeorologici nelle diverse regioni italiane (**a**); distribuzione geografica delle stazioni meteorologiche automatiche utilizzate dagli ASs; il rosso indica dato non pervenuto (**b**).*

It is remarkable that all Italian NUTS2 have currently their own agrometeorological services. A study carried out in 2000 reported that a half of services had an experience of more than 10 years, while some of these were going to start their activity (Micale, 2000). Therefore now the services have an experience which ranges from more than 30 to at least 15 years.
The core of the survey is the recognition of the main features of the agrometeorological networks at NUTS2 level[1]. The figure 1(b) illustrates the overall distribution of the 1832 automatic weather stations used by the ASs for agrometeorological purposes. The figure highlights an almost heterogeneous density among the different regions. It should be underlined that there is a case of non-response, related to the Region Umbria (red colour), perhaps due to the recent earthquake issues. A special attention should be paid to the high network density recorded in some northern regions (Liguria, Emilia Romagna, Friuli Venezia Giulia), where the agrometeorological networks are strictly integrated with other meteorological networks.
In addition to the automated stations, the survey has revealed that some mechanic stations (approximately 70) are still operative, mainly located in Emilia Romagna (these latter ones are not reported in the map in figure 1).
A more detailed information is derived by the table 1(a), which reports the station density, referred to the UAA, at NUTS2 level. Such density is quite high for almost all NUTS2 agrometeorological networks, with peaks of 37 and 10 stations per 10,000 ha of UAA in two Northern networks (Liguria and Friuli Venezia Giulia, respectively), also due to a different organization of the ASs. At a national scale, the average density of the agrometeorological network assumes a value of 1.4 per 10,000 ha of UAA.
The noticeable availability of agrometeorological stations in Italy have already been highlighted in relation to the other European Countries. The table 1(b) shows some results on the number of stations in the network of agrometeorological observations, drawn from a global survey on the National Meteorological and Hydrological Services (NMHSs) carried out in 2009 (WMO, 2009). With reference to the European context, aside the number of stations, the table reports the relative density per 10,000 ha of UAA computed using the Eurostat UAA of 2010 (European Commission Eurostat, 2010). In order to compute such density, 2010 has been chosen as reference year, as UAA data of 2009 were not available for Italy. The Italian value of 0.23 is remarkably higher than densities reported for most other southern and eastern countries and is quite in line with the Germany one.

[1] *Nomenclature des Unités Territoriales Statistiques -second level* corresponding to the Italian administrative regions

DOI 10.6092/unibo/amsacta/5692

More detailed information has been collected about automated stations. As regards WMO standard compliance, it has been assured for most stations (at least 50%) in 14 regions, while less than 25% of stations meet these standards in 5 regions, mainly located in Northern and Central Italy. With reference to the location, most stations (at least 50%) are located in agricultural areas in 18 regions and their altitude is lower than 400 m asl in 16 regions. Higher altitudes are generally few represented; they characterize more than 25% of stations only in Veneto Region. A further attribute is related to the station working: overall, more than 75% of the stations are active in almost all regions and their maintenance is carried out by an external company in 12 regions. The maintenance periodicity ranges from sub-six-monthly to annual in all regions but 4, which assure only extraordinary maintenance. Moreover there is a case (Umbria Region) in which no maintenance is carried out.

Tab. 1: Density of agrometeorological stations in relation to Agricultural Area in Use in the administrative regions. Data sources: questionnaire responses for the number of stations of agrometeorological networks and Istat statistics for UAA data (Istat, 2010) ***(a)****. Density of agrometeorological stations in relation to Agricultural Area in Use in most European Countries. Data sources: WAMIS report of 2009 for the number of stations in the network of Agro-meteorological observations (WMO, 2009) and Eurostat statistics for UAA data of 2010. (2009 UAA is missing for Italy)* ***(b)****.*
Tab. 1: Densità di stazioni agrometeorologiche rapportate alla SAU delle regioni (o delle province autonome). Fonti: il numero di stazioni è tratto dalle risposte del questionario, mentre per la SAU sono state utilizzate le statistiche ufficiali dell'Istat (2010) ***(a)****. Densità di stazioni agrometeorologiche rapportate alla SAU nazionale in vari paesi europei. Fonti: il numero di stazioni è stato tratto dal rapporto WAMIS del 2009 (WMO, 2009), mentre la SAU si riferisce al dato Eurostat del 2010 (la stima Eurostat del 2009 per l'Italia non è disponibile)* ***(b)****.*

(a)

Region level (NUTS 2)	Number of stations	UAA 2010 (ha)	Station density (no./10,000 ha)
Piedmont	140	1,008,173	1.4
Aosta Valley	12	58,388	2.1
Lombardy	25	977,383	0.3
South Tyrol	2	237,285	0.1
Trentino	85	143,190	5.9
Veneto	171	800,741	2.1
Friuli Venezia Giulia (*)	219	219,047	10.0
Liguria (*)	168	44,869	37.4
Emilia Romagna (*)	300	1,078,960	2.8
Tuscany	97	757,431	1.3
Umbria	65	326,239	2.0
Marche	70	470,510	1.5
Lazio	92	637,406	1.4
Abruzzo	24	454,362	0.5
Molise	26	197,472	1.3
Campania	28	546,948	0.5
Apulia	94	1,287,107	0.7
Basilicata	40	519,137	0.8
Calabria	36	549,198	0.7
Sicily	96	1,387,559	0.7
Sardinia	42	1,154,641	0.4
Italy	**1832**	**12,856,048**	**1.4**

(*) these regional values include also non-agrometeorological stations

(b)

	Number of stations	UAA 2010 (ha)	Station density (no./10,000 ha)
Bulgaria	29	5,051,860	0.06
Denmark	70	2,676,200	0.26
Germany	500	16,704,040	0.30
Ireland	26	4,568,930	0.06
Greece	15	4,839,390	0.03
Spain	25	23,719,230	0.01
Italy	**300**	**12,885,190**	**0.23**
Lithuania	43	2,772,300	0.16
Luxembourg	25	131,220	1.91
Portugal	11	3,653,800	0.03
Romania	55	14,156,480	0.04
Slovenia	53	482,650	1.10
Slovakia	50	1,921,610	0.26
Bosnia and He	10	1,715,000	0.06

A particular attention has been paid to the sensor equipment of the stations, in order to know the actual suitability and potentiality of the networks for agrometeorological applications. Aside from the main sensors of temperature and precipitation, which are installed on almost all stations, the regional networks are equipped with several other sensors, in a very heterogeneous way. The maps in figure 2 highlight the availability of the main sensors required for agro-meteorological aims, represented in terms of density in relation to the regional UAA. This density varies greatly depending on the parameter measured; overall it is higher for relative humidity and wind speed, which are measured in all regional networks, while it results very heterogeneous for solar radiation, leaf wetness and soil temperature. The soil temperature sensor is not available in almost a third of regional networks.
The maps show a high density for all sensors in some mountainous regions (Liguria, Friuli Venezia Giulia, Calabria and Trento province) as well as in Veneto and Marche (aside from soil temperature). The sensor density is instead relatively high for leaf wetness and relative humidity but quite low for the other three sensors in Piedmont and Umbria.
The questionnaire also surveyed the data recording interval adopted for each parameter in the different networks. The results have again highlighted the great heterogeneity among regions, but it is possible to draw out some common points: for almost all regions hourly values are recorded: hourly averaged values for air temperature, relative humidity, wind speed, atmospheric pressure and soil temperature (when these parameters are measured) and hourly total values for precipitation, solar radiation, leaf wetness. Some ASs adopt many different intervals to collect data; among these, in Emilia Romagna each parameter is recorded in the database for all the interval data (real-time, hourly and daily average or total or extremes values).

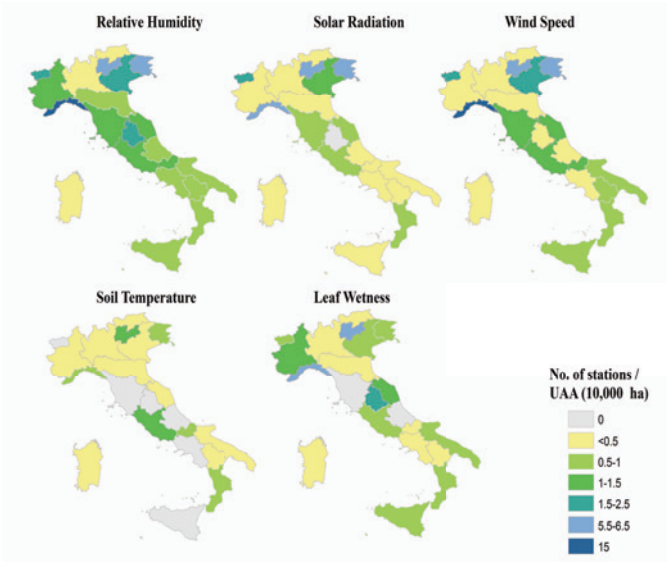


Fig. 2: Regional density of the main agrometeorological sensors per 10,000 ha of UAA.
Fig. 2: Densità regionale dei principali sensori agrometeorologici per 10.000 ha di SAU.

As regards the soil temperature, also the sensor depth has been investigated: with respect to a total of 15 regions where this parameter is measured, in most cases (12) there is at least a sensor at a maximum depth of 20 cm. Deeper sensors are located at a depth of 20-30 cm or higher than 30 cm in 5 and 6 cases, respectively.
A specific session of the questionnaire has been devoted to collect some preliminary information about data processing and storing for the implementation of the regional agrometeorological databases; this part will be further investigated within the NTF. Data quality control is performed by more than 2/3 of cases and 10 regions also compute validation indexes. Regarding to the missing data imputation, it is performed by almost a half of regions. Many regions (15) calculate agrometeorological indexes and several statistics, while evapotranspiration and leaf wetness are estimated by 9 and 3 regions, respectively.
As shown in the figure 3, data are spatialized by most regions, save 3 southern ones, and regular grids are applied only in 6 cases; however each regional dataset is independent from other ones and they are not homogeneous among them. Overall the spatial data resolution ranges from less than 5 km to more than 10 km.

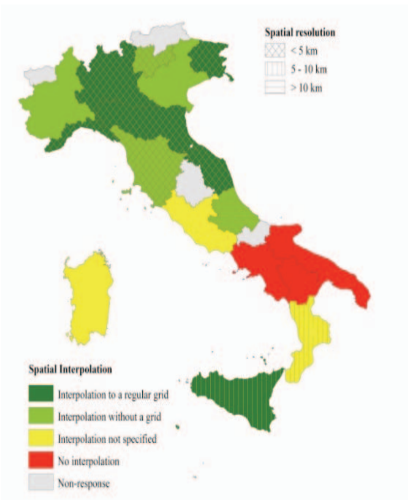


Fig. 3: Production of spatial agrometeorological data and related resolution at NUTS 2 level.
Fig. 3: Produzione di dati agrometeorologici spazializzati e relativa risoluzione a livello regionale.

Most regions use a modellistic approach to handle meteorological data in order to support farmers for pest and disease management; generally also phenological and crop models are applied. Moreover in 1/3 of cases the database is used for water balance modeling.
More than a half of regions calculate their own climatologies, with very different reference periods. In many cases, shorter and more recent periods, generally referred to the last 10-15 years, suitable for agrometeorological applications, are preferred to the standard periods (1961-1990, 1971-2000, 1981-2010).
The survey also focused on communication and dissemination activities, which are carried out by almost all regions. As reported in the figure 4(a), aside 3 non-responses, regions are equally divided in real-time/not real-time data publication; moreover, in many cases also more or less long time series are available. As shown in figure 4(b), in most cases specific

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

bulletins are issued with different periodicity; only 5 regions (red colour) don't publish any bulletin.

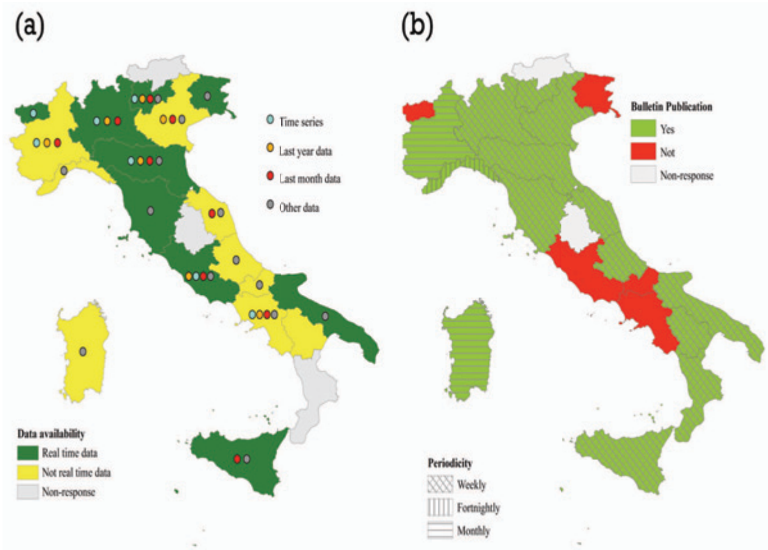


*Fig. 4: Real-time availability of agrometeorological open data and maximum length of accessible data series (**a**); agrometeorological bulletin publication and their periodicity (**b**).*
*Fig. 4: Disponibilità in tempo reale di open data agrometeorologici e lunghezza massima delle serie di dati (**a**); pubblicazione di bollettini agrometeorologici e loro periodicità (**b**).*

The last section of the questionnaire was devoted to gather information on the main critical issues encountered by each regional service in carrying out its activities. The most cited issues (approximately one half of cases) are referred to budget and personnel lack, network obsolescence and maintenance, data quality assurance, agrometeorological model design and implementation. Another weak point which has been underlined for several regions is related to the web communication. Overall, several critical aspects have been reported for most regions, aside 3 regions for whose any problem has been expressed. In some cases, it seems that these issues could threaten the efficiency of the services; even the ASs with a longer experience show a general need to be updated and improved.

Conclusions

The overall framework of agrometeorological services in Italy derived from the results of this preliminary survey is very heterogeneous, as already reported by Marletto (2016), with some strengths and some weaknesses. In particular, the main positive point lies in the quite high density (stations/UAA) of almost all NUTS2 agrometeorological networks. The survey has also pointed out many weaknesses, in particular related to the inadequate resources, such as the limited budget and the underpowered personnel, and to a general lack of interoperability among the different services.
In this regard, this study represents the first step of a process, to be realized in the framework of the AGROMETEORE project, for integrating and improving the agrometeorological resources currently available in Italy, in line with the proposal presented by Marletto (2016), with the aim of adequately meeting the CAP requirements.

Acknowledgements

This paper is possible thanks to research promoted by the National Rural Network 2014-2020. Special thanks are due to Pasquale Falzarano, representative of the Ministry of Agricultural, Food and Forestry Policies, and all regional representatives of the National Task-Force (NTF) for their precious participation to the survey.

References

F. Micale, 2000. Lo stato dei servizi agrometeorologici in Italia. Atti del workshop nazionale di agrometeorologia AIAM: "Domanda e offerta di agrometeorologia in Italia". Roma 24 maggio 2000: 85-100.

V. Marletto, 2016. Condivisione e interpolazione dei dati agrometeorologici regionali a livello nazionale: una modesta proposta. Atti del XIX Convegno Nazionale AIAM: "Nuove avversità e nuovi servizi per gli agro ecosistemi". Bologna, 14-16 giugno 2016: 28-29.

Italian National Institute of Statistics - (Istat), 2010. Censimento agricoltura - dati riferiti al Comune di localizzazione dei terreni/allevamenti. Utilizzazione del terreno per ubicazione delle unità agricole. [Data warehouse]. Retrieved from http://dati-censimentoagricoltura.istat.it/Index.aspx?DataSetCode=DICA_UTILTERRUBI (consulted on 31 May 2017).

World Meteorological Organization (WMO), 2009 National Progress Reports in Agricultural Meteorology 2006-2009. World Agro Meteorological Information Service (WAMIS), Retrieved from http://www.wmo.int/pages/prog/wcp/agm/agmp_en.php (consulted on 31 May 2017).

European Commission Eurostat, 2010. Eurostat Table UUA, Europe Data Database. Retrieved from http://ec.europa.eu/eurostat/data/database?node_code=tag00025 (consulted on 31 May 2017).

A DEGREE DAY MODEL FOR DURUM WHEAT (Triticum durum, Desf.) ACROSS THE ITALIAN PENINSULA

MODELLO FENOLOGICO DI GRANO DURO (Triticum durum, Desf.) PER L'ITALIA PENINSULARE

Arianna Di Paola[1*], Francesca Ventura[2], Marco Vignudelli[2], Maurizio Severini[3]

[1] Euro-Mediterranean Center on Climate Change, Impacts on Agriculture, Forests and Ecosystem Services , Viterbo, Italy.
[2] Dipartimento di Scienze Agrarie, Università di Bologna, Viale Fanin 44, 40127, Bologna
[3] Department of Ecology and Sustainable Development, University of Tuscia, Viterbo, Italy
* arianna.dipaola@cmcc.it

Abstract
Phenological field observations were used to parameterize and test a Degree Day model for durum wheat (*Triticum durum, Desf.*) across the Italian peninsula. Data come from different experimental fields located in northern, central and southern Italy and encompass scalar sowing dates, allowing to parameterize a model representative for a wide range of sites and growing seasons.
To assure the basic assumption of the Degree Day method, wheat subphases were identified to enable the best linear relationship (less data dispersion and higher coefficient of determination) between developmental rates and average air temperature. Under proven linear temperature responses, the model gave satisfactory simulations of wheat phenology over different locations and sowing period (R^2 = 0.96; RMSE = 8,4 days; no bias, minimal complexity), even if the heat supply (growing degree days counted from 0°C) was very different among sites.

Keywords: phenology, degree day method, crop modelling .
Parole chiave: fenologia, somma termica, modelli colturali

Introduction
A great deal of crop models predict plant development by means of the Degree Days (DD) algorithm, e.g. AFRCWHEAT (Weir et al., 1984), CERES (Ritchie et al., 1998), EPIC (Cabelguenne et al., 1990), Shootgro (McMaster et al., 1991), SIRIUS (Jamieson et al 1998). They stated that the simplest definition of crop development can be predicted by the accumulation of specific quantity of heat (hereinafter *growing degree days*) above a certain threshold base temperature (hereinafter *base temperature*), below which plant development stops (Ritchie and Nesmith, 1991; Wang, 1960).
The underlying assumption of the DD method requires that the rate of crop development (i.e. the reciprocal of the time to mature a given phase, d^{-1}) is a linear function of temperature, whose slope and intersection with the axis of temperature represent the reciprocal of the growing degree days and the related base temperature, respectively (Davidson and Campbell, 1983; Slafer 1996). Hence, the accuracy of the DD method to predict crop development mostly depends on *i*) the strength of the linear relationship between developmental rate and air temperature and *ii*) the accuracy of the base temperature.
Base temperature showed large variability among wheat phases, varieties, and environments (Angus et al., 1981; McMaster and Smika, 1988; Slafer and Rawson, 1995), leading to a lot of uncertainty about its determination. In order to avoid this shortcoming, a predefined and constant base temperature of 0 °C is often used (McMaster et al., 2008). However, also the growing degree days for a given variety grown in different locations and/or in different seasonal period, when counted from a predefined base temperature, revealed large variability (Masle et al. 1989; McMaster and Smika 1988). Consequently, to date the DD method is widely used by crop modelers albeit *i*) it should be regarded as site- and growing season- specific (Wang 1960; Ritchie and Nesmith, 1991); *ii*) the issue of linearity is poorly explicitly addressed or discussed, despite its relevance.
In the present work we used phenological observations on durum wheat (*Triticum durum*, Desf.) collected from different locations and sowing dates to parameterize a DD model representative of a wide range of sites and growing seasons. To assure the basic assumption of the DD model (linearity), we empirically identified wheat phases among all suitable combinations enabling the best linear relation between developmental rates and average air temperature. Under proven linear response, the model gave satisfactory simulations of wheat phenology over different locations and sowing period (R^2 = 0.96-0.99; RMSE =7.1-8,4 days, no bias, minimal complexity), even if the heat supply (growing degree days counted from 0°C) among sites was very different

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Materials and Methods

Data used for calibration/validation encloses phenological field observations from the PHEANGRI project (http://phenagri.entecra.it/) and the agrometeorological station of Cadriano (University of Bologna, DipSA, Italy) covering the periods 1996-1999 and 2003-2016, respectively. Phenological observations were reported in the BBCH scale (Meier, 1997) following the PHENAGRI operational protocol.

To calibrate and test a DD model for durm wheat, we distinguished two subsets of data from the PHENAGRI database, namely:

- *Calibration dataset*: Observations on two varieties of durum wheat, Creso and Simeto, broadly known as late and early variety, respectively. Phenological events were obtained from experiments with scalar sowing dates, covering the period from October 1996 to July 1999, in Garica di Podenzano (PC), Vasto (CH) and Cassibile (SR), located in the north, central and south of Italy, respectively.
- *Validation dataset*. Observations on other four varieties of durum wheat, namely Ares, Cirillo, Colosseo and Zenit (early, mid-late, mid-late and late variety, respectively) obtained as above (i.e. scalar sowing dates covering the period October 1996 - July 1999) from two different experimental fields respect to the calibration dataset: S. Angelo Lodigiano (LO) and Foggia (FG), sited in northern and central Italy, respectively.

Data form the the agrometeorological station of Cadriano were used to make a further validation, completely independent.

Wheat phenological events (BBCH centesimal scale (Meier, 1997) intro brackets) were: sowing (BBCH 00), emergence (BBCH 09), three leaves unfolded (BBCH 13-14), beginning of stem elongation (BBCH 30), second node detectable (BBCH 32), beginning of booting (BBCH 41), beginning/end of heading (BBCH 51/59), beginning/end of anthesis (BBCH 61/69), milk maturity (BBCH 73-77), physiological maturity (BBCH 89). Details on the operational protocol of the PHENAGRI project are reported in Botarelli et al. (1999).

Among all suitable combinations to define the whole wheat cycle, we empirically identified wheat phases enabling the best linear relation between developmental rates and average air temperature, namely phases resulting with less data dispersion and higher coefficient of determination (R^2). A Developmental Rate Function (DRF) was then calibrated for each sub-phases by means of linear regression, using ordinary least squares technique. The slope and the intersection of DRF with the axis of temperature represent the reciprocal of the growing degree days and the related base temperature, respectively (Davidson and Campbell, 1983; Slafer 1996).

Results

Linear relationships between developmental rates and average air temperature for durum wheat are shown in Figure 1, whilst the corresponding DRFs' parameters are given in Table 1. Best linear relationship were empirically indentified between the following phases: sowing to three leaves unfolded (S-3L); three leaves unfolded to second node detectable (3L-2N); second node detectable to beginning of heading (2N-H); beginning of heading to physiological maturity (H-M).

Tab. 1: Wheat subphases and corresponding DRFs estimated from the calibration dataset. T_0 = base temperature; 'a' and 'b' = parameters of the linear regression; GDD = growing degree day requirement; ε = error variable (used to track back the uncertainty on the base temperature); 'r' and 'p'= Pearson correlation coefficient and related p-value.

Tab. 1: Fasi del grano e relative Funzioni Tasso di Sviluppo stimati con il subset di calibrazione. T_0 = zero di sviluppo; 'a' e 'b' = parametri della regressione lineare; GDD = fabbisogno termico; ε = errore (usata per determinare l'incertezza sullo zero di sviluppo); ' r' e 'p' = coefficiente di correlazione di Pearson e relativo p-value associato.

			DRF = a + b T +ε				
phase	**T_0 [C°]**	**GDD [°Cd] =1/ b**	**a [d^{-1}]**	**b [$°C^{-1}d^{-1}$]**	**ε [d^{-1}]**	**r**	**p**
S-3L	-3.6 ± 3.0	610	0.0059	0.0016	0.0049	0.84	$0.2 \cdot 10^{-3}$
3L-2N	3.3 ± 1.6	269	-0.0122	0.0037	0.0060	0.88	$0.1 \cdot 10^{-3}$
2N-H	9.6 ± 1.4	82	-0.1164	0.0122	0.0177	0.83	$0.7 \cdot 10^{-3}$
H-M	11.6 ± 1.0	324	-0.0359	0.0031	0.0031	0.68	$0.2 \cdot 10^{-2}$

Base temperatures increased throughout the wheat life cycle, ranging from -3.5°C in S-3L to 11.6°C in H-M, whilst uncertainty resulted largest in the first phases (S-3L) and decreased throughout the life cycle of plant. Rates of development increased regularly throughout the vegetative phases, to slow down after heading. Residuals (not shown) revealed homogeneous variance and no bias.

Simulated wheat development in the validation sites obtained by the resulting DRFs are shown in Figure 2 for two PHENAGRI sites (LO and FO) and Figure 3 for Cadriano (BO). Overall, simulations caught fairly well the general pattern

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

of wheat development (R^2 = 0.96-99). Large errors were found only in two simulations of 3L over LO that anticipated the observations of 24 and 21 days, equal to a relative error of 28% and 23%, respectively. Similarly, two simulations of 2N (FO) anticipate the observations of 27 and 21 days, equal to a relative errors of to 26% and 21%, respectively. Overall, the model has a RMSE of 7.1-8.4 days, without bias (SRE ~0 days).

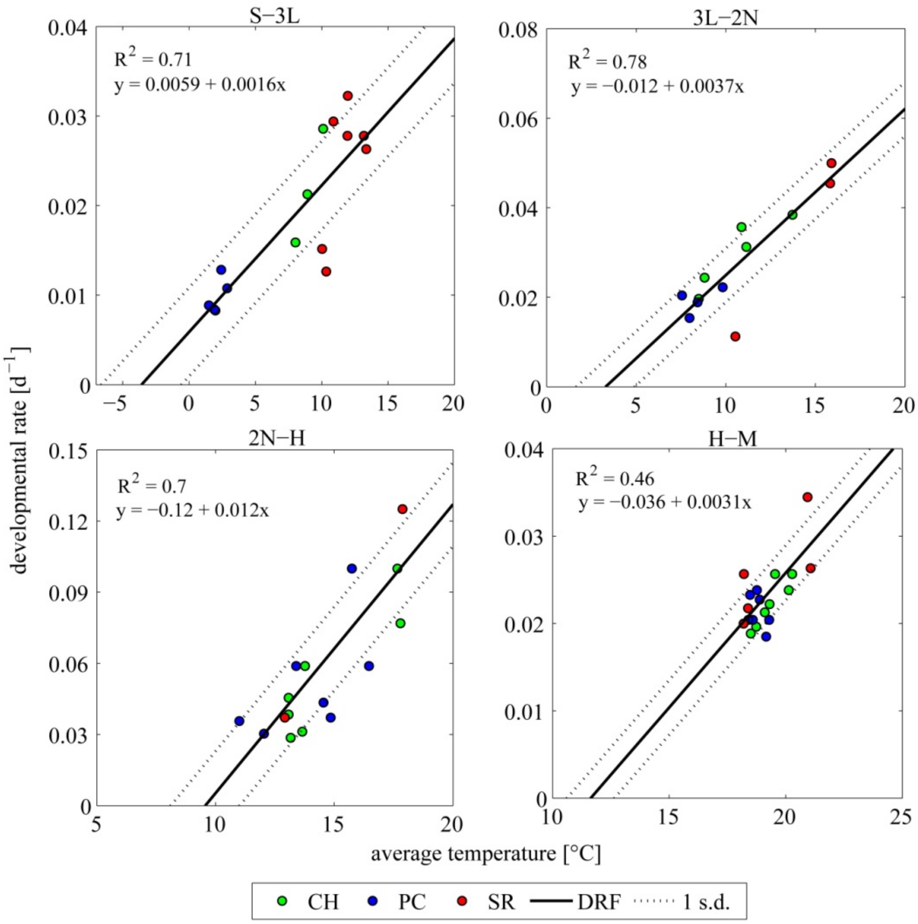


Fig. 1. Linear relationship between durum wheat developmental rates and average air temperature (from the calibration dataset) for phases that enabled the best linear relationships (less data dispersion and higher R^2). R^2 = coefficient of determination; Black lines: DRFs, dotted lines: 1 standard deviation.

Fig. 1. Relazioni lineari tra tassi di sviluppo del grano duro e temperature media dell'aria (dal subset di calibrazione) delle fasi che hanno permesso le migliori relazioni lineari (minore dispersione, maggiore R^2). R^2 = coefficiente di determinazione; linea nera: Funzione Tasso di Sviluppo: linea tratteggiata = 1 standard deviation.

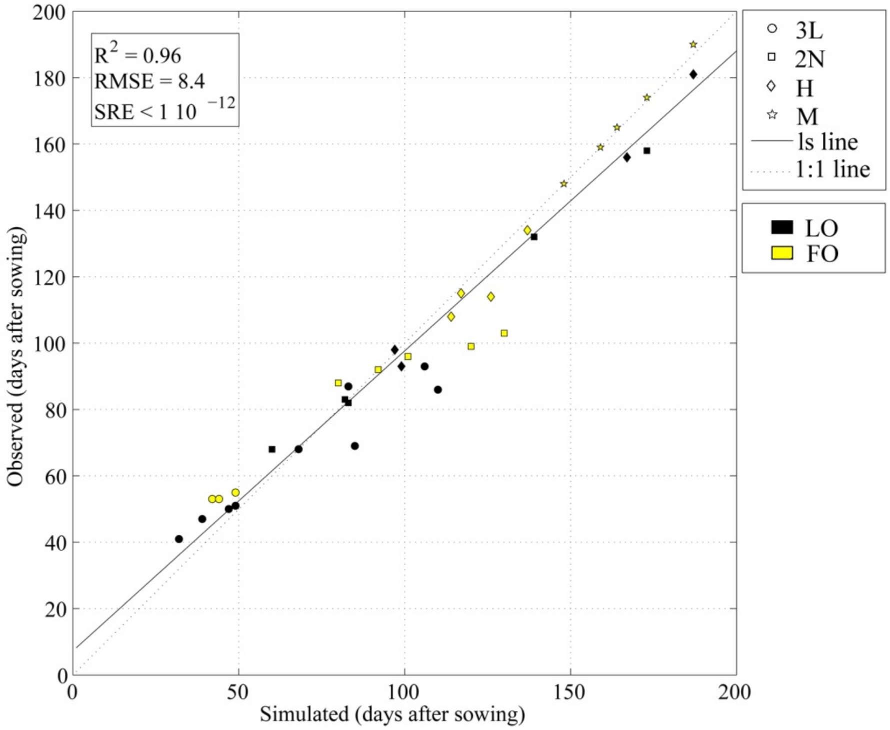


Fig. 2. Model validation: simulated vs. observed durum wheat phenology over S.A Lodigiano (LO) and Foggia, (FO).
Fig. 2. Validazione del modello: fenologia del grano simulata vs. osservata sul sito di S.A Lodigiano (LO) e Foggia, (FO).

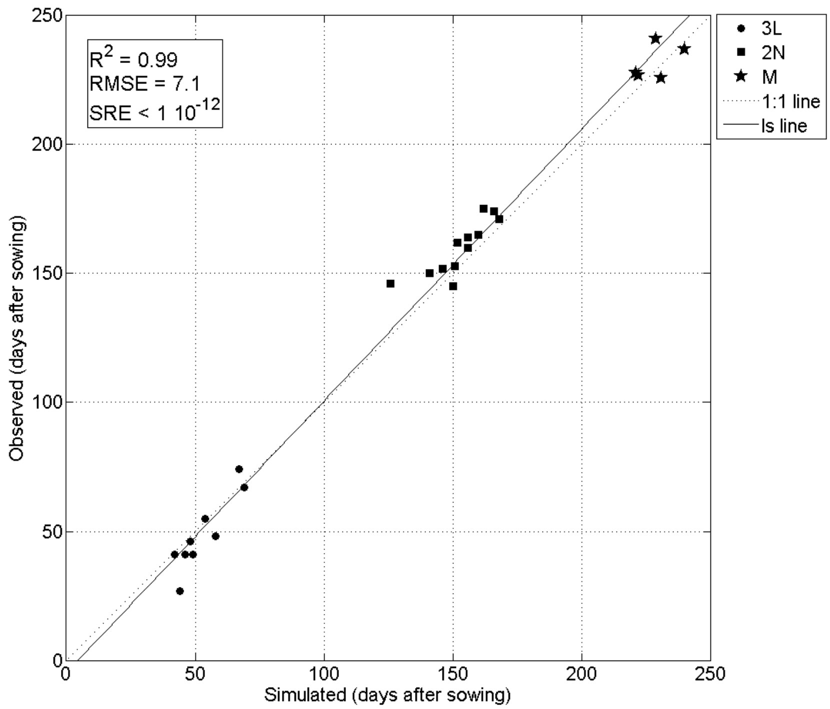


Fig. 3. Model validation: simulated vs. observed durum wheat phenology over Cadriano (BO)
Fig. 3. Validazione del modello: fenologia del grano simulata vs. osservata sul sito di Cadriano (BO).

Discussion

In the present work we recalled that the DD method can adequately simulate crop phenology if the underlying assumption of a linear relationship between developmental rate and air temperature is respected and, thus, suitable phases identified. Otherwise, the degree day method could result inadequate, especially if referred to long phases or applied under different climate regimes, unless it is regarded as site- and growing season- specific (Wang 1960; Ritchie and Nesmith, 1991; McMaster and Smika, 1988).

In the explicative case proposed here, we identified the phases of durum wheat enabling the best linear relation between developmental rates and temperature to calibrate a DD model under proven linear temperature response. Overall, the model obtained allowed to simulate durum wheat development under different locations and sowing dates with good approximation (R^2 = 0.96-0.99; RMSE = 7.1-8.4 days), no bias (SRE≈0 days) and minimal complexity: only four linear DRFs with no additional factors due to photoperiod, vernalization, optimal threshold temperatures, environmental effects and varietal characteristics. These findings can be explained by assuming that, wherever temperature does explain most of the observed variability in plant development, then a general relationship between temperature and development can be identified, regardless of location (local climate) and sowing period.

Conclusions

Phenology is a critical components of crop models, whose uses as part of decision aids to assess agricultural strategies have increased over the last decades. We suggested a simple yet reliable and replicable method to assure the basic assumption of the DD method, in order to return a crop model able to fairly simulate phenological development over different locations and scalar sowing dates with minimal complexity and no bias. We hope that our contribution could help scientific community to make clear some ambiguities on the degree day approach and modelers to improve phenological sub models

References

Angus, J. F., Mackenzie, D. H., Morton, R., & Schafer, C. A. (1981). Phasic development in field crops II. Thermal and photoperiodic responses of spring wheat. *Field crops research*, 4, 269-283.

Botarelli, L., Brunetti, A., Pasquini, A., & Linoni, F. (1999). Aspetti generali delle osservazioni agrofenologiche. Collana di Agrofenologia, MiPAF, PF Phenagri, *Fenologia per l'Agricoltura*. Vol, 1, 110.

Cabelguenne, M., Jones, C. A., Marty, J. R., Dyke, P. T., & Williams, J. R. (1990). Calibration and validation of EPIC for crop rotations in southern France. *Agricultural Systems*, 33(2), 153-171.

Davidson, H. R., & Campbell, C. A. (1983). The effect of temperature, moisture and nitrogen on the rate of development of spring wheat as measured by degree days. *Canadian journal of plant science*, 63(4), 833-846.

Jamieson, P. D., Semenov, M. A., Brooking, I. R., & Francis, G. S. (1998). Sirius: a mechanistic model of wheat response to environmental variation. *European Journal of Agronomy*, 8(3), 161-179.

Masle, J., Doussinault, G., Farquhar, G. D., & Sun, B. (1989). Foliar stage in wheat correlates better to photothermal time than to thermal time. *Plant, Cell & Environment*, 12(3), 235-247.

McMaster, G. S., & Smika, D. E. (1988). Estimation and evaluation of winter wheat phenology in the central Great Plains. *Agricultural and Forest Meteorology*, 43(1), 1-18.

McMaster, G. S., Klepper, B., Rickman, R. W., Wilhelm, W. W., & Willis, W. O. (1991). Simulation of shoot vegetative development and growth of unstressed winter wheat. *Ecological Modelling*, 53, 189-204.

McMaster, G. S., White, J. W., Hunt, L. A., Jamieson, P. D., Dhillon, S. S., & Ortiz-Monasterio, J. I. (2008). Simulating the influence of vernalization, photoperiod and optimum temperature on wheat developmental rates. *Annals of Botany*, 102(4), 561-569.

Meier, U. (1997). Growth stages of mono-and dicotyledonous plants. Blackwell Wissenschafts-Verlag.

Ritchie, J. T., & Nesmith, D. S. (1991). Temperatures and crop development. Modeling plant and soil systems. Agronomy Monograph No. 31. ASA-CSSA-SSSA, Madison, WI53711, USA.

Ritchie, J. T., Singh, U., Godwin, D. C., & Bowen, W. T. (1998). Cereal growth, development and yield. In Understanding options for agricultural production (pp. 79-98). Springer Netherlands.

Slafer, G. A. (1996). Differences in phasic development rate amongst wheat varieties independent of responses to photoperiod and vernalization. A viewpoint of the intrinsic earliness hypothesis. *The Journal of Agricultural Science*, 126(04), 403-419.

Slafer, G. A., & Rawson, H. M. (1995). Photoperiod×temperature interactions in contrasting wheat genotypes: time to heading and final leaf number. *Field Crops Research*, 44(2), 73-83.

Wang, J. Y. (1960). A critique of the heat unit approach to plant response studies. *Ecology*, 41(4), 785-790.

Weir, A. H., Bragg, P. L., Porter, J. R., & Rayner, J. H. (1984). A winter wheat crop simulation model without water or nutrient limitations. *The Journal of Agricultural Science*, 102(02), 371-382.

CLIMATE CHANGE IMPACTS ON THE ITALIAN WINE SECTOR: CHALLENGES AND PROSPECTS FOR SANGIOVESE PRODUCTION IN THE ROMAGNA AREA

IMPATTI DEI CAMBIAMENTI CLIMATICI SUL SETTORE VINICOLO ITALIANO: SFIDE E PROSPETTIVE PER LA PRODUZIONE DEL SANGIOVESE IN ROMAGNA

Eva Merloni[1*], Giulio Malorgio[1], Luca Camanzi[1], Luca Mulazzani[1], Gabriele Antolini[2], Giovanni Nigro[3]

[1] Dipartimento di Scienze e Tecnologie Agro-Alimentari, Università di Bologna, Bologna
[2] Agenzia Regionale Prevenzione Ambiente Energia – Servizio IdroMeteoClima, Bologna
[3] Centro Ricerche Produzioni Vegetali, Faenza
*eva.merloni2@unibo.it

Abstract
This study investigates the adaptive capacity of agri-food firms facing climate change, with particular focus to the Emilia-Romagna wine-growers that produce Sangiovese. More precisely, the main objectives of the study are to assess the main factors influencing producers when dealing with the new environmental challenges and to evaluate the effectiveness of their adaptation strategies.
To do that, a holistic and innovative approach is developed so as that it can be implemented in different contexts and sites. In fact, a number of different factors are considered, including climate variability, farm structure, farmer perception and environmental attitude.
Hence, a set of research hypotheses are formulated and verified through empirical analysis, gathering various types of data from two main sources: a 15-year time series of climate data (temperature and rain) and information collected through a questionnaire administered to 56 wine growers who produce Sangiovesein Emilia-Romagna.
Data collected have been classified and elaborated by means of multivariate statistical technique (cluster analysis) and the Bayesan Network has been applied in order to better understand the relation between the variables that influence capacity of farms to bear the economic management of climate change.
The results show that, in the short-run, farmers perceive the ongoing change in climate conditions and that they react by adjusting agronomic practices and balancing technical and economic issues. However, the probability to be negatively impacted by the effects of climate change is largely affected by structural and technical farm characteristics and by farmer readiness to embrace change. The local climatic conditions are also relevant factors for the adaptation issue. To overcome the new climatic challenges the adoption of focused management and adaptation strategies (irrigation system, mechanized harvesting, investment) are found to be crucial, as well as appropriate policies in terms of regulation, incentives and support.

Keywords: climate change, adaptation strategies, adaptation practices, wine business, Bayesian Network.
Parole chiave: cambiamento climatico, strategie di adattamento, pratiche di adattamento, modello Bayesiano

Introduction

The tight connection between climate change and wine production is today widely recognized (Stock et al., 2005). In fact, wine grape yield and quality are largely dependent on climatic conditions, particularly during the growing season (Jones and Davis 2000; van Leeuwen et al. 2004; Urhausen et al. 2011) and weather fluctuations are likely to occur along the thirty years of a vineyard life cycle. Further, in the last decades, global warming and extreme atmospheric events intensified significantly. The main effects of climate change on wine production entail increasing plant diseases, variations in alcoholic and sugar content, leaching out and soil erosion (Anderson et al., 2008; Ashenfelter and Storchmann, 2014; Sadras, et al., 2012), that in turn have huge repercussions on prices, rents and profits. In cases of extreme extent the typical wine-growing regions (between 20 and 53° latitude in the northern hemisphere and 20 and 42° in the southern hemisphere) may also become unsuitable terroir. This is why, an increasing number of contributes in the scientific literature focus on the most appropriate adaptation practices and strategies, such as night-time harvesting, berry spoilage (quicker delivery of the berries to the winery), Integrated Pest Mangement, the use of more alcohol-tolerant yeast strains, etc. (Keller, 2010; Butt and Copping, 2000; Vink et al., 2009; Schultz, 2000).
Given these premises, this study investigates the adaptive capacity of agri-food firms facing climate change, with particular focus to the Emilia-Romagna wine-growers that produce Sangiovese. More precisely, the main objectives of the study are to assess the main factors influencing producers when dealing with the new environmental challenges and to evaluate the effectiveness of their adaptation strategies.
Furthermore, the research aimed at developing a method for assessing adaptation capacity sufficiently specific to capture local variation but which can also be transferred to other sites and crops later.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Materials and Methods

In light of the background research and the literature review conducted, to achieve the general and specific objectives, the logical framework has been build on an holistic approach that allows to combine different information from different sources. The research has been set up into three main economic theories:

- the Natural Resource-Based View (NRBV) theoretical approach (Hart, 1995) that traces the link between environmental actions and profit and it establishes a direct connection between the firms capabilities to gain competitive advantages while coping with the challenge of irreversible environmental change
- the behavioural economics (Artikov et al., 2006; Hu, 2006) and life cycle thinking theory (Falcone et al., 2015). can be well used to explain the intentions for adopting specific adaptation practices and strategies and climate-friendly behavior in the context of climate change
- the geographical proximity theory (Marshall, 1980; Porter, 2000), according to which farms that interact within a territory at a meso-economic level, allowing cost reduction, knowledge exchange and the level of innovation of individual businesses.

The analysis of those economic theories applied to the context of climate change, allows to identify the main factors that can influence the adaptation capacity, including climate variability, farm structure, farmer perception and environmental attitude.

Hence, a set of research hypotheses are formulated and verified through empirical analysis, gathering various types of data from two main sources: a 15-year time series of climate data (temperature and rain) (secondary data) and information collected through a questionnaire (primary data) administered to 56 wine growers who produce Sangiovese in Emilia-Romagna region. Data collected from 56 wine firms and from climatic data at vineyard level have been classified and elaborated by means of multivariate statistical technique (cluster analysis) to categorize respondents and variables into groups based on the factor that influence the adaptation capacity to bear the economic management of climate change.

Then the Bayesian network (BN) has been applied. Bayesian network is a probabilistic graphical model, in order to facilitate learning about causal relationships between variables, combining quantitative and qualitative data and integrating social, ecological and economic factors to assess the process of adaptive management.

Results and Discussion

The climatic data elaboration at vineyard level shows that the vineyards that have undergone greater temperature variation, associated with the Winkler index, are the vineyards located predominantly in the south of Romagna, in the province of Rimini, and in the pre-hilly area of the province of Cesena. while the greatest variability in water surplus is recorded mainly in the provinces between Forlì and Imola, in the hilly areas (Pictures 1 and 2).

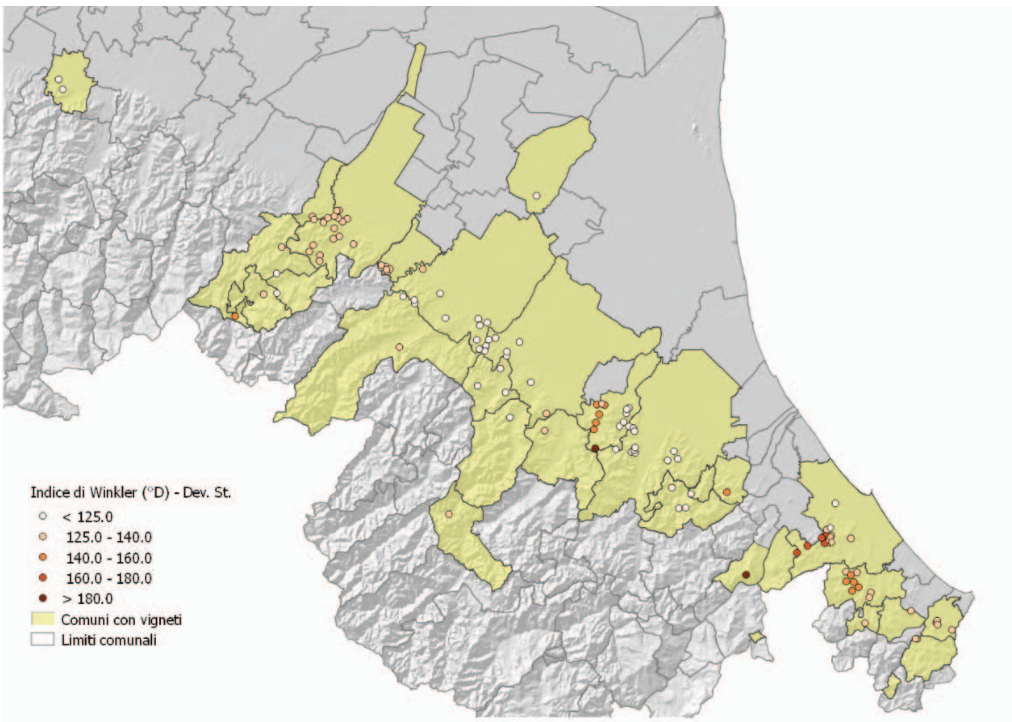


Fig. 1: Winkler index variability values at vineyard level.
Fig.1: Valori di variabilità dell'indice di Winkler calcolati a livello di vigna.

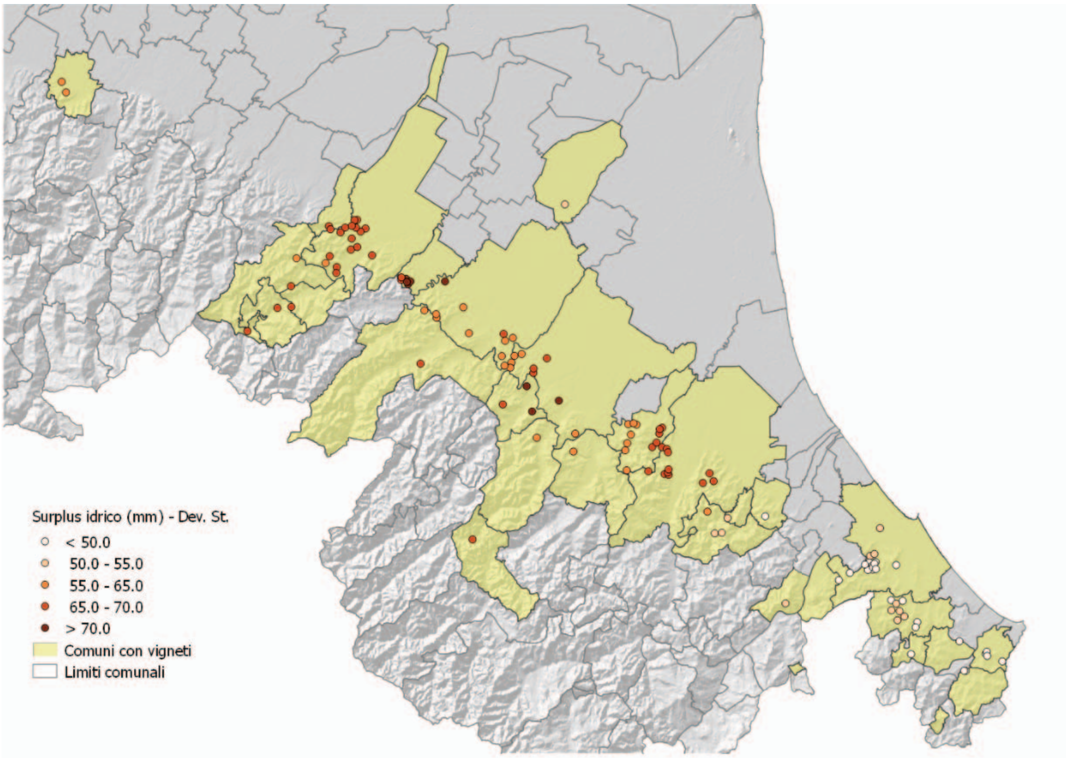


Fig.1: Water surplus variability values at vineyard level.
Fig.1: Valori di variabilità del surplus idrico calcolati a livello di vigna.

Data collected from 56 wine firms and from climatic data at vineyard level have been classified and elaborated by means of multivariate statistical technique (cluster analysis) to categorize respondents and variables into groups based on the factor that influence the adaptation capacity to bear the economic management of climate change. The results show that, in the short-run, farmers perceive the ongoing change in climate conditions and that they react by adjusting agronomic practices and balancing technical and economic issues. However, the probability to be negatively impacted by the effects of climate change is largely affected by structural and technical farm characteristics and by farmer readiness to embrace change. The local climatic conditions are also relevant factors for the adaptation issue. To overcome the new climatic challenges the adoption of focused management and adaptation strategies (irrigation system, mechanized harvesting, investment) are found to be crucial, as well as appropriate policies in terms of regulation, incentives and support.

Conclusions

The management and adaptation strategies can largely reduce the potential impacts of climate change and climate variability on wine production and farmer income. However, the adaptation capacity of wine-making enterprises is related to producer behavior (adaptation practices and strategies and readiness to change) and it is largely dependent on structural and technical farm characteristics, producer perception of climate change and climate variability. In particular, the climate variability influences more the long term vision of the producers than the day-by-day adaptation. For this reason it will be necessary improve the accuracy in predictions of climate phenomena at the micro level.

In any case, the producers are aware of the efforts which are required to cope climate change in the future, in fact they perceive the necessity to implement adaptation strategies such as new rootstock, new varieties, specific investments, in particular for the irrigation system and mechanized harvesting. Thus, in order to support the wine farms and to safeguard the wine production in the future, it is necessary to improve the level of knowledge, information and research about the innovative management systems and adaptation options. Furthermore, the introduction of tools and form of assistance for the adoption of adaptation and mitigation measures in the local supporting policies is crucial.

Finally, the survey shows how the producers interviewed declare to rely on, for the choice of practices and strategies to be implemented, mainly on personal knowledge and / or on confrontation with colleagues. This aspect confirms the theory of proximity or geographical proximity, according to which geographic enterprises, such as regional clusters that are in specific climatic conditions and soil composition, worker sharing, in terms of human capital, and specialized suppliers, developing common strategies for the sector.

References

Anderson, K. et al., 2008. Viticulture , wine and climate change. Commissioned Paper for the Garnaut Climate Change Review, (June), p.22.

Artikov, I. et al., 2006. Understanding the Influence of Climate Forecasts on Farmer Decisions as Planned Behavior*. Journal of Applied Meteorology and Climatology, 45(9), pp.1202–1214. Available at: http://journals.ametsoc.org/doi/abs/10.1175/JAM2415.1.

Ashenfelter, O. and Storchmann, K., 2014. American Association Of Wine Economists. 152.

Butt, T.M. & Copping, L.G., 2000. Fungal biological control agents. Pesticide Outlook, 11(5), pp.186–191. Available at: http://pubs.rsc.org/en/content/articlehtml/2000/po/b008009h

Falcone, G. et al., 2015. Integrated sustainability appraisal of wine-growing management systems through LCA and LCC Methodologies. Chemical Engineering Transactions, 44, pp.223–228. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84939131952&partnerID=tZOtx3y1.

Hart, O., 1995. Firms, Contracts, and Financial Structure - Oliver Hart - Google Libri Clarendon Press, ed., Available at: https://books.google.it/books?hl=it&lr=&id=t417I3nRmuMC&oi=fnd&pg=PA1&dq=Hart+(1995&ots=6518qIvKni&sig=ILgk7mN5WNqtu8iH6s93pDNKOF4#v=onepage&q=Hart (1995&f=false.

Hu, Q. et al., 2006. Understanding farmer's forecast use from their beliefs, values, social norms, and perceived obstacles. Journal of Applied Meteorology and Climatology, 45(9), pp.1190–1201. Available at: wttp://vnweb.hwwilsonweb.com/hww/jumpstart.jhtml?recid=0bc05f7a67b1790e331f3c605ea16e8b8c4a6665b3c1eb371a5bfaba0b2ee4dd159d58229e3725a6&fmt=H http://vnweb.hwwilsonweb.com/hww/jumpstart.jhtml?recid=0bc05f7a67b1790e331f3c605ea16e8b8c4a6665b3c1eb371a5bfaba0b.

Jones, G. V. & Davis, R.E., 2000. Climate Influences on Grapevine Phenology, Grape Composition, and Wine Production and Quality for Bordeaux, France. Am. J. Enol. Vitic., 51(3), pp.249–261. Available at: http://www.ajevonline.org/content/51/3/249.short.

Keller, M., 2010. Managing grapevines to optimise fruit development in a challenging environment: a climate change primer for viticulturists. Australian Journal of Grape and Wine Research, 16, pp.56–69. Available at: http://doi.wiley.com/10.1111/j.1755-0238.2009.00077.x.

Van Leeuwen, C. et al., 2004. Influence of Climate, Soil, and Cultivar on Terroir. Am. J. Enol. Vitic., 55(3), pp.207–217. Available at: http://www.ajevonline.org/content/55/3/207.short.

Marshall, A., 1980. Principles of Economics: An introductory volume Eighth Edition. London: Macmillan, ed.,

Porter, M.E., 2000. Location, competition, and economic development: Local clusters in a global economy. Economic development quarterly 14.1 (2000): 15-34. Available at: https://books.google.it/books?hl=it&lr=&id=CW-wCwAAQBAJ&oi=fnd&pg=PR10&dq=Alfred+Marshall+1890&ots=O8yU_dJTj2&sig=B8iPpxzWZWK8CAR7cVNAu7ujQQM#v=onepage&q=Alfred Marshall 1890&f=false.

Sadras, V.O., Bubner, R. & Moran, M.A., 2012. A large-scale, open-top system to increase temperature in realistic vineyard conditions,

Schultz, H.R., 2000. Physiological mechanisms of water use efficiency in grapevines under drought conditions. Acta Horticulturae, (526), pp.115–136. Available at: http://www.actahort.org/books/526/526_9.htm.

Stock, M. et al., 2005. Reliability of climate change impact assessments for viticulturE. Acta Horticulturae, (689), pp.29–40. Available at: http://www.actahort.org/books/689/689_1.htm.

Urhausen, S. et al., 2011. Climatic conditions and their impact on viticulture in the Upper Moselle region. Climatic Change, 109(3–4), pp.349–373. Available at: http://link.springer.com/10.1007/s10584-011-0059-z.

Vink, N., Deloire, A., Bonnardot, V., & Ewert, J., 2009. Terroir, climate change, and the future of South Africa's wine industry. In pre-AARES conference workshop on The World's Wine Markets by. Vol. 2030. 2009.

ENERGY YIELD OF BIOMASS IN SORGHUM GROWN UNDER DEFICIT IRRIGATION

RESA ENERGETICA DEL SORGO DA BIOMASSA IN REGIME IRRIGUO DEFICITARIO

Pasquale Campi[1a], Alejandra Navarro[2], Francesca Modugno[3], Marcello Mastrorilli[1]

[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria – Centro Agricoltura Ambiente (CREA-AA), Via C. Ulpiani, 70125 Bari
[2] University of Antwerp, Department of Biology, Centre of Excellence PLECO, Campus Drie Eiken, Room C.006b, Universiteitsplein 1, 2610 Wilrijk, Belgium
[3] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria – Centro Politiche e Bioeconomia (CREA-PB), Via Po', 14 00198 Roma
[a] pasquale.campi@crea.gov.it

Abstract
The sustainability of biomass sorghum (*Sorghum bicolor* L. Moench) in the Mediterranean environments is related to obtain convenient yield levels also under deficit irrigation. Field experiments were conducted in Southern Italy during two growing seasons to determine the biomass production and to estimate the yielded energy from sorghum cultivated under full and deficit irrigation. The data obtained showed that, under full irrigation, biomass sorghum yields more above-ground dry matter and energy than crops growing under deficit irrigation (23.5 vs 14.8 t ha^{-1} and 443 vs 258 GJ ha^{-1}). Different indices of water use efficiency were calculated for analyzing the effects of the water regimes on the biomass sorghum productivity.

Keywords: agro-energy crops; higher heating value; water use efficiency.
Parole chiave: colture energetiche; potere calorifico; efficienza d'uso dell'acqua.

Introduction

Sorghum production is encouraged by policies on non-food crops in the European Union and the global environmental policy of the Kyoto Protocol. *Sorghum bicolor* (Moench) is a multipurpose C4 crop for food, forage, fiber and fuel production. Sorghum is a suitable option in drought-prone environments (Barbanti et al., 2006) and in low-input cultivation systems thanks to its deep and dense root system (Stone et al., 1996) and to its high photosynthetic efficiency under drought (Zegada-Lizarazu et al., 2012). For this reason, sorghum has been indicated as a sustainable crop for the production of biogas in marginal environments (Amaducci et al., 2016). The productivity of sorghum, in terms of biomass, has been repeatedly emphasized and its energy potential has been deeply examined. In a Mediterranean environment, a recent study (Campi et al, 2016) has shown that biomass sorghum crops can produce 335 GJ ha^{-1} in full irrigation conditions. However, in semiarid environments, this agronomic option is not consistent with economic and environmental issues and it is important to identify the capacity of this species to adapt to lower water supplies (Vasilakoglou et al, 2011).

This is a crucial point under the Mediterranean climates, where high temperature and solar radiation levels are in favor of the sorghum eco-physiology, but the scarcity of water resources limits its cultivation. Therefore, in order to achieve a better irrigation strategy that optimizes biomass yield, it is necessary to know the response of the crop energy production when irrigation volumes vary.

The aim of this paper is to assess the sustainability of the irrigation deficit on the energy yield of biomass sorghum through the analysis of water use efficiency indices (WUE).

Materials and Methods

The field trials were carried out at the experimental farm of the Agriculture and Economic Research Council - Agriculture and Environment Center (CREA - AA), in Rutigliano (Ba, Lat: 40 ° 59 ', long: 17 ° 59', alt: 147 m a.s.l).

The area is characterized by Mediterranean climate with warm and dry summers: a maximum air temperature ranging from 32°C to 43°C, a minimum relative humidity ranging from 15% to 40% and the annual average precipitation was of 560 mm, Data from 1977 to 2011, (Campi et al, 2016)

The soil of the experimental field contains 40% clay and 45% silt, the field capacity and wilting point of the soil are 36% and 22% (in volume) respectively. It is a shallow soil (0.4 to 0.8 m in depth) with moderate amount of available water (66 mm in 0.6 m rhizosphere).

The sorghum hybrid KWS Bulldozer was used. It is characterized by a medium-late vegetative cycle, high size, good tolerance to bending, and high yields in dry and green biomass. Sorghum was sown on June 7th 2013 and May 19th 2014 with a plant density of 18 plants m^{-2}. Agro-techniques aiming at reducing external inputs were adopted (weeding control at the initial stage of the crop and nitrogen fertilization of 100 kg N ha–1 after 30 days from sowing).

Two irrigation treatments (IRR and STR) per seasons were imposed according a complete randomized experimental design and three repetitions (each block 400 m^2 in surface). IRR restored 100% of the water lost through evapotranspiration (ET) calculated according to the FAO56 approach (Allen et al, 1998). For IRR were provided 304 mm in 2013 and 241 mm in 2014 of irrigation water. The deficit irrigation in STR was scheduled differently in the two seasons: in 2013 by restoring 50% of the water lost through ET (seasonal irrigation volume: 125 mm); in 2014 by supplying 100% of the ET until the stem elongation stage (51 days after sowing), subsequently sorghum was grown under rainfed conditions (seasonal irrigation volume: 147 mm).

During two seasons, at regular intervals (every 7–10 days), dry biomass was measured. At the end of the sorghum cycle (on second week of September) all plants from 20 m^2 plots were harvested and aboveground biomass determined.

The higher heating value (HHV; MJ kg−1) of sorghum was measured using a bomb calorimeter (LECO Corp., MI, USA) end the energy yield per hectare was calculated (GJ ha^{-1}, HHV x Kg ha^{-1}).

Data were analyzed using the statistical package Statgraphics Plus 5.1 (Stat Point Technologies Inc., Warrenton, VA). Duncan's multiple range test was used to separate treatment means when ANOVA results indicated significant differences

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Results and Discussion

Under full water supply (IRR), biomass production (25.5 t ha^{-1} of dry matter) in both seasons (Table 1) is consistent with literature (Gherbin et al., 1996; Mastrorilli et al 2011, Campi et al, 2016) for the Mediterranean environment. As evidenced by the statistical analysis (significance of interaction between irrigation treatments and season of growth), season influences production, due to weather conditions. The gap of 8 t ha^{-1} of dry biomass between the IRR treatments is due to the difference in rain during the two growing seasons (262 mm in 2014 and 72 in 2013).

STR treatment significantly reduces dry biomass production by 58% compared with IRR treatment (Tab. 1).

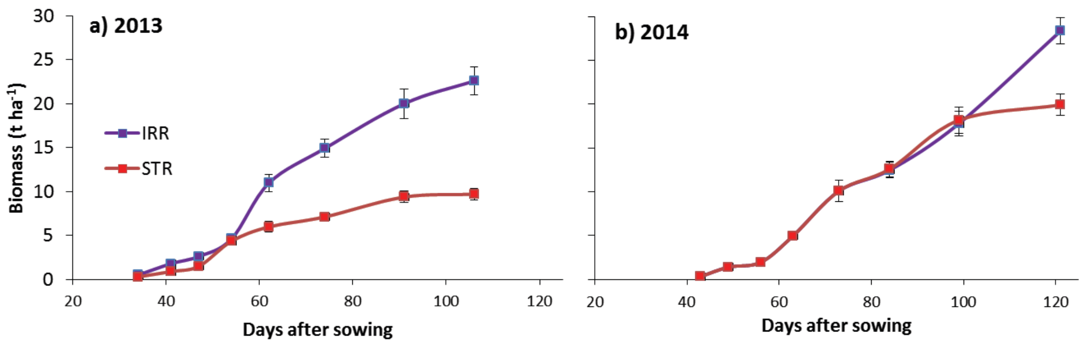


Fig. 1: Effect of irrigation treatments (IRR and STR) on growth of sorghum during 2013(a) and 2014 (b) seasons.
Fig. 1: Effetto dei trattamenti irrigui (IRR e STR) sull'accrescimento del sorgo durante due stagioni (2013 e 2014)

Sorghum growth (Fig. 1) is affected by irrigation treatment. The differences between IRR and STR occur 50 days after sowing in 2013 and 100 days after sowing in 2014. Despite the suspension of irrigations from the 51st day after sowing, in 2014 the exceptional amount of rain in July (124 mm) reduces the effect of the deficit irrigation.

The best performance in energy yielding is achieved by full irrigation (IRR), with the highest values in 2014. HHV measures agree with those reported by Fernando et al. (2010) and Campi et al., (2016), in the case of optimal irrigation. Effects of water stress on HHW are not reported literature and the observations here shown underline that the irrigation regime does not affect significantly HHV values (Tab. 1).

*Tab. 1: Effects of growing season (S), irrigation treatment (I) and their interaction (SxI) on biomass (bWUE) and energy (eWUE) water use efficiency. *** = significance at 0.001; ns = absence of significance. Different letters in the columns indicate significant differences between treatments (Duncan's test, P < 0.05).*
*Tab.1: Effetti della annata (S), dell'irrigazione (I) e della interazione (SxI) sull'efficienza d'uso dell'acqua in biomassa (bWUE) e energia (eWUE). *** = significatività a 0.001 e ns = assenza di significatività. Lettere diverse nelle colonne indicano differenze significative tra i trattamenti (test di Duncan, P <0.05).*

		Biomass (t ha^{-1})		HHV (MJ kg^{-1})		Energy yield (GJ ha^{-1})		bWUE (kg m^{-3})		eWUE (MJ m^{-3})	
Season (S)	2013	16.1	b	17.5	a	282	b	7.5	b	131	b
	2014	24.1	a	17.3	a	417	a	12.4	a	215	a
Irrig. (I)	IRR	25.5	a	17.4	a	443	a	9.3	b	162	b
	STR	14.8	b	17.5	a	258	b	10.8	a	190	a
P[1]	S	***		ns		***		***		***	
	I	***		ns		***		***		***	
	SxI	***		ns		***		***		***	

The conversion index of irrigation water into biomass (bWUE, kg of dry matter per m^{-3} of irrigated water) is a criterion for analyzing the effectiveness of the irrigation regime and it is a requisite in modeling the agro-energy crops in the Mediterranean environment. On the contrary, the conversion index of irrigation water into bioenergy (eWUE, MJ m^{-3}) represents a general criterion for assessing the economic value of the irrigation supplied to the biomass crops. For the sorghum, biomass (bWUE) and energy (eWUE) water use efficiencies are significantly higher for deficit irrigation (STR) and during the rainy season (Tab. 1).

Data from the literature clearly showed that bWUE in sorghum grown in the Mediterranean area can vary remarkably from 5.84 to 22.81 kg m^{-3}, even with similar water amounts of irrigation (Mastrorilli et al., 2011; Palumbo et al., 2014). This can be mainly explained by the genotype and the rainfall trend during the sorghum growing season. The bWUE values calculated in 2014 are significantly higher due to the greater amount of precipitation. The eWUE values reported by Campi et al. (2016) are lower (105 MJ m^{-3}) than those calculated after the observations collected in this field trial. In the seasons 2013 and 2014 the higher eWUE value is due to favorable climatic conditions for sorghum that resulted in an increased dry biomass production (25.5 vs 20.4 t ha^{-1}).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Conclusions

This study confirms that irrigation is the main agro-technique affecting the biomass yield in the Mediterranean environments. However, the agro-meteorological trend does influence yields, both under full or deficit irrigation regime (up to 50% more dry matter in the rainy summer).

The original results reported in this work concern the application of controlled stress irrigation on dedicated energy crops in the Mediterranean area. In general, sorghum biomass production is reduced by water stress and, as a consequence, also the production of energy per unit of cultivated area tends to decrease. Sorghum crops under deficit irrigation can produce appreciable biomass yields (15 t ha^{-1} of above-ground dry matter) with high efficiency in converting irrigation water in biomass (bWUE = 11 kg m^{-3}). Reducing by the 50% the supplied irrigation water amount (273 mm in IRR and 136 mm in STR) the loss of energy yielded *per* hectare is less than proportional. Calculated eWUE shows that under deficit regime, sorghum improves the efficiency of transforming irrigation water into energy by 17% if compared to the eWUE calculated for the full irrigation. This experimental evidence allows to retain that full irrigation regime for the biomass sorghum crops should be reconsidered for attaining a sustainable goal in the water management.

References

Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998. Crop evapotranspiration. Guide-lines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56.

Amaducci S., Colauzzi M., Battini F., FracassoA., Perego A., 2016. Effect of irrigation and nitrogen fertilization on the production ofbiogas from maize and sorghum in a water limited environment. Europ. J. Agronomy 76, 54–65.

Barbanti, L., Grandi, S., Vecchi, A., Venturi, G., 2006. Sweet and fibre sorghum (Sorghum bicolor (L.) Moench), energy crops in the frame of environmental protection from excessive nitrogen loads. Eur. J. Agron. 25, 30–39.

Campi P., Navarro A., Palumbo A.D., Modugno F., Vitti C., Mastrorilli M., 2016. Energy of biomass sorghum irrigated with reclaimed wastewaters. Europ. J. Agronomy 76, 176–185

Gherbin, P., Perniola, M., Tarantino, E., 1996. Sweet and paper sorghum yield as influenced by water use in southern Italy. In: Proceedings of the First European Seminar on Sorghum for Energy and Industry, INRA, Toulouse, France, 1–3April, pp. 222–227.

Mastrorilli, M., Campi, P., Palumbo, A.D., Navarro, A., Modugno, F., Turci, V., 2011.Water use efficiency of sorghum cultivated for energy in Mediterranean environments. In: Proceedings of the 19th European Biomass Conference and Exhibition, Berlin, Germany, 6–10 June, pp. 565–568.

Palumbo, A.D., Vonella, A.V., Garofalo, P., D'Andrea, L., Rinaldi, M., 2014. Response of a two-year sugar beet-sweet sorghum rotation to an agronomic management approach diversified by soil tillage and nitrogen fertilization. Ital. J. Agron. 9 (3), 109–114.

Stone, L.R., Schlegel, A.J., Gwin Jr., R.E., Khan, A.H., 1996. Response of corn grain sorghum, and sunflower to irrigation in the High Plains of Kansas. Agric. Water Manage. 30, 251–259.

Vasilakoglou, I., Dhima, K., Karagiannidis, N., Gatsis, T., 2011. Sweet sorghum productivity for biofuels under increate soil salinity and reduced irrigation. Field Crops Res. 120, 38–46.

Zegada-Lizarazu, W., Zatta, A., Monti, A., 2012. Water uptake efficiency and above-and belowground biomass development of sweet sorghum and maize under different water regimes. Plant Soil 351, 56–60.

Acknowledgements

This work was supported by the Italian Ministry of Agriculture (MiPAAF) under the AGROENER project (D.D. n. 26329, 1 april 2016) - http://agroener.crea.gov.it/

THREE YEARS OF KAMUT® KHORASAN PRODUCTION: YIELD AND GRAIN QUALITY PARAMETERS
TRE ANNI DI PRODUZIONE DI KAMUT® KHORASAN: ANALISI DELLA RESA E DEI PARAMETRI QUALITATIVI

Giovanni Dinelli[1*], Alessandro Di Loreto[1], Valeria Bregola[1], Ilaria Marotti[1], Rocco Enrico Sferrazza[1], Sara Bosi[1]

[1] Dipartimento di Scienze Agrarie, Università di Bologna, Viale Fanin 44, 40127, Bologna
*giovanni.dinelli@unibo.it

Abstract
The increasing interest in organic food products and in particular in the functional food sector, has emphasised the importance of investigate the relationship between growing environmental conditions of wheat, agronomic traits and quality parameters of grain. Therefore, the aim of this study was to evaluate the nutrient/nutraceutical composition of KAMUT® khorasan wheat and its agronomic quality profile in relation with growing location. The research underlined the strong influence of the environmental factors on crop productivity and quality, in terms of nutritional and nutraceutical value.

Keywords: *Triticum turgidum* spp. *Turanicum; yield; quality traits; quality maps*
Parole chiave: *Triticum turgidum* spp. *Turanicum; resa; parametri qualitativi; mappe di qualità*

Introduction
KAMUT® khorasan is the trademark of an ancient wheat cultivar, the khorasan wheat (*Triticum turgidum* ssp. *turanicum*) derived from a natural hybrid between *Triticum durum* and *Triticum polonicum*, which occurred in the Fertile Crescent (Khlestkina *et al.,* 2006). Cultivation of KAMUT® khorasan wheat is exclusively managed by a license agreement which requires organic certification of the crop and several quality specifications related both to nutritional characteristics and growing conditions (Quinn, 1999).
The research aimed at determining the nutrient, fibre and antioxidant composition of KAMUT® khorasan grain as a function of the growing location and understanding the environmental dynamics affecting the yield and grain quality profile. The study involved an area covering approximately 240000 km^2 (Canada and USA) which included several different farms and environments. Growing environmental conditions are known to strongly influence the expression levels of plant secondary metabolites and, therefore, may affect the production and the accumulation of nutritional compounds during kernel development. This is the first study in which an organically grown crop is investigated in a region of such broad extension with several different environments.
The elaboration of data concerning grain yield, test weight and protein content allowed a comparison between the agronomic performance and the nutritional/nutraceutical profile of KAMUT® grain. In addition results were elaborated using Geographic Information System (GIS) to develop *quality maps*.

Materials and Methods
Grain samples: the study was carried out using a collection of KAMUT® khorasan wheat (*Triticum turgidum* spp. *turanicum*) harvested in North America in 2010, 2011 and 2012. The grain collection consisted of 112 samples for the first year (2010), 118 for the second (2011) and 149 for the third year (2012), all cropped in accordance with the strictly specifications required by Kamut International, Ltd. At maturity, yield, test weight and protein content were recorded. Whole-grain samples were ground to semolina using a domestic stone mill (100% flour extraction) (Billy 200, Hawos Mulini, Bad Homburg, Germany). All determinations were replicated three times and results expressed on a dry weight (DW) basis.
Starch analysis: resistant (RS) and total starch (TS) were measured using a Megazyme assay kit (Megazyme International Ireland Ltd, Wicklow, Ireland), as described by Di Silvestro *et al*., (2012).
Dietary Fibre components: total (TDF), insoluble (IDF) and soluble (SDF) dietary fibre contents were determined following the enzymatic/gravimetric method described by Prosky *et al.* (1988) using a Megazyme assay kit.
Phenolic compounds: phenolic compounds were extracted as previously described by Dinelli et *al*., (2011). Extracts were analysed for the free (FP), bound (BP) and total polyphenol (TP) content, following the colorimetric procedure based on the Folin–Ciocalteu reagent (Singleton *et al*., 1999). Furthermore same extracts were analysed for free (FF), bound (BF) and total (TF) flavonoid content following the spectrophotometric method described by Dinelli *et al*. (2011). The absorbance values were converted using gallic acid and catechin as standard for polyphenols and flavonoids, respectively.
Statistical analysis: one-way analysis of variance (ANOVA) in conjunction with Tukey's honest significant difference was performed for comparing flour samples from 2010, 2011 and 2012 cropping seasons. Significance between means was determined by least significant difference values for $P < 0.05$. Correlation analyses was performed on the standardised

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

matrix of the nutrient and phytochemical content of 2010, 2011 and 2012 data set using Statistica 6.0 software (2001, StatSoft, Tulsa, OK, USA). Whole data set of 2010, 2011 and 2012 KAMUT® khorasan production were also elaborated using open source QGIS 2.6.1 - Brighton software.

Results and Discussion

Between the three years of cultivation, significant differences were observed for the grain production: the highest yield (1,30 t/ha) was recorded during the 2010 season (17.3% higher than 2011 and 2012). Protein content of KAMUT® khorasan, ranged from 9% to 17% with an average value of 12% in the second season and of 13% in the first and third year (Tab. 1). Protein was negatively correlated with test weight ($-0.7<r<-0.3$), while no significant correlation was observed between protein and yield.

As regards starch analyses, the comparison of samples cropped in 2010, 2011 and 2012 showed a great variability and significant differences in TS and RS content, with the 2012 KAMUT®khorasan production that showed highest avearge values (Tab. 1). A negative correlation between protein and starch content was observed in the 2011 KAMUT®khorasan production.

Significant differences ($p<0.001$) between the wheat samples cropped in 2010, 2011 and in 2012 were also observed in terms of dietary fiber; in particular, grain samples harvested in 2010 showed lowest values of SDF, IDF and TDF (Tab. 1).

Combining data from the three years of cultivation, yield was positively correlated with test weight ($0.3<r<0.7$) and altitude ($0.3<r<0.7$) while a negative correlation with total dietary fibre ($-0.3<r<0$) and temperature ($-0.3<r<0$) were observed.

Tab. 1: Range of variation and mean values of yield and quality traits, starch and dietary fibre components. Different letters in a column indicate statistically different values.(TS , RS= Total and resistant starch; IDF,SDF; TDF= Insoluble, soluble and Total Dietary Fibre).

Tab. 1: Range di variazione e valori medi dei parametri produttivi e qualitativi considerati, e delle componenti di amido e fibra. Lettere differenti per colonna indicano valori statisticamente significativi. (TS , RS= amido totale e amido resistente; IDF,SDF; TDF= fibra insolubile, solubile e totale).

Years of production	Yield (t/ha)	Test Weight (kg/hl)	Protein (%)	TS (g/100g)	RS (g/100g)	IDF (g/100g)	SDF (g/100g)	TDF (g/100g)
2010	0.28-2.81	60.35-77.06	11-16	52.22-69.19	0.22-1.78	11.16-19.15	1.26-4.89	13.58-22.62
	(1.30) a	(71.69) b	(13) a	(63.56) b	(0.65) b	(14.29) b	(3.27) c	(17.57) b
2011	0.15-2.17	61.23-77.69	9-16	55.94-71.98	0.18-2.15	10.76-23.05	1.99-6.43	13.86-26.09
	(1.05) b	(73.13) a	(12) b	(65.29) a	(0.55) c	(16.13) a	(3.64) b	(19.76) a
2012	0.11-2.30	55.37-78.30	9-17	57.97-74.90	0.14-2.10	12.14-19.78	1.97-5.43	15.55-23.82
	(1.08) b	(73.16) a	(13) a	(65.93) a	(0.79) a	(15.39) a	(3.94) a	(19.33) a

Considering nutraceutical charachterization, in the present work significant differences ($p<0.001$) were observed for polyphenols and flavonoids compounds, among 2010, 2011 and 2012 samples (Tab. 2). FP and TP were significatively higher in 2010 season (81.62 mg/100g and 166.46 mg/100g respectively) in respect to 2011 and 2012 season, while as regards bound fractions, they were higher for both 2010 and 2011 cropping season in respect to 2012 one (Tab. 2). Some interesting correlations were observed: a negative correlation ($-0.3<r<0$) were found between TP and protein content and between TP and total starch amount, confirming the opposite relationship existing between products of primary and secondary metabolism. Moreover, a positive correlation was observed between TP content and the level of precipitation ($0.3<r<0.7$). This can be explained considering that phenolic biosynthesis can be induced by biotic stress and therefore the observed variability among years of cultivation may also be related to fungal diseases present at different levels of severity.

Concerning flavonoids, TF determination highlighted that in 2012, KAMUT® has accumulated on average 45.40 mg/100g in the kernel, showing higher values than season 2010 (38.81 mg/100g) and 2011 (38.35 mg/100g). The same trend was observed for FF, while for the bound fraction the mean value were detected in the samples harvested in the 2011 cropping season (Tab. 2).

The quality maps elaborated showed the variability of the phytochemical amounts among North American farms and allowed the identification of areas in which bioactive compounds had accumulated at a higher level in the wheat grains (data not showed).

Conclusions

The research underlined the strong influence of the environmental factors on crop productivity and quality, in terms of nutritional and nutraceutical value. In the functional food scenario, the choice of a growing location in which the accumulation of health-promoting compounds (i.e. polyphenols, fibres) is stimulated by specific climatic conditions could be a key factor for the production of organic wheat foodstuff.

Tab.2: Range of variation and mean values of antioxidant compounds. Different letters in a column indicate statistically different values(FP;BP, TP=free, bound and total polyphenols; FF;BF, TF=free, bound and total flavonoids).
Tab. 2: Range di variazione e valori medi dei composti antiossidanti. Lettere differenti per colonna indicano valori statisticamente significativi. (FP;BP, TP = polifenoli liberi, legati e totali; FF;BF, TF= flavonoidi liberi, legati e totali).

Years of production	FP (mg/100g)	BP (mg/100g)	TP (mg/100g)	FF (mg/100g)	BF (mg/100g)	TF (mg/100g)
2010	34.50-130.72	56.59-115.33	117.24-223.38	14.04-72.67	6.63-20.54	22.45-83.60
	(81.62) a	(84.84) a	(166.46) a	(27.59) b	(11.22) c	(38.81) b
2011	41.21-131.11	44.00-143.64	98.57-217.69	4.68-51.67	0.47-39.10	18.51-84.72
	(68.57) b	(88.32) a	(156.90) b	(23.50) c	(14.85) a	(38.35) b
2012	20.87-94.76	9.99-101.61	43.94-178.83	20.08-46.14	3.45-31.79	32.09-70.44
	(55.81) c	(60.19) b	(116.00) c	(31.89) a	(13.50) b	(45.40) a

References

Khlestkina E.K., Pshenichnikova T.A., Röder M.S., Salina E.A., Arbuzova V.S. and Börner A., 2006. Comparative mapping of genes for glume colouration and pubescence in hexaploid wheat (*Triticum aestivum* L.). Theor. Appl. Genet.113: 801–807.

Quinn R.M., 1999. Kamut®: ancient grain, new cereal. In: Perspectives on new crops and new uses. Alexandria: ASHS Press. p. 182–183.

Di Silvestro R., Marotti I., Bosi S., Bregola V., Segura Carretero A., Sedej I., Mandic A., Sakac M., Benedettelli S., Dinelli G., 2012. Health-promoting phytochemicals of Italian common wheat varieties grown under low-input agricultural management, J. Sci. Food Agr. 92: 2800 - 2810

Prosky L., Asp N.G., Schwizer T.F., De Vries J.W. and Furda I., 1988. Determination of insoluble, soluble and total dietary fiber in foods and food products: interlaboratory study. J. Assoc. Off. Anal. Chem. 71:1017–1023.

Dinelli G., A. SeguraCarretero, R. DiSilvestro, I. Marotti, D.ArraezRoman, S. Benedettelli, L. Ghiselli & A. FernandezGutierrez, 2011. Profiles of phenolic compounds in modern and old common wheat varieties determined by liquid chromatography coupled with time-of-flight mass spectrometry. J. Chromatogr. A 1218: 7670–7681.

Singleton V. L., Orthofer R. and Lamuela-Raventos R. M., 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin–Ciocalteu reagent. Methods Enzymol. 299:152–178.

APPLICATION OF SOD SEEDING TECHNIQUES TO TEMPERATE RICE IN ITALY

APPLICAZIONE DI TECNICHE DI SEMINA SU SODO AL RISO TEMPERATO IN ITALIA

Eleonora Cordero[1*], Barbara Moretti[1], Luisella Celi[1], Cristina Lerda[1], Gianluca Beltarre[2], Daniele Tenni[2], Marco Romani[2], Dario Sacco[1]

[1]Dept. of Agricultural, Forest and Food Sciences, University of Turin, Grugliasco, Italy
[2]Rice Research Centre, Ente Nazionale Risi, Castello d'Agogna, Italy
*eleonora.cordero@unito.it

Abstract
Conservation agriculture (CA) can improve sustainable rice production. This work evaluated the effect of different CA practices on rice agronomic system. A four-year experiment (2013-2016) was carried out in Crescentino (VC), North-West Italy, comparing three tillage managements (sod dry seeding, sod wet seeding and ploughing), combined with three N fertilisation levels (0-110-160 kg N ha^{-1}) and two straw management (straw retained and removed). Yield and yield components were influenced by both tillage practices and N fertilisation, but not by straw management. Sod seeding reduced grain yield of about 16% with respect to ploughing, because of the lower panicle density and higher sterility. Rice responded to N fertilisation, but the higher sterility limited the positive effect at high N rates. Moreover, in sod seeding, high N supply increased Apparent Recovery (AR). Straw retention improved soil quality, increasing soil organic carbon concentration.

Keywords: conservation agriculture, sod seeding, nitrogen efficiency, soil organic matter
Parole chiave: agricoltura conservativa, semina su sodo, efficienza dell'azoto, sostanza organica del suolo

Introduction
Conservation agriculture (CA) is one of the best management practice for sustainable crop production (Zheng *et al.*, 2014). As for other cropping systems, CA techniques may be effective in rice cultivation, because of their potential benefit for labor saving and soil conservation. Many studies have been undertaken to investigate the effect of CA and nitrogen (N) fertilisation on rice yield and components (Huang *et al.,* 2015). However, environmental and management conditions largely influence final results. The purpose of this study was to analyze the rice cropping system, evaluating grain yield, yield components, N efficiency and soil C and N content related to the main CA practices, N rates of applications and straw managements.

Materials and Methods
A specific field experiment was carried out from 2013 to 2016 in Crescentino (VC), North-West Italy. The soil texture was silty-loam. The experiment compared three tillage managements: sod seeding based on dry seeding and delayed flooding (sod dry seeding), sod seeding based on water seeding (sod wet seeding) and conventional tillage based on water seeding (ploughing). These three different tillage practices were combined with three N fertilisation rates (0-110-160 kg N ha^{-1}) and two different straw managements (straw retained and straw removed). The treatments were laid out in a split split plot randomized complete block design, with tillage practices in the main plots, N fertilisation rates in the subplots and straw managements in the sub-subplots. Three blocks were established. The rice cultivar was CL 26, a long B grain variety, sown at a seed rate of 180 kg ha^{-1}.
Grain yield normalized to a moisture content of 14% was determined at harvest. Moreover, yield components (i.e. panicle density, number of spikelets per panicle, 1000-grain weight and sterility) were measured. Apparent Recovery (AR) was determined as the ratio between the difference of the amount of N taken up by the fertilised crop and the N uptake of the unfertilised treatment, divided by the N supplied. Finally, the effect of CA practices on soil C and N content and soil organic matter was evaluated.
Data were analyzed through a linear mixed effects model. If significant, differences between means were separated through Bonferroni post hoc test.

Results and discussion
Tillage practices and N fertilisation affected both yield and yield components. However, no interaction resulted to be significant except for spikelets number per panicle and sterility. Straw management had a negligible effect on the analysed parameters.
Both sod seeding techniques produced about 16% less grain than ploughing (*Figure 1*). Since the experiment was four-year old, and no interaction with year resulted to be significant, it could be hypothesized that this yield gap would not reduce over time.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

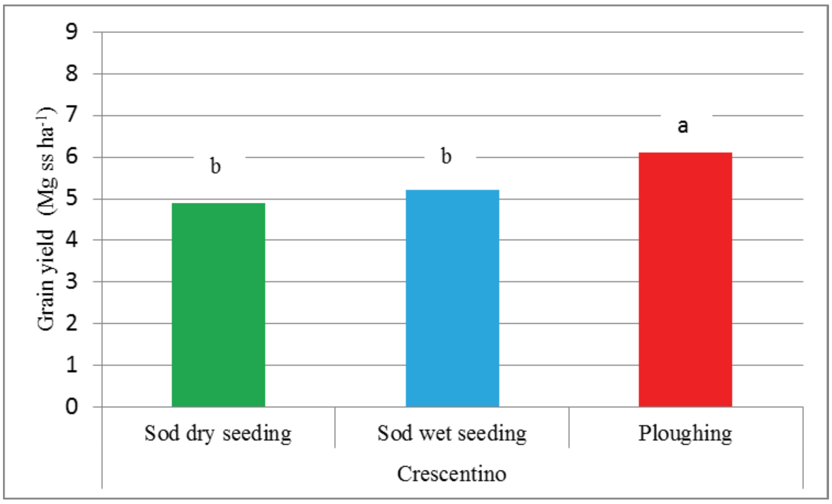


Fig. 1: Effect of different tillage management on grain yield. Different letters show significant differences according to Bonferroni post hoc test (P<0.05).
Fig. 1: Effetto di diverse tecniche di lavorazione sulla produzione di granella. Lettere differenti indicano differenze significative per il test post hoc di Bonferroni (P<0.05).

The main reason leading to yield gap in sod seeding treatments was the limited panicle density (*Table 1*), that induced a higher number of spikelets per panicle, especially in sod dry seeding. Unfortunately, the increased panicle length was combined with a higher sterility, compromising final grain yield.

Tab. 1: Effect of different tillage management on grain yield components. Different letters show significant differences according to Bonferroni post hoc test (P<0.05).
Tab. 1: Effetto di diverse tecniche di lavorazione sulle component della produzione. Lettere differenti indicano differenze significative per il test post hoc di Bonferroni (P<0.05).

Tillage management	**Panicle density (Panicle m^{-2})**	**1000-grain weight (g)**	**Spikelets number per panicle (n°)**	**Sterility (%)**
Ploughing	628 a	22.6	101 c	15.8 c
Sod dry seeding	520 c	22.6	131 a	23.4 a
Sod wet seeding	514 b	22.6	114 b	18.3 b

In this experiment, N fertilisation was studied in order to check the possibility of compensating yield losses in sod seeding with a higher N supply. The increased grain production obtained in the higher fertilisation rates was compromised by an increase in sterility percentage. Consequently, grain yield did not show any statistical differences between the two fertilised treatments (*Figure 2*).

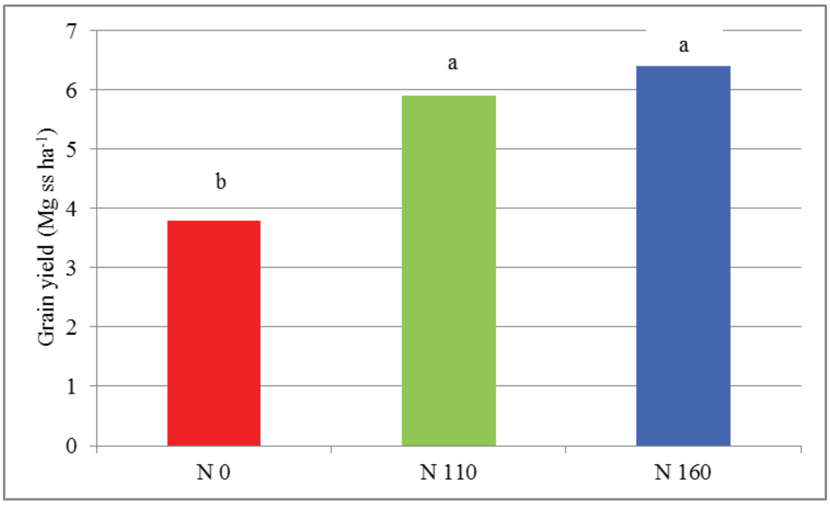


Fig. 2: Effect of different N rates on grain yield. Different letters show significant differences according to Bonferroni post hoc test (P<0.05).
Fig. 2: Effetto di diversi apporti di azoto sulla produzione di granella. Lettere differenti indicano differenze significative per il test post hoc di Bonferroni (P<0.05).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

N fertilisation rates affected grain and total N concentration and consequently N uptake. The interaction between tillage and fertilisation was significant (*Figure 3)* and highlighted by the steeper increase in sod seeding treatments than in ploughing.

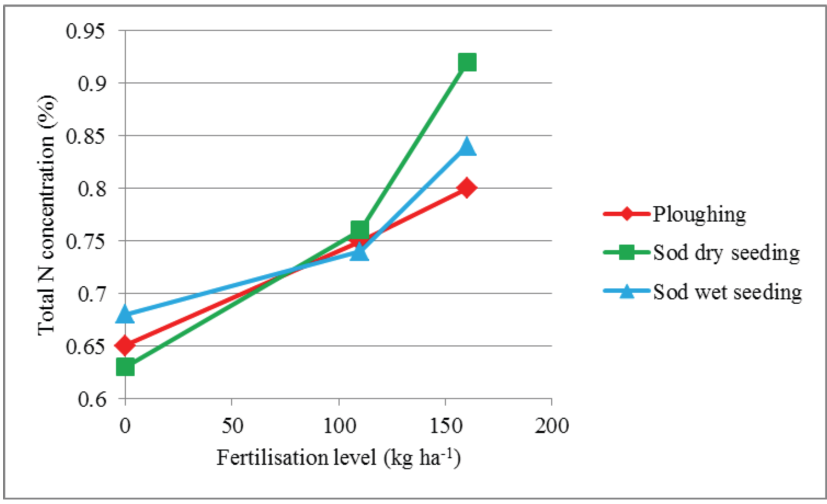


Fig. 3:Relationship between N fertilisation and total N concentration.
Fig. 3:Relazione tra apporti di N e concentrazione di N nella pianta intera.

Consequently, sod seeding treatments showed a higher AR in the higher N rate. Conversely, in ploughing treatment the increase in N fertilisation lead to a lower AR (*Figure 4*).Therefore, it is possible to improve nitrogen use efficiency in sod seeding treatments by increasing N supply up to 160 kg N ha^{-1}.

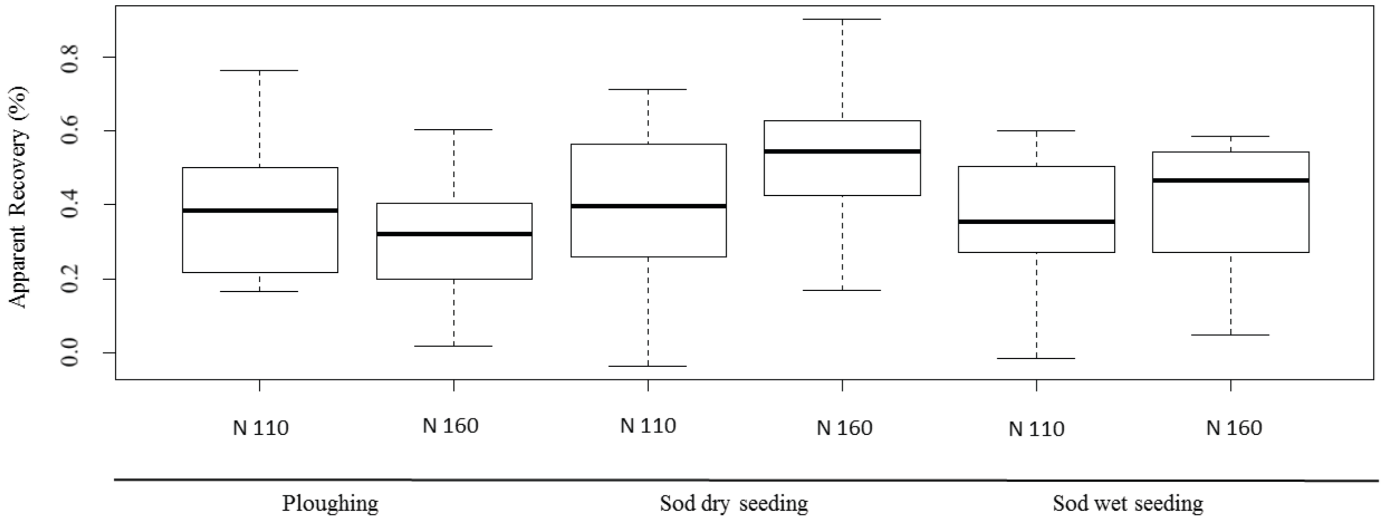


Fig. 4: Influence of tillage practices and N fertilisation on Apparent Recovery.
Fig. 4: Influenza di tecniche di lavorazione e apporti di azoto sull'Apparent Recovery.

C concentration and C/N ratio did not vary between the different treatments. However, straw retention increased C and C/N parameter in the labile organic fractions (FPOM). Focusing on this labile C, the distribution along the soil profile was more homogeneous in the ploughed treatments, as no differences emerged between 0-12.5 cm and 12.5-25 cm layer (*Figure 5*). Conversely, in sod seeding it was evident the accumulation of FPOM in the upper layer.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

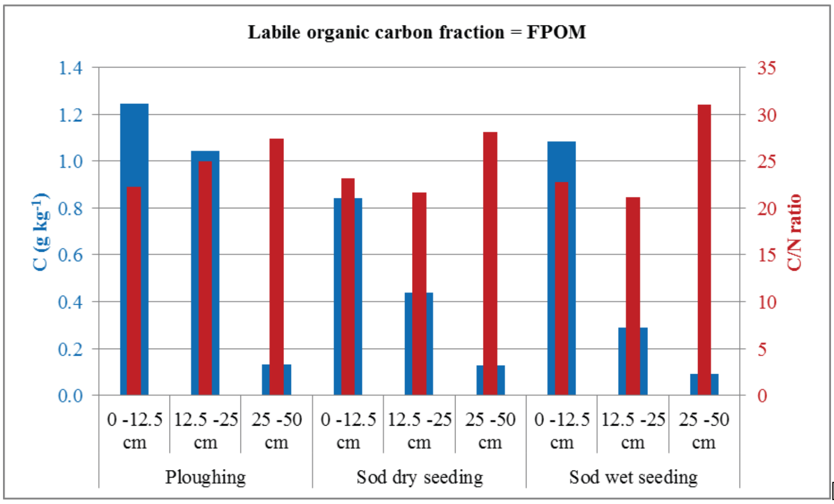


Fig. 5: C concentration and C/N ratio of the labile organic matter (FPOM) in the soil profile.
Fig. 5: Concentrazione di C e rapporto C/N della frazione labile di sostanza organica (FPOM) lungo il profilo del suolo.

In ploughed treatments, FPOM degradation decreased whit depth, as shown by the higher C/N ratio. Instead, sod seeding treatments showed a faster degradation in the 12.5-25 cm, as demonstrated by a lower C/N. This fact can be explained considering that less labile organic matter reaches this layers, but this amount remains here longer, having then more time for degradation.

Conclusions

Sod seeding techniques applied to rice compromised rice grain yield, as a result of low panicle density and high sterility. Rice varieties more adapted to CA, able to compensate the lower panicle density by increasing yield components, could probably limit the yield reduction. Alternatively, seeding rate in sod seeding treatments could be increased in order to compensate the yield gap.
The increase of N supply up to 160 kg N ha^{-1}in sod seeding treatments seems also an efficient solution to reduce grain yield losses as it does not imply any reduction in N use efficiency, but sterility must be controlled.
Finally, straw return has to be promoted as an efficient tool for soil quality improvement. However, it could limit plant emergence, so its adoption is recommended to be coupled with the use of row cleaners and/or straw spreaders.

References

Huang M., Zhou x., Cao F., Xia B., Zou Y., 2015. No-tillage effect on rice yield in China: a meta-analysis. Field Crops Research 183:126-137.
Zheng C., Jiang Y., Chen C., Sun Y., Feng J., Deng A., Song Z., Zhang W., 2014. The impacts of conservation agriculture on crop yield in China depend on specific practices, crops and cropping regions. The Crop Journal 2:289-296.

AN INDICATOR OF CROPPING SYSTEMS ECONOMIC ROBUSTNESS
UN INDICATORE DI ROBUSTEZZA ECONOMICA DEI SISTEMI COLTURALI

Alicia Ayerdi Gotor[1], Elisa Marraccini[2], Olivier Scheurer[3], Christine Leclercq[2*]

[1] UP 2012-10-102 AGHYLE, UniLaSalle, Beauvais (France)
[2] UP 2012-10-103 INTERACT, UniLaSalle, Beauvais (France)
[3] UniLaSalle, Beauvais (France)
*christine.leclercq@unilasalle.fr

Abstract
In a context of increasing variability of weather conditions and prices, robustness is becoming a required characteristic of farming and cropping systems. We propose and test an indicator of cropping systems robustness based on gross margin variations. The method probably leads to underestimate gross margin variability because of the input data, the indicator appeared sensitive. However, it allowed to identify the variability of the major variation factors and, above all, to evaluate *ex-ante* several alternative cropping systems in a test loops design process. The method will be tested on several arable cropping systems besides other tools to forecast yields variability.

Keywords: robustness, resilience, cropping systems, *ex-ante* assessment
Parole chiave: robustezza; resilienza; sistemi colturali, valutazione *ex-ante*

Introduction
Agriculture has always been submitted to climatic fluctuations that impact practices and yields. Moreover, in Europe, climate change leads to more frequent extreme weather conditions during crop growth (Bindi & Olesen, 2011). Farmers have not only to deal with hazardous climatic conditions leading to yield variability but also to input price volatility (Ott, 2012). In addition, Global markets and crops yield variability at a global level have a significant impact on commodity price instability.
Since 20 years, many methods and indicators have been proposed to assess farming and cropping systems and their economic, social and environmental performance (Stockle *et al*., 1994; Bockstaller *et al*., 2009; Castoldi & Bechini, 2010). However, the evaluation of economic robustness has only been recently acknowledged in scientific literature (Urruty, 2015; Massot *et al.*, 2016).
In this paper, we propose to define robustness as the frequency of satisfying economic performance (*i.e.* above break-even point) in a defined time span. A general and famous law indicates that diversification (of activities and, in particular, of species) increases farming system robustness (Hodbod *et al*., 2016). Moreover, according to Zimmer (2012) a reduction of labor and machinery costs can increase farming systems' robustness. How can one increase cropping systems' robustness? Researchers, advisors and farmers develop participatory approaches to design innovative cropping systems able to deal with various objectives and specific constraints (Reau *et al.*, 2012). Before testing the designed cropping systems on the farm, they need to assess their performance *ex ante* and to identify their weaknesses in order to ameliorate them though several test loops (Bergez *et al*., 2010). We tested an indicator for *ex ante* assessment of the economic robustness of cropping systems and to evaluate its capacity to discriminate different cropping systems according to their robustness towards weather conditions and price variability. Annual gross margin of the whole cropping system has been chosen as the economic performance indicator and calculated under nine different weather scenarios and eight commodity and inputs (energy and fertilizers) price scenarios according to those identified by Massot *et al.* (2016). As the frequency of each price scenario is not defined yet, the cropping system robustness has been assessed for each price scenario through "r" defined as the frequency of gross margin above the farm specific break-even point within the weather scenarios, and "R" defined as the number of prices scenarios that allowed "r" to get or overtake eight out of ten. A cropping system has been considered robust if "R" got or overtook six out of eight.

Materiel and methods
The method has been tested preliminary on two cropping systems of the same farm: an on-going cropping system and an alternative system co-designed with the farmer to be more robust thanks to larger crop diversity and a lower dependence on fertilizers and pesticides. Nine weather scenarios, based on the weather conditions in the Oise region from 2005 to 2014 were used to simulate yields on different rotations with the STICS crop model (Brisson *et al*., 2002). Soil types were described according to the regional typology (Ansel *et al*.,1997). In order to rub out weather conditions and crop interactions, we considered that all the crops of the rotation were cultivated every year. The method will be further applied on other on-going and alternative co-designed cropping systems of different Oise region farms. $Yield_{ij}$ was simulated with STICS under weather conditions scenario j, in the cropping system soil, crop position in the rotation and crop management. To adjust simulated yields as much as possible to the real encountered yields, when references were available at farm level or, at least, regional level, the ratio "reference yield / average simulated yield" was applied as a corrective factor. When a

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

new crop was introduced or if simulated yields appeared aberrant, the annual average yield in the region was applied. Eight price scenarios have been described by the French Network on Innovative cropping systems (http://www6.inra.fr/systemesdecultureinnovants/) according to the observed fluctuations of commodity, energy and fertilizer prices from January 2007 to July 2014 (Massot *et al.*, 2016). Some crops such as fiber flax, winter barley or seed growing (clover) being absent of the price scenarios, their prices were thus considered as constant.
Variable costs were calculated based on crop management whereas nitrogen fertilizer was determined through an official decision-making tool under the weather conditions scenario j, according to soil type and cropping system (Fig. 1). As pests pressure remains impossible to forecast, pesticides costs were considered not to be dependent on weather conditions. They were calculated based on the treatment frequency index (TFI) and coefficients from the Stephy tool (Attoumani-Ronceux *et al.*, 2011). In the alternative cropping system, the quantities were reduced according to new means selected at designing step to reduce pesticides use (Attoumani *et al.,* 2011).

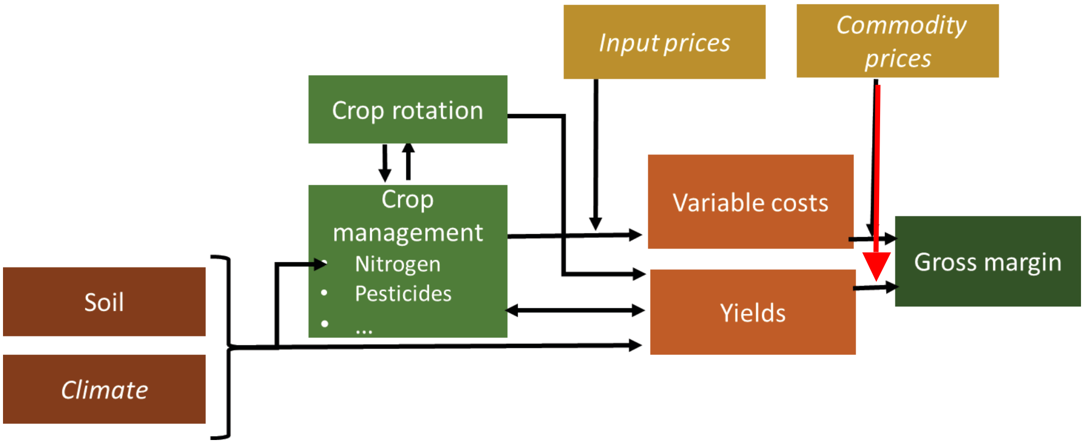


Fig.1: Cropping system gross margin factors as considered in this study. In italics variable factors

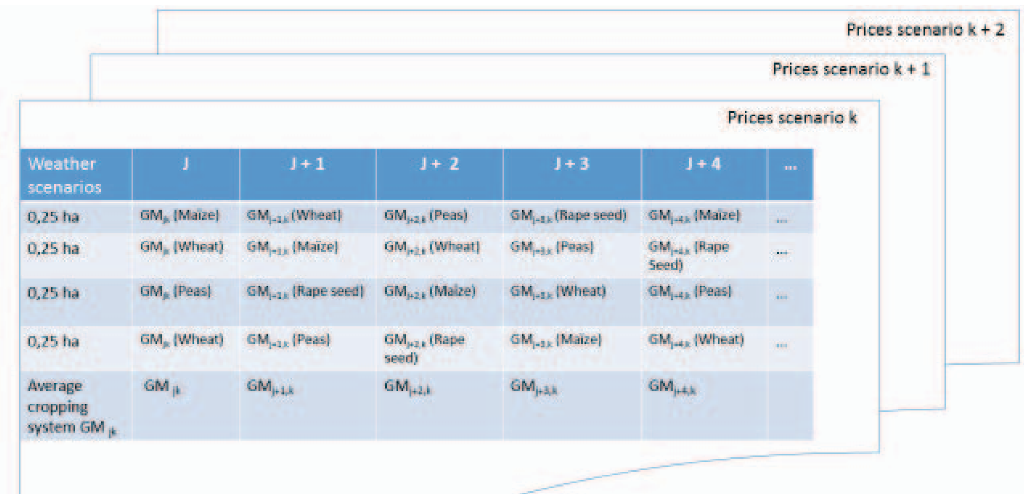
Gross Margin €/ha of crop i under weather conditions scenario j and price scenario k is calculated as (Fig. 2)

$$\text{Gross Margin}_{ijk}\ /\text{ha} = (\textit{commodity price}_k * \textit{yield}_{ij}) + \textit{CAP subsidies}_i\ /\textit{ha} - \textit{variable costs}_{ijk}\ /\textit{ha}$$

Gross Margin$_{jk}$ €/ha of the croping system under weather conditions scenario j and price scenario k is calculated as

$$\text{Gross Margin}_{jk}\ /\text{ha} = \Sigma\ (\textit{commodity price}_k * \textit{yield}_{ij} * k_i) + \textit{CAP subsidies/ha} - \textit{variable costs}_{ij}\ /\textit{ha}$$

where k_i represents the frequency of crop i in rotation.



Weather scenarios	J	J + 1	J + 2	J + 3	J + 4	...
0,25 ha	GM_{jk} (Maize)	$GM_{j+1,k}$ (Wheat)	$GM_{j+2,k}$ (Peas)	$GM_{j+3,k}$ (Rape seed)	$GM_{j+4,k}$ (Maize)	...
0,25 ha	GM_{jk} (Wheat)	$GM_{j+1,k}$ (Maize)	$GM_{j+2,k}$ (Wheat)	$GM_{j+3,k}$ (Peas)	$GM_{j+4,k}$ (Rape Seed)	...
0,25 ha	GM_{jk} (Peas)	$GM_{j+1,k}$ (Rape seed)	$GM_{j+2,k}$ (Maize)	$GM_{j+3,k}$ (Wheat)	$GM_{j+4,k}$ (Peas)	...
0,25 ha	GM_{jk} (Wheat)	$GM_{j+1,k}$ (Peas)	$GM_{j+2,k}$ (Rape seed)	$GM_{j+3,k}$ (Maize)	$GM_{j+4,k}$ (Wheat)	...
Average cropping system GM_{jk}	GM_{jk}	$GM_{j+1,k}$	$GM_{j+2,k}$	$GM_{j+3,k}$	$GM_{j+4,k}$	

Fig. 2: Annual average gross margin (GM) calculation of a four years rotation under different weather condition scenarios and different price scenarios (example of the ongoing cropping system)

As frequency of each price scenario is not defined yet, each cropping system gross margin /ha variability had to be described separately for each price scenario *i.e.* within nine weather condition scenarios, as statistical studies are not yet possible except variation coefficient.

Results and Discussion

In the ongoing cropping system, Fig. 3 shows that two price scenarios (7 and 8), did not allow to reach the break-even point in any weather condition, even with CAP subsidies. At the opposite, under four prices scenarios (1, 3, 4, 5), gross margin reached robustness level (78 %) and even for two of them, in any weather condition (scenarios 3 and 4). The frequency "r"

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA. Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

of situations where gross margin overtakes this break-even point, for each prices scenario, with CAP subsidies appeared higher in any prices scenario for co-designed alternative cropping system.
Tab. 1 confirmed this conclusion and compares robustness of the two systems with and without CAP subsidies. Co-designed alternative cropping system appeared more robust but still dependent on CAP subsidies.

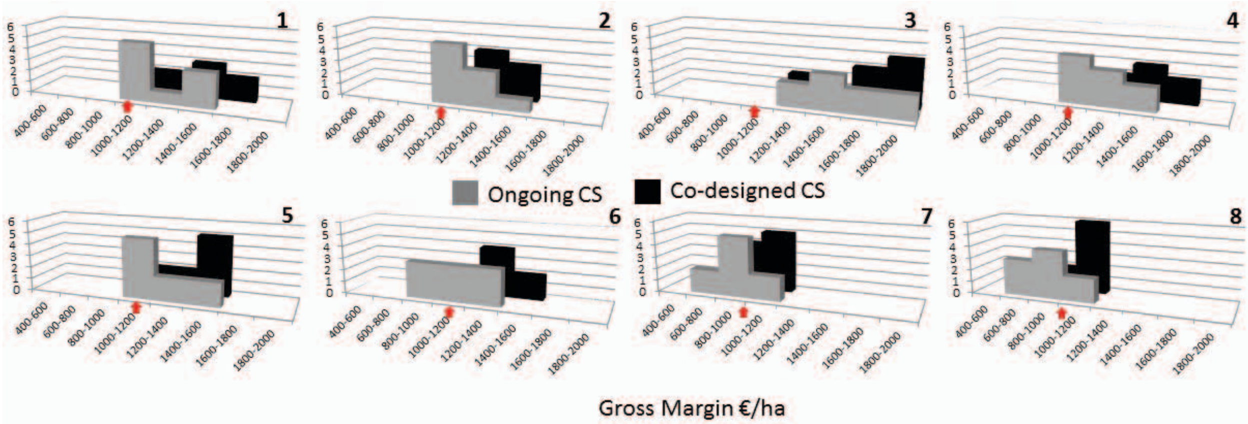


Fig. 3: For every price scenario, the distribution of cropping system (CS) annual gross margin under the nine weather scenarios (with CAP subsidies). In grey: ongoing cropping system (Peas / Rape seed/ Winter wheat/ Maize), under a conventional crop management), in black: co-designed alternative cropping system (Peas/ Rape seed/ Wheat/ Maize/ Faba bean/ Rape seed/ Winter wheat, under a conventional crop management). Red arrow indicates the break-even point (in this case: 1116 €/ ha). For each prices scenario, "r" indicator is the frequency of situations where gross margin overtakes this point.

	With CAP subsidies		Without CAP subsidies	
Price scenario	**Ongoing CS**	**Co-designed CS**	**Ongoing CS**	**Co-designed CS**
1	78%	100%	22%	56%
2	56%	78%	0%	22%
3	100%	100%	44%	78%
4	100%	100%	22%	56%
5	78%	78%	11%	22%
6	33%	78%	0%	0%
7	0%	22%	0%	0%
8	0%	44%	0%	0%
Robustness "R"	**4/8**	**7/8**	**0/8**	**1/8**

Tab.1: Frequency of situations where gross margin overtakes the break event point "r", for each prices scenario, with and without CAP subsidies CS means cropping system.

The high variation coefficient of rape seed yield (1.07), as well as the high variation coefficient of rape seed and maize prices (0.74) may be weak points of the ongoing (and alternative) cropping system. But the sequence of two winter crops and two spring crops contributes to contain weed pressure and pesticide costs as long as rape seed takes more advantages of nitrogen residues mineralization from peas than from wheat. Trying to identify the crop(s) responsible for a low robustness would be tantamount to calculating advantages and disadvantages of each crop ignoring interactions within the cropping system. Even though the assessment method does not take into account all those interactions, improving the system in prototyping process is more based on simulations than on a deep diagnosis.
More situations have to be tested to validate these first conclusions.
Agronomists usually consider that twenty years are necessary to represent weather variability while this study is based only on nine scenarios. Nevertheless, climate scientists say that, as climate changes faster, the last ten years would better (in fact, less badly) forecast weather conditions variability for the next 10 years.
Several reasons may reduce the gross margin variability and possibly lead to overestimate robustness such as the panel of weather conditions (*i.e* would taking into account 2016 conditions have substantially changed results?), the use of an annual average yield in cases of new crops or aberrant simulated yields , or a corrective factor below one (when simulation seemed to overestimate yields for example for wheat and rape seed). As new crops may be introduced in alternative cropping systems, their robustness has been more overestimated as long as the gap between ongoing and alternative systems.
To avoid yields simulations based on uncertain data mandatory for STICS, other tools such as Persyst could be tested to forecast yield variability according to weather variability and rotation and crop management (Guichard, 2010)

DOI 10.6092/unibo/amsacta/5692

The used nitrogen decision making tool is devoted to determine *ex ante* nitrogen amount to reach the aimed yield, not *ex post* amount according to obtained yield. Yet, potential yield at the moment of decision is supposed to be higher or equal to obtained yield which may be maintained or reduced according to the growth conditions after the choice of the nitrogen amount. So nitrogen costs may have been underestimated as well as their variability.
Neglecting pest pressure could lead to overestimate yields. Besides, neglecting pest pressure or using average farm or region references yields and pesticides costs leads to underestimate their variability and, thus, gross margin variability. Consequently, robustness may be underestimated or overestimated according to the over or underestimation of average gross margin. Last, using two thresholds (for "r" and "R") may lead to consider as robust a cropping whose gross margin overtakes break-even point 7*6 times among 9*8 that is to say in only 58 % of the situations.
When the frequency of price scenarios will be evaluated, it will be possible to describe each cropping system's gross margin per hectare variability and robustness with statistical indicators, to compare more precisely different cropping systems' robustness and to fix a more demanding threshold for robustness.

Conclusions

The method for *ex ante* assessment of cropping system's economic robustness through the indicator "R" appeared feasible. With the exception of yield simulation that requires time, special competencies and precise weather conditions data, evaluation of nitrogen amount, pesticides use, variable costs and annual gross margin need data usually available in farm (TFI, nitrogen balance input data, seeding rates) and can be achieved through former or specific calculation tools.
For two cropping systems, ongoing and alternative, the method has permitted to assess cropping systems' gross margin variability indicator according to weather conditions and prices even if probably underestimated. The indicator has shown its capacity to discriminate different cropping systems according to their robustness towards weather conditions and price variability. The different tools allow the calculation to be highly traceable, enable a diagnosis of weak points and facilitate the simulation of changes.

References

O. Ansel, V. Epinat, O. Scheurer, 1997. Guide agronomique des sols du département de l'Oise. ISAB/Conseil général de l'Oise/Chambre d'Agriculture de l'Oise. Retrieved the 5th of April 2016 at http://www.chambres-agriculture-picardie.fr/menus-horizontaux/oise/la-chambre-dagriculture-de-loise/outils-pratiques/guide-des-sols.html
A. Attoumani-Ronceux, J.N. Aubertot, L. Guichard, L. Jouy, P. Mischler, B. Omon, M.S. Petit, E. Pleyber, R. Reau, A. Seiler, 2011. Guide pour la conception de systèmes de culture plus économes en produits phytosanitaires - application aux systèmes de polyculture. Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'aménagement du territoire.
M. Bindi, J.E. Olesen, 2011. The responses of agriculture in Europe to climate change. Regional Environmental Change, 11 (1): 151-158.
C. Bockstaller, L. Guichard, O. Keichinger, P. Girardin, M.B. Galan, G. Gaillard, 2009. Comparison of methods to assess the sustainability of agricultural systems: a review. In Sustainable Agriculture (pp. 769-784). Springer Netherlands.
N. Brisson, F. Ruget, P. Gate, J. Lorgeou, B. Nicoullaud, X.Tayot, B. Mary, 2002. STICS: a generic model for simulating crops and their water and nitrogen balances. II. Model validation for wheat and maize. Agronomie, 22(1): 69-92.
N. Castoldi, L. Bechini, 2010. Integrated sustainability assessment of cropping systems with agro-ecological and economic indicators in northern Italy. European journal of agronomy 32 (1): 59-72.
S. Di Falco, J.P. CHAVAS, 2008. Rainfall shocks, resilience, and the effects of crop diversity on agroecosystem productivity. Land Economy 84: 83–96.
J. Hodbod, O. Barreteau, C. Allen, D. Magda, 2016. Managing adaptively for multifunctionality in agricultural systems. Journal of Environmental Management 183 (2): 379-388.
K. Matsushita, F. Yamane, K. Asano, 2016. Linkage between crop diversity and agro-ecosystem resilience: Nonmonotonic agricultural response under alternate regimes. Ecological Economics 126: 23-31.
R. Reau, L.A. Monnot, A. Schaub, N. Munier-Jolain, I. Pambou, C. Bockstaller, M. Cariolle, A. Chabert, P. Dumans, 2012. Les ateliers de conception de systèmes de culture pour construire, évaluer et identifier des prototypes prometteurs. Innovations Agronomiques 20: 5-33.
N. Urruty, C. Huyghe, D. Tailliez-Lefebvre, P. Gate, 2015. Characterization and quantification of robustness for designing more sustainable and robust wheat productions. Poster presented at 5th International Symposium for Farming Systems Design 7-10 September 2015, Montpellier, France.
L. Guichard, C. Bockstaller, C. Loyce, D. Makowski, 2010. PERSYST, a cropping system model based on local expert knowledge. In: Proceedings of 'Agro2010 the XIth ESA congress, Wery, J, Shili-Touzi I, Perrin A (Eds.), Agropolis international Editions, Montpellier, France, 827-828
C.O. Stockle, R.I. Papendick, K.E. Saxton, G.S. Campbell, F.K. Van Evert, 1994. A framework for evaluating the sustainability of agricultural production systems. American Journal of Alternative Agriculture, 9(1-2): 45-50.
Y. Zimmer, 2012. Production Cost in the EU and in Third Countries: past Trends, Structures and Levels. Workshop on the Outlook for EU Agriculture by COPA, COGECA, European Crop Protection & Fertilizers Europe Brussels, June 27th.

SPATIAL YIELD GAP ANALYSIS ON SPRING BARLEY IN SCOTLAND

ANALISI SPAZIALE DI YIELD GAP SU ORZO PRIMAVERILE IN SCOZIA

Davide Cammarano[1*]

[1] James Hutton Institute, Invergowrie, Scotland, DD25BQ
*davide.cammarano@hutton.ac.uk

Abstract
The objective of this study was to conduct a spatial analysis of yield gap on spring barley, over the growing areas of Scotland, trying to identify the main reasons for the small changes of National yield in the last 30 years. To identify the barley growing areas the Land Capability Map for Agriculture was used and overlayed with the Scottish Soils Knowledge and Information Base in order to extract only the relevant soil types. Gridded daily weather data were used to simulate daily growth and development using a crop simulation model. Overall, the results of this study showed that while in the West it is not possible to increase actual yields due to climate conditions, in the Eastern part of the country there are opportunities to increase yields. This can be achieved through better agronomic practices such as changing planting density, planting dates, and precision fertilizer management in order to close the gap with the yield potential.

Keywords: crop simulation model; yield gap; spring barley; spatial yield variability.
Parole chiave: modelli di simulazione; yield gap; orzo primaverile; variabilita' spaziale della produzione.

Introduction
Given the global projections of population increase and global food demand, by 2050 agriculture is faced with the dilemma of producing more food on the same (or even less) cultivated areas, without polluting the environment but without reducing the farmers' income. (Godfray et al., 2010; Foley et al., 2011). In most cases it would be possible to increase current yields, even in the near-term, because some of the world's regions have greater potential to produce more food (van Ittersum et al., 2013). Yield is the product of many spatial and temporal interactions and taking all of them into account it would hard. But, among the most important factors causing conditions of non-optimal yield levels are agronomic management, and water. Van Ittersum et al. (2013) concluded that the reasons for conducting a spatial yield gap analysis were because the analysis will: a) help to identify the most important factor between climate, crop, soil, and management that affects the gap; b) help to indentify the best management practice that would optimize yield and minimize the environmental impact; c) be used to link it with economic models that assess food security at global scale. In Scotland, spring barley (*Hordeum vulgare, spp*) it is one of the most important crops, due to the significant impact to the Scottish economy, especially for the whisky and the animal industries (RESAS, 2016). However, when looking back at the national average yields for the last 30 years there was not much change, and the average reported yield of about 5500 kg ha^{-1} showed little change since the late 1970s (Ellis and Kirby, 1980).
Therefore, in this study we conduct a spatial analysis of yield gap on spring barley over the growing areas of Scotland trying to identify what are the main reasons for these small changes.

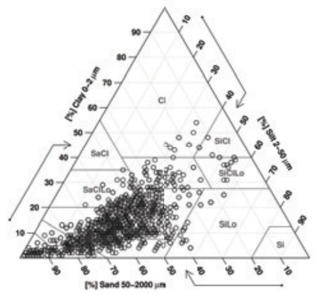


Figure 1: Soil texture triangle of the individual 333 soil types at each individual depth. The triangle is based on the USDA soil classification (Soil Survey Staff, 2015).
Figura 1: Tessitura dei 333 suoli utilizzati nello studio sovrapposti al triangolo di tessitura basato sulla classificazione USDA.

Materials and Methods
The whole growing area of spring barley was selected using the Land Capability Map for Agriculture (Soil Survey of Scotland Staff, 1981). Gridded weather data were obtained from the United Kingdom Meteorological Office, using hte UKCP09: Gridded observation dataset (UK Met Office, 2017) while solar radiation was purchased from SolarGIS (solargis.com). The soil data were obtained from the Scottish Soils Knowledge and Information Base (SSKIB) comprising of more than 1,000 soils for the whole Scotland. The soils that occur in the barley growing areas were 333, and these soils were described, for each soil depth to a maximum of 100 cm, in terms of texture (Fig. 1), organic carbon, bulk density, and hydraulic properties. The Decision Support System for Agrotechnology Transfer (DSSAT) v 4.6 (Hoogenboom et al., 2010) was utilized for modelling spring barley growth across Scotland (hereafter indicated as CM). The CM was calibrated for matching phenology (anthesis and maturity), and grain yield using variety trials information (HGCA, 2006). The variety trials were made at different 2 locations and three data points were available per location. The evaluation of the model was done using observed yield data from the James Hutton Institute Balruderry and Dundee experimental farms, and from published results of agronomic trials on Orkney Island (Chappell, et al., 2017). In addition, data from the Scottish Government National Statistics (RESAS, 2016)

that report harvested barley yield at National level were used to further evaluate the CM. An on-going effort was set up to include in the evaluation dataset data from farms' following a North-South transect. More than 100 farms were identified, and the process of gathering data and include them in the evaluation is still on the way.

The crop model was run in potential conditions (***Yp***) where the crops did not experience nitrogen (N) and water (W) stress following the Wageningen production concepts for optimal production system (Van Ittersum et al., 2013). Next, the model was run by allowing W dynamics to be simulated but with no N stresses (N sub-routine off) (***Yw***), and the model run with both W and N sub-routines turned on (***Ya***).

Results and Discussion

The difference between simulated *Yp* and *Ya* showed values ranging between 3000 and 9600 kg ha^{-1} with higher values along the coasts and lower values in inner areas (Fig. 2). The differences between *Yp* and *Yw* showed lower gaps respect to the yield potential, with higher gaps in some inner areas of the West. The difference between *Yw* and *Ya* ranged between 700 and 3500 kg ha^{-1} with the highest values on both East and West coast. The combined results of the difference maps and daily simulation data analyzed across selected areas (data not shown) showed that water was the main issue causing the gaps observed on the West and on the East coasts. The former, was expected because the West was generally wetter than the East and waterlogging was often experienced by the crop (which was simulated by the CM). The latter, was mostly due to periods of low rainfall and therefore water stress build-up; a condition that was common among farmers on the East (Squire G., personal communication). Overall, the potential production situation (although simulated with no stress) represented the areas where some of the high yielding farms were located. On the West, the drainage practices might not be enough to increase *Ya* given that the annual amount of rainfall exceed the 1000 mm and currently the Government is not planning to economically support drainage techniques. On the East, through better agronomic practices there is a way to increase *Ya*. Studies are under way to evaluate the impact of changing planting density, planting dates, precision fertilizer management that can help close the gap with the *Yp*.

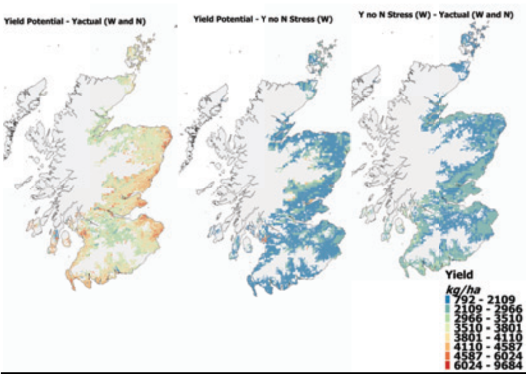


*Figure 2. Spatial distribution of the differences between (**a**) yield potential and actual yield; (**b**) yield potential and the yield simulated with nitrogen (N) routine switched off; (**c**) yield with no N stress and actual yield.*

Figura 2: Distribuzione spaziale della differenza di produzione tra: (a) produzione potenziale e quella attuale; (b) quella potenziale e quella simulata spegnendo la sub-routine dell'N; (c) tra quella senza stress azotati e quella attuale.

Acknowledgments

This work was funded by the Rural & Environment Science & Analytical Services Division of the Scottish Government. The author thanks the UK Meteorological Office for the weather data.

References

Agricultural and Horticultural Development Board: AHDB, former HGCA, 2006. The Barley growth guide. HGCA project 2514, Project Report 38, pp 1-28.

Chappell, A., Scott, K.P., Griffiths, I.A., Cowan, A.A., Hawes, C., Wishart, J., Martin, P., 2017. The agronomic performance and nutritional content of oat and barley varieties in a northern maritime environemnt depends on variety and growing conditions. Journal of Cereal Science, 1–10.

Ellis, R.P., Kirby, J.M., 1980. A comparison of spring braley grown in England and Scotland: 2. Yield and its components. Journal of Agricultural Science, 95, 111–115.

Foley, J., et al., 2011. Solutions for a cultivated planet. Nature 478, 337–342.

Goodfray, C., et al., 2010. Food security: the challenge of feeding 9 billion people. Science 327, 812–818.

Hoogenboom, G., Jones, J.W., Wilkens, et al., 2010. Decision Support System for Agrotechnology Transfer (DSSAT), Version 4.5 (CD-ROM). University of Hawaii, Honolulu, HI.

van Ittersum, M.K., Cassman, K.G., Grassini, P., Wolf, J., Tittonell, P., Hocman, Z., 2013. Yield gap analysis with local to global relevance – A review. Field crop research, 143, 4–17.

RESAS: Rural and Environment Science and Analytical Services division, 2016. The Economic Report on Scottish Agriculture (ERSA), available online at: http://www.gov.scot/Resource/0050/00501417.pdf (verified Jan 2017).

Soil Survey of Scotland Staff, 1981. Land Capability for Agriculture maps of Scotland at a scale of 1:250 000. Macaulay Institute for Soil Research, Aberdeen.

United Kingdom Meteorological Office, 2017. UKCP09 Gridded observation data sets http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/ (verified Jan 2017).

CROPPING SYSTEMS FOR CULTIVATION OF VERY EARLY MATURITY MAIZE HYBRIDS

PERCORSI AGRONOMICI PER LA COLTIVAZIONE DEI MAIS PRECOCISSIMI

Massimo Blandino*, Giulio Testa, Diego Gallinotti, Amedeo Reyneri

Dipartimento di Scienze Agrarie, Forestali e Alimentari, Università di Torino, Largo Braccini 2, 10095, Grugliasco (TO)
*massimo.blandino@unito.it

Abstract

A new generation of very early maturity hybrids (FAO class 200) was recently introduced in Italy. These new maize hybrids are characterized by several crop features that could radically modify their role in the cropping system due to a reinforced early vigor, a greater plant development and size, a higher grain production, a good grain quality. This research analyzes for early and late planting time different crop density by the application of two inter-row on productive and quality parameters and compare this results with a full season maturing hybrid cropped under more convention practice. As main crop, the very early hybrids were harvested 1 month before the full season maturing ones. The results pointed out a positive increasing of yield up to 10.5 plants m^{-2} for the wider inter-row spacing, and until 12.0 or 10.5 plants m^{-2} for the narrow as main or inter-crop respectively. Despite yield potentiality is clearly raised reaching 14 t ha^{-1}, full cycle hybrid resulted in an higher yield up to 26%; this productive deficit does not eliminate completely the yield gap involving the very early hybrids. Thus, very early maize hybrids remain profitable for grain production as main crop in supply food chain agreements that valorize their higher sanitary and technological quality or when environmental constrains are awaited.

Keywords: maturity class, sowing time, plant population, yield, grain quality.
Parole chiave: precocità di maturazione; epoca di semina; densità colturale, produttività, qualità.

Introduction

Recently in the Italian growing maize area (Po plain) a new generation of very early maturity hybrids (FAO Class 200, < 85 days from plant emergence to physiological maturity) were introduced. Traditionally hybrids classified as ultra-early maturity (FAO 100), very early maturity (FAO 200) and early maturity (FAO 300) have been utilized mainly for delayed planting after a winter cereal as barley or wheat in the irrigated areas. Nevertheless, under dry conditions, as the main crop, early maturing hybrids were also cultivated in the more stressed areas for spring planting time. Until the last years, as a consequence of the short crop cycle and of the more severe constrains of the crop practice, the expected grain yield of the early maturing hybrids were generally much lower compared to the medium (FAO 4-500) or late (FAO 6-700) maturing hybrids. More recently a generation of new very early hybrids, were introduced: compared to the previous generation, these genotypes are characterized by several crop features that could radically modify their role in the crop system. In particular these hybrids show a reinforced early vigor, a greater plant development and size, a higher grain production, a good grain quality (semi-vitreous kernel, for food purpose) and a lower attitude to mycotoxin severe contamination.

These features stress to explore the opportunity to introduce these hybrids not only in the more stressed areas or for delayed planting times, but also in more favorable conditions, considering the prospect to reduce variable cost of irrigation and nitrogen fertilization, protection (insecticide application) and post-harvest drying (Lindsey et al., 2015). However, also considering the potential economic advantages linked to the reduction of the variable cost, the yield gap compared to full season hybrids is still the limiting factor for the diffusion of very early maturing hybrids. Nevertheless, the favorable plant architecture and the kernel ripeness collocation in the middle of the summer suggest the possibility of increasing plant density in order to enhance the radiation intercepted by the canopy and grain yield (Li et al., 2015; Testa et al., 2016).

The aim of this research has been to analyze different crop density by the application of two inter-row spacings on different productive and quality parameters and to compare these results with a more traditional medium or late maturing hybrid cropped under more standard practice.

Materials and Methods

Field trials were conducted in the 2015 and 2016 growing seasons at Chivasso and Carignano (TO), in the North West of Italy, characterized by a sandy-loam soil and medium content of organic matter.

The experiment was carried out on very early maturity hybrids (FAO maturity group 200, 85 days of relative maturity): KWS Ronaldinio (2015 experiment) and KWS Kasimens (2016 esperiment).

In each year and location the compared treatments were a factorial combination of:

- 2 cropping systems that differ for planting time: maize as main crop, planted in early spring; maize as inter-crop, planted after barley harvest;

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

- 2 inter-row spacings:- 0.75 m wide, standard inter-row spacing, representing the reference spacing for the maize crop system;- 0.5 m wide, narrow inter-row spacing
- 4 planting densities:- 9, 10.5, 12 and 13.5 plants m^{-2}.

The treatments were assigned to experimental plots using a completely randomized block design, with four replications. The plot size was 10 x 3 m, and each plot consisted of 8 rows. The plot alleys, orthogonal to the maize rows, were one meter wide. In each location and year the very early maturity hybrid was compared also to a reference condition, carried out in farm field cultivated with a full season maize hybrids (FAO maturity group 500, 125 days of relative maturity) with a plant density of 8 plants m^{-2}.

Conventional agronomic techniques were adopted for the field experiments in both growing seasons. Briefly, the previous crop was maize, and mechanical sowing was carried out after an autumn ploughing (30 cm) and disk harrowing to prepare a suitable seedbed. All the plots received the same amount of nutrients: 250, 100 and 100 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Irrigation was carried out by means of the furrow surface method in order to prevent drought stress until the end of the dough stage (GS 87). All the plots were sprayed at GS 75 with pyrethroid lambda-cyhalothrin insecticide (Karate® Zeon, Syngenta Crop Protection S.p.A., Milan, Italy) at 0.019 kg AI ha^{-1} using a self-propelled ground sprayer (Eurofalcon E140®, Finotto, Italy). The treatment was performed, according to the growth stage, in the middle of July for the early sowing date and in the first decade of August for the late sowing date, in order to minimize the ear injuries caused by the activity of the European Corn Borer (ECB – Ostrinia nubilalis, Hübner). The sowing, harvest and the flowering dates for each growing season and site are reported in Table 1.

The following morphological features were recorded: plant height, stalk area at the first internode, leaf area index (LAI). Ears were collected by hand from 6 m^2 (2 rows x 4 m) of each plot at harvest maturity in order to quantify the grain yield (adjusted to a 14% moisture content). The ears were shelled using an electric sheller, and kernels from each plot were mixed thoroughly to obtain a random distribution. The normal distribution and homogeneity of variances were verified by performing the Kolmogorov–Smirnov normality and Levene test. The analysis of variance (ANOVA) was run, using a completely randomized split plot design in order to analyze the effect of combination of plant density and the inter-row spacing separately for the considered cropping system (main crop, inter-crop), by considering the experiment (combination of site and year) as a random factor. When necessary, post-hoc multiple comparison tests were performed, according to the Ryan-Einot-Gabriel-Welsh F (REGWF) test.

Tab. 1: Main information of experimental trials
Tab. 1:Principali informazioni agronomiche delle prove sperimentali

Year	**Site**	**Maturity class (FAO)**	**Cropping system**	**Dates** planting	flowering	harvest
2015	Chivasso	500	Main crop	03 April 2015	30 June 2015	07 September 2015
		200	Main crop	03 April 2015	16 June 2015	11 August 2015
		200	Intercrop	19 June 2015	01 August 2015	14 October 2015
	Carignano	500	Main crop	02 April 2015	01 July 2015	10 September 2015
		200	Main crop	02 April 2015	19 June 2015	13 August 2015
		200	Intercrop	17 June 2015	03 August 2015	26 October 2015
2016	Chivasso	500	Main crop	07 April 2016	06 July 2016	14 September 2016
		200	Main crop	07 April 2016	24 June 2016	31 August 2016
		200	Intercrop	13 June 2016	04 August 2017	19 October 2016
	Carignano	500	Main crop	31 March 2016	07 July 2016	22 September 2016
		200	Main crop	31 March 2016	22 June 2016	24 August 2016
		200	Intercrop	15 June 2016	05 August 2016	18 October 2016

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Results and Discussion

In both growing seasons planting took place within the first decade of April as main crop and the middle of June as intercrop, according to a possible sowing following a barley harvest.

The two growing seasons differed in terms of rainfall and temperature, mainly during summer period. Lower temperature were recorded in 2016 resulting in a slowdown of ripening and a delayed of the harvest of the very early maturing hybrids, while for the full maturing hybrids the harvest time was rather similar (Table 1). As main crop, the very early hybrid has anticipated the harvest of about 1 month, compared to the full season one,

The interactions among treatments (combination of plant density and inter-row spacing) x location and treatments x year were never significant: thus the data shows the average of the 2 locations and the 2 years.

The effect of cropping system, planting density and inter-row on the plant morphological traits is summarized in table 2. Plant height was never influenced by the planting techniques, while the stalk area for the main crop stand was negatively influenced by the enhancement of the crop density and by the wider inter-row (75 cm) compared to the narrow one (50 cm). The plant leaf area was significantly reduced by the increase of the crop density, in both the cropping systems; despite this reduction, the canopy LAI was linearly increased by the crop density from 3.8 to 5.2 considering the extreme condition of 9.0 and 13.5 plants m^{-2}.

Tab. 2: Effect of plant density and inter-row spacing on morphological traits of very early maturity maize hybrid under different cropping system.

Tab. 2: Effetto della densità colturale e del sesto di impianto sui parametri morfologici di ibridi di mais precocissimi nell'ambito di sistemi colturali con differente epoca di semina.

Cropping System	Inter-row	Plant density (plant m^{-2})	Plant height (cm)	Stalk area (cm^2)	Leaf area (cm^2 $plant^{-1}$)	LAI
Main crop	75 cm	9	233 a	3.0 bc	4138 a	3.7 E
		10.5	233 a	2.7 d	3993 ab	4.2 D
		12	232 a	2.5 e	3839 b	4.6 C
		13.5	234 a	2.4 e	3816 b	5.2 A
	50 cm	9	230 a	3.3 a	4185 a	3.8 E
		10.5	232 a	3.1 b	4113 a	4.3 D
		12	235 a	2.8 cd	4088 a	4.9 B
		13.5	234 a	2.7 de	3823 b	5.1 A
Intercrop	75 cm	9	218 a	2.8 ab	3888 ab	3.5 D
		10.5	220 a	2.6 bcd	3752 abcd	3.9 C
		12	223 a	2.5 cd	3616 bcd	4.3 B
		13.5	221 a	2.4 d	3520 d	4.8 A
	50 cm	9	222 a	2.9 a	3943 a	3.5 D
		10.5	227 a	2.9 a	3809 abc	4.0 C
		12	221 a	2.7 bc	3692 abcd	4.4 B
		13.5	223 a	2.4 d	3566 cd	4.8 A

Within each cropping system, means followed by different letters are significantly different ($p<0.05$)

Enhancing crop population increased ear density for both the inter-row spacings, although under the highest densities an increased number of barren plants (plant without fertile ears) was recorded (Table 3). Although the negative effect of crop population on the plant fertility, the kernel density (kernels m^{-2}) was always linearly increased by the enhancement of the crop density, although in intercrop condition the thousand kernel weight (TKW) was negatively influenced by the more dense stands (Table 3).

Tab. 3: Effect of plant density and inter-row spacing on yield component of very early maturity maize hybrid under different cropping system.
Tab. 3: Effetto della densità colturale e del sesto di impianto sui componenti della resa di ibridi di mais precocissimi nell'ambito di sistemi colturali con differente epoca di semina.

Cropping System	Inter-row	Plant density ($n\ m^{-2}$)	Ear density ($n\ m^{-2}$)	Barren plant (%)	Kernel ($n°\ m^{-2}$)	TKW (g)
Main crop	75 cm	9	9.0 d	1.3 c	3465 d	332 a
		10.5	10.6 c	1.6 c	3919 bcd	332 a
		12	11.4 b	3.6 bc	4078 ab	325 a
		13.5	11.8 b	9.3 a	4050 ab	323 a
	50 cm	9	9.1 d	1.7 c	3553 d	336 a
		10.5	10.6 c	1.4 c	4003 abc	336 a
		12	12.0 b	1.6 c	4297 ab	326 a
		13.5	12.5 a	6.5 ab	4461 a	325 a
Intercrop	75 cm	9	8.8 d	2.3 d	2882 d	316 abc
		10.5	10.0 c	7.0 bc	3033 cd	309 bcd
		12	10.5 c	9.9 ab	3027 cd	302 cd
		13.5	11.1 b	11.7 a	3208 bc	294 d
	50 cm	9	8.9 d	2.6 d	2947 cd	328 a
		10.5	10.1 c	2.6 d	3232 bc	320 ab
		12	11.2 b	5.6 cd	3468 ab	298 d
		13.5	12.2 a	6.8 bc	3605 a	297 d

Within each cropping system, means followed by different letters are significantly different ($p<0.05$)

Cropping system, planting density and inter-row spacing have influenced grain yield and moisture (Table 4). On average, the cultivation of very early maturity hybrid as main crop has increased yield by the 48% compared to the intercrop. On the other hand, the narrow inter-row (0.50 cm of inter-row) has positively influenced the production, showing a 7% grain yield for both the cropping systems. However the influence of the crop density was different within the applied inter-row spacing: significant increasing of yield was recorded until 10.5 plants m^{-2} for the wider inter-row spacing (75 cm) and until 12.0 plants m^{-2} for the narrow one (50 cm). The yield advantage of narrow inter-row spacing is mainly linked to the lower incidence of barren plants achievable at high plant density with the application of this pattern compared to the conventional one. Grain moisture was only clearly influenced by crop density in the late planting time (maize as intercrop).
Full cycle hybrid that was grown as comparison for the main cropping system has yielded 16.1 t ha^{-1} with an increase of 26% for the best crop density for the wider inter-row and of 15% with the narrow inter-row.

Conclusions

With the introduction of a new generation of very early maturity hybrids (FAO Class 200) yield potentiality is clearly raised under irrigated conditions reaching 14 t ha^{-1}. These productions were obtained only when seeding took place in the beginning of the spring adopting a very high crop density with a narrow inter-row spacing to reduce canopy self-shading. In this condition anthesis occurs in the second decade of June corresponding to the most intensive radiation and the plant photosynthesis is at the highest rate. Very early hybrids under late seeding conditions as intercrop, has proved to effectively reduce yield compared to spring sowing; moreover, the more limiting radiation of August at anthesis has stressed the evidence to sustain lower plant density and then to be less influenced by a narrow inter-row.
The clear enhance of yield under a more intensive plant population, reduce but does not eliminate completely the competitive gap in respect to a full season maturing hybrid. Thus, very early maize hybrids will be profitable for grain production in as main crop in supply food chain agreements that could valorize the lower contamination of mycotoxins and the high hardness of kernel or in all the conditions when nutritional factors are limiting or other environmental constrains are awaited.

Tab. 4: Effect of plant density and inter-row spacing on grain yield and moisture of very early maturity maize hybrid (FAO 200) under different cropping system, in comparison to a full season hybrid (FAO 500).
Tab. 4: Effetto della densità colturale e del sesto di impianto sulla produzione e l'umidità della granella di ibridi di mais precocissimi (FAO 200) nell'ambito di sistemi colturali con differente epoca di semina, in confronto a un ibrido di ciclo pieno (FAO 500).

Cropping System	**Hybrid class**	**Inter-row**	**Plant density** ($plant\ m^{-2}$)	**Yield** ($t\ ha^{-1}$)	**Grain moisture** (%)
Main crop	500	75 cm	8.0	16.1	24.9
Main crop	200	75 cm	9.0	11.8 e	24.8 a
			10.5	12.9 cd	25.5 a
			12.0	12.7 cd	25.6 a
			13.5	12.4 cde	25.7 a
		50 cm	9.0	12.3 de	25.0 a
			10.5	13.1 bc	25.6 a
			12.0	14.0 a	25.7 a
			13.5	13.6 ab	25.8 a
Intercrop	200	75 cm	9.0	8.8 b	27.1 b
			10.5	8.6 bcd	27.6 ab
			12	8.1 cd	28.6 ab
			13.5	8.0 cd	27.7 ab
		50 cm	9.0	8.8 bc	28.1 ab
			10.5	9.7 a	28.3 ab
			12	8.9 bc	28.3 ab
			13.5	8.5 bcd	28.8 a

Within each cropping system, means followed by different letters are significantly different ($p<0.05$)

References

Li, J., Xie, R.Z., Wang, K.R., Ming, B., Guo, Y.Q., Zhang, G.Q., Li, S.K., 2015. Variations in maize dry matter, harvest index, and grain yield with plant density. Agron. J. 107: 829-834.

Lindsey, A.J., Thomison, P.R., Mullen, R. Geyer, A.B., 2015. Corn response to planting date as affected by plant population and hybrid in continuous corn cropping systems. Crop, Forage & Turf management, 1: 1-7.

Testa, G., Reyneri A., Blandino, M. 2016. Maize grain yield enhancement through high plant density cultivation with different inter-row and intra-row spacings. European J. of Agronomy 72: 28-37.

ORGANIC RICE PRODUCTION SYSTEMS IN ITALY: A PRELIMINARY ENVIRONMENTAL ASSESSMENT
RISICOLTURA BIOLOGICA IN NORD ITALIA: PRIME VALUTAZIONI AMBIENTALI

Jacopo Bacenetti[1*], Francesca Orlando[1], Stefano Bocchi[1]

[1] Department of Environmental and Policy Science, Università degli Studi di Milano, Via Giovanni Celoria 2, 20133, Milano
*jacopo.bacenett@unimi.it

Abstract
The study shows the preliminary results achieved concerning the environmental impact assessment of different rice organic production systems (ORPS), compared to the conventional one, using the Life Cycle Assessment (LCA) method. In more details, the outcomes concerning one of the identified ORPS were shown, highlighting worst performances of the organic system for some environmental impacts categories, while a considerably improvement for the category related to pesticide applications. However, for final findings, the analysis needs to be extended to the variety of identified ORPS.

Keywords: Environmental impact assessment, Life Cycle Assessment, organic rice, cultivation practices, biodiversity
Parole chiave: Valutazione ambientale, Analisi del ciclo di vita, Risicoltura biologica, tecniche di coltivazione, biodiversità

Introduction
The organic farming involves the rediscovery of past and centuries-old knowledges that have been lost with the advent of the green revolution, when the introduction of technologies in agriculture, such as crop varieties genetically selected, chemical fertilizers, pesticides, herbicides, and other capital investment, allowed a significant increase of crop yield, pushing toward a high specialized production. Contrarily to the conventional farming, the best practices for organic farming involve a flexible model that changes a lot in the space, paying even more attention to the peculiarities of the environment and pedo-clime at farm scale, and in the time, in relationship to the history of each field (i.e. alternating from year to year different weed control methods).
In Europe, where rice is grown on about 425,000 ha, Italy is one of the major rice producer accounting for about 55% of European rice area, with a total production of 1,518,000 t from 227,300 ha of rice cultivation in 2015 (+3.5% than 2014), mainly the districts of Pavia, Vercelli and Novara. The conventional cultivation is by far the most common agricultural system; however, over the year, the organic one is becoming more and more important (Fusi et al., 2014). In 2015, the organic rice area was 12,425 ha (5.4% of the overall rice area), with remarkable increase in respect of 2015 (+13.9%) (SINAP, 2015).
Unless than conventional rice, where a quite standardised cultivation practice is carried out, in organic rice farming several different cultivation practices are performed, leading to a wide variability of productive performances. It is not possible to define univocal rice organic production systems (ORPS), since the management of organic paddy needs to take into account the ensemble of aspects regarding the sito-specific agro-ecological environment and peco-climatic conditions. The ORPS can vary as regard to: fertilisation (e.g. no fertilization, or crop residues, farmyard and green manures applications), sowing (e.g. with line precision seeders at 5-6 cm deep or broadcast seeding in a dry or flooded field), soil tillage (e.g. with or without primary soil tillage), water management (e.g. with continuous flooding or involving one or more aeration periods) and weed management (e.g. 'false-seeding' also called 'stale seedbed', mechanical weed control with spike harrow, etc.). However, compared to conventional rice production, the organic system is usually characterized by lower yields and, above all, by a huge yield variation over the years (Bacenetti et al., 2016).
In this study, using the Life Cycle Assessment (LCA) approach, different environmental effects related to organic rice production system were evaluated focusing the attention on one of the ORPS identified by means of surveys in organic rice farms locate in Northern Italy.

Materials and Methods
By means of surveys in several farms with organic certification, twelve rice farms, located in Lombardy and Piedmont region, were identified, taking into account the compliance with the organic cultivation guidelines and the absence of pesticides residues in the paddy soil and water.
ORGANIC RICE PRODUCTION SYSTEMS (ORPS)
The surveys in the selected farms highlighted a quite wide variablity of cultivation practices; nevertheless, for what concerns sowing, water management and weed control, three different organic rice production systems (ORPS) were identified:
- ORPS 1, that foresses a cover crop before the rice cultivation. Cover crops (i.e. single species or mixture, e.g. ryegrass, vetch, clover) are sown in autumn or spring and harvested, before the rice sowing. The latter takes place over the chopped cover crop or over the plants standing or lodged. After that: i) the paddy rice is flooded for 7-10

days, causing the fermentation of the cover crop biomass ii) an aeration period of about 20 days takes place, before the continuous flooding.

- ORPS 2, charachterized by a intensive mechanical weed control, with 'false-seeding', carried out in no-flooded paddy fields with an harrow tilling the soil (10 cm deep), in order to prepare the seed bedf and favor the weed seeds germination. After that: i) several interventions (4-6) with chain harrow are performed tilling the top soil (3-4 cm deep) until the rice emergence, ii) the rice is sown with line precision seeders at 5-6 cm deep, so that the chain harrow damages only the weed seedlings in the upper layers, iii) after sowing, an aeration period of about 20 days takes place, to allow the harrow passage, before the continuous flooding.
- ORPS3, this production system is a mix between the two ones previously described. More in details, as in ORPS1 a cover crop (usually a mix of pulse crops and italian ryegrass) is carried out as green manure with the aim to increase the availability of nutrient for the rice cultivation and, as in ORPS2, sowing is carried out in non flooded paddy fields with precision line seeder.
- ORPS 4, that involves the rice sowing in flooded paddy fields, preceded by mechanical weed control performed through passages (1-3) in flooding soil with modified harrow, in order to deliberately cause the soil destruturation and dispersion, leanding to the formation of pudding, defined as mixing soil and water that hampers the weed emergence.

LIFE CYCLE ASSESSMENT

Over the last decades, to assess the environmental performances of agricultural systems, different methods were developed. Among these, the Life Cycle Assessment (LCA) is the most used. LCA is a standardised method designed for the holistic assessment of the environmental impacts and resources used associated to a product throughout its entire life cycle. By using LCA it is possible to analyse the potential environmental impacts of products (processes or services).

Results and Discussion

This study shows in details the results for the ORPS3, the inventory data concerning the consumption of the different production factors such as seed, organic fertilisers, fuels etc were collected by surveys at the farm and by means of intervuiews with the farmers. The results for the evaluate environmental impact categories are reported in Table 2.

Impact category	Unit	Score
Climate Change	kg CO_2 eq.	3269.75
Ozono depletion	kg CFC-11 eq.	$8.08 \cdot 10^{-5}$
Human toxicity	CTUh	$2.75 \cdot 10^{-5}$
Particulate matter	kg PM2.5 eq	2.38
Photochemical ozone formation	kg NMVOC eq.	8.76
Terrestrial acidification	molc H+ eq.	100.95
Terrestrial eutrophication	molc N eq.	453.38
Freshwater eutrophication	kg P eq.	0.14
Marine eutrophication	kg N eq.	38.69
Freshwater ecotoxicity	CTUe	899.47
Min, fossil res. Depl.	kg Sb eq.	$8.94 \cdot 10^{-3}$

Tab. 3: Environmental impacts of BS. (All impacts are expressed per 1 t of paddy rice at commercial moisture).
Tab. 3: Impatto ambientale relativo alla produzione di una tonnellata di risone all'umidità commerciale.

Conclusions

These results are preliminary outcomes, while to obtain a complete framework on the organic rice cultivation sustainability, it is necessary to apply the LCA method to the wide range of cropping systems adopted by the farms, with a careful parameters calibration for different and innovative used machineries. Moreover, it is necessary to take into account the limits of LCA, integrating their impact indicators, with others concerning missed environmental aspects, such as biodiversity and landscape conservation (Reale et al., 2017).

References

Bacenetti, J., Fusi A., Negri, M., Fiala, M., Bocchi, S. 2016. Organic production systems: Sustainability assessment of rice in Italy. Agricultural, Ecosystems and Environment, 225, 33-44

Fusi, A., Bacenetti, J., González-García, S., Vercesi A., Bocchi S., Fiala, M. 2014. Environmental profile of paddy rice cultivation with different straw management. Sci. Total Environ. 494-495, 119-128.

SINAB - Sistema d'Informazione Nazionale sull'Agricoltura Biologica, 2015 (http://www.sinab.it/content/bio-statistiche).

Reale, F., Cinelli, M., & Sala, S. 2017. Towards a research agenda for the use of LCA in the impact assessment of policies. The International Journal of Life Cycle Assessment, 1-5.

Weidema, B.P., Bauer. C., Hischier, R., Mutel, C., Nemecek, T., Reinhard, J., Vadenbo, C.O., Wernet, G., 2013. Overview and methodology. Data quality guideline for the ecoinvent database version 3. Ecoinvent Report 1(v3). St. Gallen: The Ecoinvent Centre.

CEREAL QUALITY NETWORK PROJECT PLUS - RQC-MAIZE: AIMS, RESULTS AND FUTURE PERSPECTIVES.
PROGETTO RETE QUALITÀ CEREALI PLUS - RQC-MAIS: SCOPI, RISULTATI E PROSPETTIVE FUTURE.

Carlotta Balconi[1*], Sabrina Locatelli[1], Amedeo Reyneri[2], Paola Battilani[3], Massimo Blandino[2], Paola Giorni[3], Chiara Lanzanova[1]

[1]Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria – Centro di Ricerca Cerealicoltura e Colture Industriali CREA-CI, Sede di Bergamo, via Stezzano 24 24126 Bergamo.
[2] Dipartimento di Scienze Agrarie, Forestali e Alimentari –DISAFA - Università di Torino (UNITO), Via Leonardo da Vinci, 44, 10095 Grugliasco (TO)
[3] Dipartimento di Scienze delle produzioni vegetali sostenibili – DIPROVES - Università Cattolica del Sacro Cuore, Piacenza (UNICATT), Via Emilia Parmense, 84, 29122 Piacenza
*carlotta.balconi@crea.gov.it

Abstract
Evaluation of maize quality is the main aim of the three year (2014-2017) "Cereal Quality Network Project Plus - RQC-Maize" financed by MiPAAF (Ministero delle Politiche Agricole Alimentari e Forestali) in order to develop a national plan devoted to maize crop chain safety improvement and subsequent increased feed and food industry competitiveness. Maize (*Zea mays* L.), a major crop in Italy for animal feed and direct human consumption, can be infected by several fungal species, some of them mycotoxin producers (*Fusarium verticilliodes; Fusarium graminearum; Aspergillus flavus; Fusarium proliferatum; Fusarium subglutinans)*. One of the RQC-Maize Project focus is to highlight that a systematic network to monitor the occurrence and levels of mycotoxin content in maize grain represents a fundamental tool for collecting information useful to deepen knowledge about Emerging Mycotoxins (EM) and to predict annual risk exposure in Italy.
Activities performed by the Research Groups involved in the present Project, were coordinated by CREA-CI Bergamo (WP0) and organized in three Work Packages (WPs).
A synthesis of main activities performed in the Project, some outputs and future perspectives are illustrated.

Keywords: *Zea mays* L.; quality; mycotoxins; monitoring; agronomic factors; predictive models
Parole chiave: *Zea mays* L.; qualità; micotossine; monitoraggio; fattori agronomici; modelli previsionali

Introduction
Mycotoxin contamination of maize (*Zea mays* L.) grain is a worldwide threat to safety both for human food and animal feed (Balazs and Schepers 2007). Mycotoxins are secondary metabolites produced by fungi, which may be toxic to or have other debilitating effects on living organisms (Castegnaro and McGregor 1998). Regulations for the maximum mycotoxin content accepted in food and feed have been put in place in most countries; the more recent binding EU regulations on toxin contamination for human consumption and recommendations for animal feeding (European Commission, 2006a, 2006b, 2007, 2011), have forced a renewed interest in breeding efforts for ear rot resistance (Balconi et al., 2010, 2014) and for various methods of control and monitoring (Berardo et al., 2011). Good agriculture and management practices are recommended during pre- and post-harvest stages of production and processing of crops to avoid mycotoxin contamination exceeding the legal limits (Reyneri et al., 2015).
A sustainable approach can be based on the prediction of mycotoxin risk to optimize crop chain management and analytical efforts. The most influential risk factors with regard to *Fusarium* and *Aspergillus* ear rot and mycotoxin accumulation are temperature, drought stress, insect damage, other fungal diseases, and maize genotype (Miller 2001). Mechanistic models are available to predict *Fusarium verticillioides* and fumonisin, so as for *Aspergillus flavus* and aflatoxin, growth and toxin production (Battilani et al., 2003, 2014). Genotype by environment interactions are likely to be very important in determining mycotoxin contamination; Abbas *et al*. (2005) reported that some years favored aflatoxin production while other years appeared to favor FBs production. Logistic regression modelling of cropping systems to predict FBs contamination in maize, based on 438 maize samples collected in five regions of Northern Italy in a six years period (2002-2007), explained around 69% of variability with major roles for longitude, maturity class, and growing weeks (Battilani *et al*., 2008).
Activities performed by the Research Groups involved in the present Project, were coordinated by CREA-CI Bergamo (WP0) and organized in three Work Packages (WPs) as described in Figure 1.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

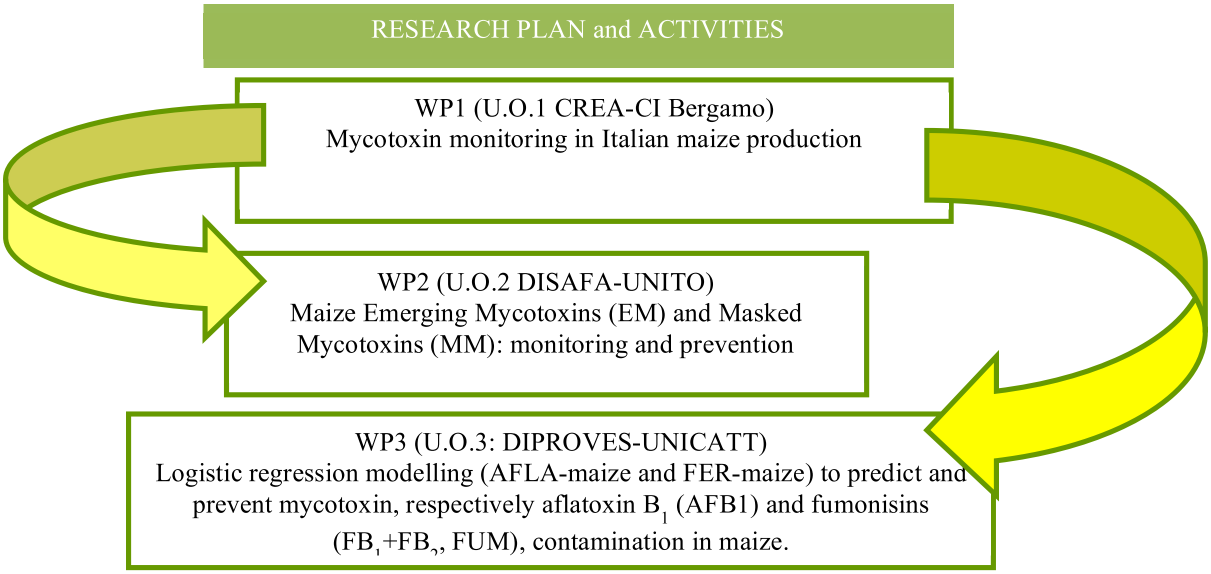


Fig. 1: RQC-MAIS synthetic research plan and Partner interaction in the frame of some selected activities.
Fig. 1: Sintesi del programma di ricerca del progetto RQC–MAIS e interazione tra i Partners nell'ambito di alcune attività selezionate.

Materials and Methods

WP1: MYCOTOXIN MONITORING IN ITALIAN MAIZE PRODUCTION.

Within the project RQC-Mais the CREA monitors large-scale enterprise of samples included in the "agronomic trials - varietal network". In addition, were monitored commercial consignments from numerous storage centers to assess the contamination of the main mycotoxins in the early stages of storage and preservation. The current study was undertaken in Northern Italy, the core area of maize production (Piemonte, Lombardia, Veneto, Friuli Venezia Giulia, Emilia Romagna).

Ridascreen ELISA test kits were used for analyses. Mycotoxin extraction and tests were performed according to the manufacturer's instructions.

WP2: MAIZE EMERGING MICOTOXINS (EM), MONITORING AND PREVENTION.

A monitoring was carried out on 200 commercial maize lots from 4 Regions (Piemonte, Lombardia, Veneto, Emilia Romagna) collected during the period 2012-2015. In addition, a series of field experiments have been conducted in North West Italy in order to evaluate the effect of different crop practices on the contamination of emerging mycotoxins in common and durum wheat and in maize grains. All the experiments have been carried out under naturally-infected field conditions and the following agricultural practices have been considered: hybrids with different susceptibility, planting time, soil tillage, planting time and density, N fertilization and insect control trough insecticide. Detection and quantification of mycotoxins was performed through a multi-mycotoxin method (Malachova et al., 2014).

WP3: DEVELOPMENT OF PREDICTIVE MODELS.

The activity of WP3 can be shared in 3 topics: 1. Validation of predictive models FER-maize and AFLA-maize. 2. Improvement of FER-maize e AFLA-maize 3. Definition of not genetic markers for resistance to toxigenic fungi

- *Validation of predictive models FER-maize and AFLA-maize*

Daily meteorological data of temperature (T, °C), relative humidity (RH, %) and rain (R, mm) has been used as main input for predictive models developed by DIPROVES-UNICATT. Using meteorological data as input, these predictive models give as output a probability of contamination with AFB_1 and FB_1+FB_2 in maize grain at harvest above the legal limit fixed, respectively, at 5 µg and 4000 µg for 1Kg. Using data collected in WP1, model predictions were compared to contamination detected. Validation of these models confirmed good results and the good opportunity to use prediction as support for farmers and other stakeholders.

- *Improvement of predictive models FER-maize and AFLA-maize*

Data on mycotoxin contamination in different maize hybrids were collected in WP1. Differences were observed, also due to the cropping system adopted. This information is under elaboration in order to improve model predictions. Combining this input to meteorological data it is expected an improvement in prediction performances.

- *Definition of not genetic markers for resistance to toxigenic fungi*

Different contamination levels were detected in hybrids sampled in WP1. The two hybrids showing the maximum difference were selected and analysed with a metabolomics approach in order to define not genetic markers for resistance. Data are still under elaboration. It is expected they can confirm and improve results obtained in previous studies and make available new non genetic markers for resistance to toxigenic fungi that can be applied to all maize hybrids entering the market. This could be very useful also to include the "hybrid" in predictive models.

Results and Discussion

WP1: Mycotoxin monitoring in Italian maize production.

STORAGE CENTERS MONITORING NETWORK.

A total of 1076 representative grain samples were collected, after dry processing, over a 3-year period (2014–2016) from about 50 storage centers. These storage centers represent about 8–9% of Italian maize production and are distributed across the principal maize cultivation areas. From each storage centre, 8–10 samples were collected each year. A dynamic grain sampling strategy was performed on the product in motion to obtain a representative sample.

Fusarium verticillioides is endemically present in Italy, because of specific adaptation to the environmental and climatic conditions (Locatelli et a. 2016a). Particular climatic anomalies favour the presence of *Aspergillus flavus* (Locatelli et al., 2016b) or *Fusarium graminearum* (Locatelli et al., 2015 and Locatelli et al., 2017). Monitoring activities conducted through a network of sampling stable over the years, is an essential tool for the management of domestic stocks and to highlight new mycotoxin alerts.

AGRONOMIC TRIALS – VARIETAL NETWORK

The monitoring program supported by the Agronomic trials – varietal network in which 10 fields, selected in the principal cultivation areas in Northern Italy (Piemonte, Lombardia, Veneto, Friuli Venezia Giulia, Emilia Romagna) where chosen. During 2015-2016 in each location seven hybrids, representative of the main FAO classes (500 – 600 – 700) were grown. The experimental design was a split splot design with four replicates The results obtained monitoring mycotoxin accumulation in agronomic trials - varietal network indicate that this may be an useful strategy for the prevention and containment of mycotoxin development.

WP2. (U.O.2 DISAFA-UNITO): Maize Emerging Micotoxins (EM): monitoring and prevention

Applying the multi-toxin method 25 of the most abundant mycotoxins were detected in maize samples: fumonisin B1, B2, B3, B4 (FBs), fusaric acid (FA), bikaverin (BIK), beauvericin (BEA), moniliformin (MON), fusaproliferin (FUS), equisetin (EQU), deoxynivalenol (DON), deoxynivalenol-3-glucoside (DON-3-G), 3-acetyldeoxynivalenol (3-ADON), 15-acetyldeoxynivalenol (15-ADON), zearalenone (ZEA), zearalenone-4-Sulfate (ZEA-4S), culmorin (CULM), butenolide (BUT), aurofusarin (AUR), and aflatoxin B1, B2, G1, G2 (AFs), ochratoxin A (OTA) and B.

Tab. 1: Mycotoxin contamination in maize commercial samples collected in the 4 Regions of North Italy monitored during the period 2012-2015.

Tab. 1: Contaminazione di micotossine in campioni commerciali di mais raccolti nelle 4 regioni del Nord Italia monitorate nel period 2012-2015.

Main fungi producers	**Mycotoxin**	**2012**	**2013**	**2014**	**2015**	**Positive samples**[1]
		μg kg^{-1}	μg kg^{-1}	μg kg^{-1}	μg kg^{-1}	%
Fusarium section Liseola	FBs	8997	6151	15040	9456	100
	FA	356	1236	492	230	100
	BIK	294	853	175	102	100
	BEA	187	195	135	101	100
	MON	852	344	505	574	100
	FUS	959	1551	1346	875	94
Fusarium section Gibbosum	EQU	40	55	59	15	90
Fusarium section Discolor and Roseum	DON	419	2923	3007	257	77
	DON-3-G	138	595	1247	89	89
	CULM	197	2621	970	94	79
	ZEA	26	367	490	24	85
	BUT	60	410	592	117	85
	AUR	194	4099	9642	239	85
Aspergillus	AFs	40	14	1	5	53
Aspergillus, Penicillium	OTA	2	nd	nd	Nd	2

[1] Percentage of sample above the limit of quantification considering 94 maize samples collected in 2 growing seasons. nd. not detected.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The relative percentage of presence of mycotoxins produced by Fusarium section Liseola (FBs, FA, BIK, BEA, MON, FUS) in maize commercial lot samples was 100% (Table 1). The occurrence of other mycotoxins was clearly influenced by growing season, with remarkable and hazardous AFs contamination values in 2012. The content of mycotoxins produced by Fusarium spp. of Liseola section, such as FBs, MON, FUS, FA, BIK and BEA was significantly reduced by insecticide application to reduced insect ear injuries, while it was increased by N stress and late planting times. Conversely, DON, DON-3-G, ZEA, CULM, AUR and BUT contents, produced by Fusarium spp. of Discolor and Roseum sections, were not affected significantly by the presence of insect injuries, while were clearly related to excess of N fertilization, high plant density and no tillage conditions.

WP3. (U.O.: DIPROVES-UNICATT): Development of predictive models

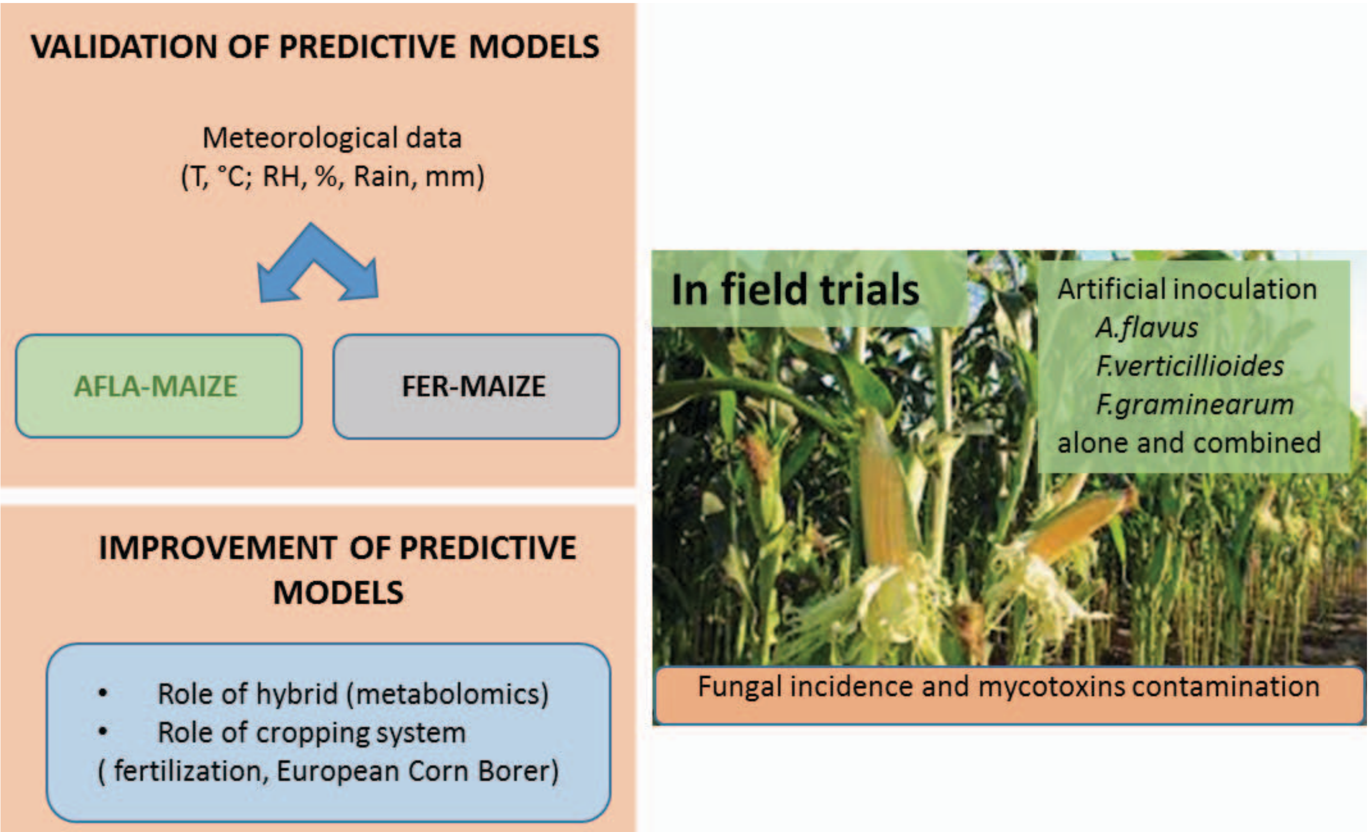


Fig. 2: WP 3 Description of activities developed for validation and improvement of predictive models
Fig. 2: WP3 Descrizione delle attività sviluppate per la validazione e il miglioramento dei modelli predittivi

Validation of predictive models (*Fig. 2*), run on a limited data set, gave good results; contamination above the legal limit was commonly correctly predicted. Hybrids showed a significant role on mycotoxin contamination, at least for fumonisins. Relevant variability in hybrid behaviour between growing areas was furthermore observed. Anyway, hybrid effect, if confirmed with the second-year data, will be included in predictive models to improve their performances.

Conclusions

Available data for the incidence of mycotoxins, in particular for EM, on maize production in Italy are limited and irregular; additionally, no national database for collecting information to predict annual risk exposure is active. Therefore, a systematic effort to monitor the levels of contaminants in maize grain production is needed.
RQC-Maize project highlighted to possibility to combine research expertise useful to develop a national plan devoted to maize crop chain safety improvement in order to increase feed and food industry competitiveness.

References

Abbas H.K., R.D. Cartwright, W. Xie and W.T. Shier, 2005. Aflatoxin and fumonisin contamination of corn (maize, Zea mays) hybrids in Arkansas. Crop Protection 25, 1-9.

Balazs E. and J.S. Schepers, 2007. The mycotoxin threat to world safety. International Journal of Food Microbiology, 119, 1-2.

Balconi C., M. Motto, G. Mazzinelli and N. Berardo, 2010. Ear secondary traits related to aflatoxin accumulation in commercial maize hybrids under artificial field inoculation. World Mycotoxin Journal 3, 239-250.

Balconi C., N. Berardo, S. Locatelli, C. Lanzanova, A. Torri, R. Redaelli, 2014. Evaluation of *Fusarium verticillioides* ear rot resistance and fumonisin accumulation in Italian maize inbred lines. Phytopathologia Mediterranea. 53, 1, 14−26. DOI:10.14601/Phytopathol_ Mediterr-11776

Battilani P., A. Pietri, C. Barbano, A. Scandolara, T. Bertuzzi and A. Marocco, 2008. Logistic regression modeling of cropping systems to predict fumonisin contamination in maize. Journal of Agricultural and Food Chemistry 56, 10433-10438.

Berardo N., C. Lanzanova, S. Locatelli, P. Laganà, A. Verderio and M. Motto, 2011. Levels of total fumonisins in maize samples from Italy during 2006–2008. Food Additives and Contaminants: Part B. 4, 116–124.

Camardo Leggieri M., Bertuzzi T., Pietri A., Battilani P., 2015. Mycotoxin occurence in maize produced in Northern Italy over the years 2009-2011: focus on the role of crop related factors. Phytopathologia Mediterranea 54, 2, 212−221 DOI: 10.14601/Phytopathol_Mediterr-14632

Castegnaro M. and D. McGregor, 1998. Carcinogenic risk assessment of mycotoxins. Revue de Medecine Veterinaire 149, 671-678.

European Commission, 2006. Commission Recommendation (EC) on the presence of deoxynivalenol, zearalenone, ochratoxin A, T-2 and HT-2 and fumonisins in products intended for animal feeding. Official Journal of European Union 229:7-9.

European Commission, 2007. Commission Regulation (EC) No 1126/2007 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards Fusarium toxins in maize and maize products. Official Journal of European Union 255:14–17.

European Commission, 2011. Commission Regulation (EC) No 574/2011 amending Annex I to Directive 2002/32/EC. Official Journal of European Union 159:7-24.

Locatelli S., Balconi C. 2015. Micotossine in mais: campagna 2014. Mangimi & Alimenti, 3:32-33.

Locatelli S., Lanzanova C., Facchinetti F., Mascheroni S., Mazzinelli G., Balconi C. 2016 (a). Mais: monitoraggio micotossine in Italia dal 2006 al 2014. Atti V Congresso Nazionale: le micotossine nella filiera Agro-Alimentare, Rapporti ISTISAN 16/28: 82-86.

Locatelli S., Facchinetti F., Mascheroni S., Balconi C. 2016 (b). Micotossine nel mais 2015: risultati del monitoraggio. Supplemento a L'Informatore Agrario 11/2016, pag. 8 – 10.

Locatelli S., Fumagalli F., Mascheroni S., Facchinetti F., Lanzanova C., Balconi C. 2017. Micotossine su mais: risultati del monitoraggio 2016. L'Informatore Agrario, 11: 51-53.

Malachova A, Sulyok M, Beltran E, Berthiller F, Krska R, 2014. Optimization and validation of a quantitative liquid chromatography - tandem mass spectrometric method covering 295 bacterial and fungal metabolites including all relevant mycotoxins in four model food matrices. J. Chromatogr. A 1362:145-156.

Reyneri A., Bruno G., D'Egidio M.G., Balconi C. (a cura di), 2015. Linee guida per il controllo delle micotossine nella granella di mais e frumento. Linee guida per il controllo delle micotossine nella granella di mais e frumento. Ministero delle politiche agricole, alimentari e forestali - Dip.to delle politiche competitive, della qualità agroalimentare, ippiche e della pesca - Piano cerealicolo nazionale, 2010.
https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/9703

Acknowledgements

The current research was performed with the financial support of Italian Ministry of Agricultural Food and Forestry Policies-MiPAAF as part of the following research Program RQC MAIS (D.D. N. 88666 del 03/12/2014).

RECOGNIZING POTENTIAL AGROFORESTRY AREAS: THE APULIA CASE STUDY
RICOGNIZIONE DI POTENZIALI AREE A DESTINAZIONE AGROFORESTRY: IL CASO STUDIO DELLA PUGLIA

Anna Rita Bernadette Cammerino, Giuliana Zita, Angela Libutti, Massimo Monteleone*

STAR*AgroEnergy - Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente, Università degli Studi di Foggia, Via Napoli 25, 71100 Foggia
*massimo.monteleone@unifg.it

Abstract
Agroforestry is an important feature of European landscapes. Nowadays different threats are progressively eroding these systems, mainly through intensification, on one hand, and abandonment, on the other. The aim of this study was to point out a methodological approach to identify potential agroforestry areas in the Apulia region. The study has been carried out in the frame of a national working group. The applied methodology is a combined and complementary double-approach, taking into account both statistical data from the *Italian Agricultural Census* and the *Biotopes Map* (ISPRA, 2013) processed with the support of a *Geographic Information System* (*GIS*). According to the two methodological approaches, the potentially suitable agroforestry areas in the Apulia region have been detected. 480.000 hectares is their total surface, corresponding to 25% of the total regional surface. The landscape analysis confirmed these results. Extensive agricultural areas, mostly characterized by complex agricultural patterns, is largely assigned to internal, marginal areas where the process of land abandonment is remarkable. Proper conversion of complex cultivation patterns as well as the conservation and management of extensive semi-natural pastoral systems should be promoted designing a set of specific and long-term strategies.

Keywords: agricultural census, landscape analysis, agroforestry suitability
Parole chiave: censimento dell'Agricoltura, analisi di paesaggio, vocazione agroforestale

Introduction
"Agroforestry" has formed traditionally an important feature of European landscapes, but many of these systems have disappeared due to economic and social changes, while the remaining ones are highly vulnerable (Nerlich et al., 2013). Socio-economic conditions, agricultural trends and policies led to a progressive decrease in profitability of these systems impairing their long-term persistence. Two divergent development processes were observed: "intensification" and "abandonment" (Asner et al., 2004). *Intensification* results in the shifting from traditional farming systems, with very low external inputs, to much higher technical inputs, in parallel with crop specialization and management simplification (Plieninger and Wilbrand 2001). *Abandonment* comes from a progressive invasion of forest at the expense of marginal agricultural systems in many parts of the world, especially including traditional agroforestry systems (Eldridge et al., 2011), notably in Mediterranean countries.
A recent assessment of the agroforestry surfaces in Europe (den Herder et al., 2015) shows that agroforestry is most practiced in southern Europe, especially in Spain, Portugal, Greece, and Italy. The importance of supporting agroforestry specifically in Europe has been reviewed by Smith et al. (2013), with the conclusion that it is able to yield both productivity and environmental protection through multiple ecosystem services.
An accurate and objective estimate on the actual extent of agroforestry in Europe is critical for the development of supporting policies. The Common Agricultural Policy (CAP) recognized that the establishment of agroforestry systems should be encouraged because of their high ecological value.
The aim of this study was to point out a methodological approach to identify potential agroforestry areas in the Apulia region. The study has been carried out in the frame of a national working group. The applied methodology is a combined and complementary double-approach, taking into account both statistical data from the *Italian Agricultural Census* and the *Biotopes Map* (ISPRA, 2013) processed with the support of a *Geographic Information System* (*GIS*).

Materials and Methods
The study area is the Apulia region, placed in the south east of Italy, about 20.000 km^2 wide. It can be divided into 11 territorial districts according to the Regional Territorial Landscape Plan (PPTR, 2013), (Figure 1). This subdivision takes into account the hydro-geo-morphological, environmental, anthropic and cultural traits of the region.
Considering the wide variability of the agroforestry systems and the difficulty of finding a precise definition with rigorous discriminatory traits, it is necessary to address a characterization that embraces sufficiently wide and diversified evaluation criteria. Two different approaches and databases were applied in order to recognize potential agroforestry areas in the region: *Agricultural census survey* and the *Landscape analysis*.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Agricultural census survey. Data of four consecutive agricultural censuses (ISTAT, 1982, 1990, 2000, and 2010) were processed. The analysis was performed considering the local administrative unit (LAU 2). Specific land use categories or category aggregation were considered in order to characterize the region. In particular, *Farm-woods*, *Pasture*, *Utilized Agricultural Area* (*UAA*) and *Total Farm Area* (*TFA*). *UAA* is the sum of the areas corresponding to the following crop categories: arable land, tree crops, and pasture. *TFA* is the sum of *UAA* and *Farm-woods*. The following four indicators were considered: *Farm-wood/UAA*, *Pasture/UAA*, *UAA/TFA*, with the addition of the *Total number of sheep and goats*. These indicators were further processed considering: *a)* the average value of the four censuses; *b)* the temporal trend in term of slope of their regression line. When the value of the pair (*a* and *b*) of each indicator was higher than the average in at least three cases out of the four, the LAU 2 was labelled as a potential agroforestry area.
Landscape analysis. After a review of the main land use/land cover databases available for the Apulia region, the Biotopes Map (ISPRA, 2013), at a 1:50.000 geographic scale, was the one considered for the analysis. The software ArcGis 10.1 was used to process the data. The biotopes possibly associated with the agroforestry definition were selected and aggregated into three categories: *bush*, *extensive and complex cultivation patterns*, *tree pasture*. *Forest and woods*, as well as *agricultural lands* were not considered in the analysis because not directly associated with agroforestry (i.e. the combination of the two). A grid of regular mesh (1 km by side) was overlapped to the land use map. The fraction of land covered by all the considered land use classes was determined for every cell. As a whole, five ranges were identified according to a *quantile* classification (20% of the data in each range). The *focal statistic* GIS function (with a circular moving window of three cells in radius and a "mean" statistic) was applied thus obtaining the *Agroforestry Suitability Map*.

Results

According to the two methodological approaches, the potentially suitable agroforestry areas in the Apulia region have been detected. 480.000 hectares is their total surface, corresponding to 25% of the total regional surface (Fig.1). The census survey approach showed that the territorial district with the highest suitability is "Monti Dauni", followed by "Gargano" and "Alta Murgia" (Tab. 1). The landscape analysis confirmed these results. Extensive agricultural areas, mostly characterized by complex agricultural patterns (Tab. 2), is largely assigned to internal, marginal areas where the process of land abandonment is more remarked.

Tab.1: Relevance (as percentage of the total) of the identified agroforestry traits for the considered landscape units in the region.
Tab.1: Incidenza (espressa in percentuale) dei caratteri potenzialmente agroforestry negli ambiti di paesaggio regionali.

Territorial district	Farm wood/ UAA	Pasture/ UAA	UAA/ TFA	Sheep and goat (n)	Total
Monti Dauni	13,09	1,87	11,22	0,94	***27,12***
Gargano	5,78	5,78	6,93	2,31	***20,80***
Alta Murgia	8,42	=	5,61	5,61	***19,64***
Murgia dei trulli	5,61	=	4,21	2,81	***12,63***
Arco Jonico Tarantino	3,93	1,96	3,93	0,98	***10,80***
Salento delle Serre	0	0,37	3,71	=	***4,08***
Tavoliere	1,57	=	0,79	0,79	***3,14***
Tavoliere Salentino	0,36	=	1,43	=	***1,79***
Campagna Brindisina	=	=	=	=	=
Ofanto	=	=	=	=	=
Puglia Centrale	=	=	=	=	=
Total	***38,76***	***9,98***	***37,83***	***13,43***	***100,00***

Tab. 2: Potential agroforestry surfaces (as percentage)according to the Biotopes Map.
Tab. 2: Distribuzione territoriale (in percentuale) delle classi di uso potenzialmente agroforestale secondo la Carta della Natura.

Territorial district	Complex cultivation patterns	Bush	Tree pasture
	(%)	*(%)*	*(%)*
Gargano	40,62	59,29	0,08
Tavoliere	53,72	25,51	20,77
Arco Jonico Tarantino	82,52	17,32	0,17
Murgia dei trulli	89,68	7,54	2,78
Alta Murgia	93,06	3,7	3,24
Tavoliere Salentino	93,16	6,84	=
Monti Dauni	93,73	6,27	=
Salento delle Serre	95,91	4,09	=
Ofanto	97,31	2,55	0,14
Puglia centrale	97,63	2,19	0,18
Campagna brindisina	99,00	1,00	=
Total	***88,28***	***10,43***	***1,29***

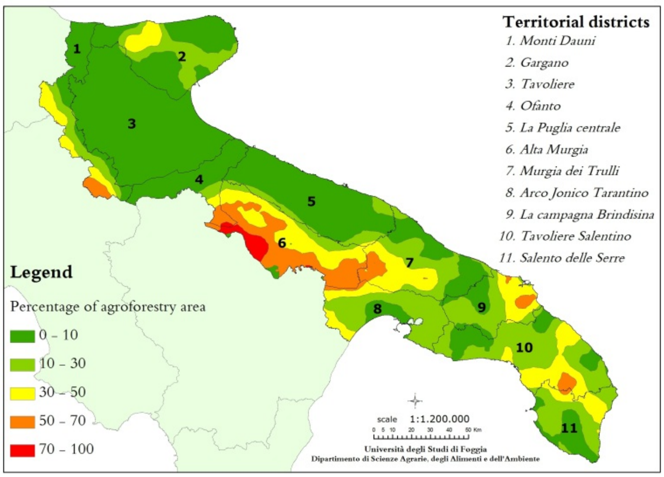


Fig. 1: Agroforestry suitability map of the Apulia region.
Fig. 1: Mappa della vocazione agroforestale delle regione Puglia

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Conclusions

A combined methodology for the detection of areas potentially suitable to agroforestry was presented. Therefore, different candidate territorial districts in the Apulia region were assessed on this respect. Proper conversion of complex cultivation patterns as well as the conservation and management of extensive semi-natural pastoral systems should be promoted designing a set of specific and long-term strategies. The CAP provides options in supporting the establishment of new agroforestry systems. In this regard, the Rural Development Program has identified (also in the Apulia region) the sub-measure 8.2 to finance activities related to the setting up and maintenance of agroforestry systems. The identified areas should be prioritized for this kind of option.

References

Asner Gregory P., Elmore Andrew J., Olander Lydia P., Martin Roberta E., Harris A. Thomas, 2004. Grazing systems, ecosystem responses, and global change. Annu. Rev. Environ. Resour. 29:261–99.

den Herder, M., Moreno, G., Mosquera-Losada, R., Palma, J., Sidiropoulou, A., SantiagoFreijanes, J.J., Crous-Duran, J., Paulo J., J., Tomé, M., Pantera, A., Papanastasis, V.,Mantzanas, K., Pachana, P., 2015. Current extent and trends of agroforestry use in the EU27, including maps with agroforestry likelihood, stratified into systems aligned with WP2-5. Deliverable 1.2 for EU FP7 Research Project: AGFORWARD613520, 74 pp..

Eldridge, D.J. Bowker MA, Maestre FT, Roger E, Reynolds JF, Whitford WG., 2011. Impacts of shrub encroachment on ecosystem structure and functioning: towards a global synthesis. Ecology Letters14: 709-722.

ISPRA, 2013. Il Sistema Carta della Natura dela Regione Puglia. Rapporto ISPRA 204.

ISTAT, 2016. Italian Institute of Statistics. Agricultural censuses. Available from: http://dati-censimentoagricoltura.istat.it/

Nerlich K., Graeff-Honninger S., Claupein W., 2013. Agroforestry in Europe: a review of the disappearance of traditional systems and development of modern agroforestry practices, with emphasis on experiences in Germany. Agroforest Syst 87:475–492.

Plieninger, T. and Wilbrand, C., 2001. Land use, biodiversity conservation, and rural development in the dehesas of Cuatro Lugares, Spain. Agroforestry Systems 51: 23–34.

PPTR, 2013. Piano Paesaggistico Territoriale Regione Puglia. http://www.paesaggio.regione.puglia.it

Smith, J., Pearce, B.D., Wolfe, M.S., 2013. Reconciling productivity with protection of the environment: is temperate agroforestry the answer? Renew. Agric. FoodSyst. 28, 80–92.

DOI 10.6092/unibo/amsacta/5692

WHAT DATA ARE AVAILABLE TO DESCRIBE CROPPING SYSTEMS AT THE REGIONAL LEVEL?

QUALI DATI SONO DISPONIBILI PER DESCRIVERE I SISTEMI COLTURALI A LIVELLO REGIONALE?

Davide Rizzo[1*], Elisa Marraccini[1], Giuliano Vitali[2], Philippe Martin[3]

[1] UP 2012-10-103 INTERACT, UniLaSalle, 19 rue Pierre Waguet, 60026 Beauvais CEDEX, France
[2] UMR SADAPT, AgroParisTech, INRA, Université Paris-Saclay, 78850 Thiverval-Grignon, France
[3]Department of Agricultural Science, University of Bologna, Viale Fanin 44, 40126 Bologna, Italy
*davide.rizzo@unilasalle.fr

Abstract

European agriculture is undergoing a rapid evolution that challenges agronomic research to scale from field to landscape. In particular, the undergoing processes (e.g. urbanization or land abandonment) and the multiple ecosystems services provided by agricultural areas are requiring to broaden the research at the regional level. Since some decades, the European Union is promoting the collection of agricultural data to evaluate the farmers' eligibility for subsidies and to assess the Common Agricultural Policy performances. Part of these datasets are being increasingly used beyond their administrative functions, as for the Farm Accountancy Data Network (FADN) and the Land Parcel Identification System (LPIS). Starting from a bibliometric analysis of the scientific literature using these datasets, we will discuss two examples of their application for characterizing cropland and cropping systems. Our aim is to discuss the relevance of these datasets as tools to improve the monitoring and management of agroecosystems at the regional level.

Keywords: land parcel identification system (LPIS), farm accountancy data network (FADN), landscape agronomy, bibliometric analysis, RPG Explorer.
Parole chiave: sistema di identificazione delle parcelle agricole (SIPA), rete di informazione contabile agricola (RICA), agronomia territoriale, analisi bibliometrica, RPG Explorer.

Introduction

European farming is evolving rapidly in the recent years and several processes are undergoing e.g. urbanization, intensification, extensification, abandonment (Plieninger et al., 2016). In addition, the number of farmers is continuously decreasing, whereas to better understand these dynamics some authors are calling for scaling the agronomic research at the regional level (Boiffin et al., 2014) even though the data sources available to characterize farming activities at this level are quite poor (Leenhardt et al., 2010). In fact, the description of agricultural dynamics at the territorial level requires to address the connections between agricultural practices and various resources (e.g., soil, water, biodiversity, know-how) as function of their spatial organization (i.e., land use patterns), as defined by the landscape agronomy framework (Benoît et al., 2012). The need for data relevant for various topics, in particular for environmental and economic issues such as the assessment of the common agricultural policy (CAP) reforms and applications moved the European Union to organize the collection of various agricultural data. Their first purpose is to evaluate the farmers' eligibility for subsidies and to assess the CAP performances. Nevertheless, also under the pressure of the greening measures, these datasets have been increasingly used beyond their administrative functions to evaluate the agroecosystem services and the territorial management of cropland and grassland. In this study, we aimed at discussing the relevance of two European datasets to improve the monitoring and management of agroecosystems at the regional level. To this end, we performed a bibliometric analysis as framework to discuss two approaches using European dataset for the regional study of cropping systems.

Materials and Methods

In this study, we focused on two European datasets having a major potential to describe cropping systems at the regional level. The first is the land parcel identification system (LPIS). It is the spatial component of the Integrated Administration and Control System (IACS). The LPIS's technical specifications vary across the Member States that defined different reference parcels (Sagris, 2013). The reference parcel can be an agricultural or a cadastral parcel, a farmer's block or a physical/topographical block, differing for the boundary definition as function of a crop group, of the ownership, of natural border, as well as for the data source, which can be the farmer's application or an administrative classification. LPIS has been often proposed as support to improve the spatial management of agriculture and the environment and many land managers have suggested incorporating it in most of the instruments for sustainable agriculture (Grandgirard and Zielinsky, 2008). In 2007, also Turkey started setting up the LPIS as fundamental tool to distribute and monitor area-based subsidies. The second dataset is the farm accountancy data network (FADN), established by the European Community (Reg. EC No 79/65), aims at monitoring and evaluating the effects of the CAP on agricultural dynamics. It is fed by an annual survey of

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

a farm sample representative of national agricultural situations. Altogether, FADN is delivering a detailed snapshot of farm structure, collecting yearly economic and technical information (Bradley and Hill, 2016).
As first step, we performed an overview the LPIS and FADN citations in the scientific literature. Several searches on different databases (Google Scholar, Web of Science, Scopus) allowed us to select the keywords. We finally opted to search the full name of the two datasets as exact phrases to avoid ambiguity (e.g., FADN occours also medical literature and LPIs may indicate landscape pattern indexes). We searched the Scopus database (May 29, 2017) in title, author keywords, abstract and in the cited references, yielding 90 items for the LPIS corpus and 284 items for the FADN corpus. Then, the bibliometric analysis was performed using the CorText (http://www.cortext.net) that is a platform dedicated to the cleaning and processing of large textual corpuses with the aim of synthesising and analysing big data. We used different analytical script to perform a lexical analysis and mapping the structure and the dynamics of the two corpora, following the settings and the example available in the literature (Ruiz-Martinez et al., 2015; Tancoigne et al., 2014).

Results and Discussion

Early results of the bibliometric analysis highlighted the different topics addressed across Countries in papers mentioning LPIS and FADN. Only France occurred among the 5 most frequent Countries for both corpora. Concerning the documents mentioning LPIS, researchers from Ireland and Germany shared its citation about bioenergy, grassland and NDVI, whereas Germany shared with Turkey the reference to the CAP (Fig. 1a). Data development analysis and sustainable intensification resulted to be the shared topics between UK and Italy in documents mentioning FADN. Netherlands and Belgium where instead mentioning FADN in research associated to dairy farming, similarly to France that referred to dairy farm (Fig. 1b). Altogether, LPIS was mainly associated with spatial analysis whereas FADN with farming types and performances.

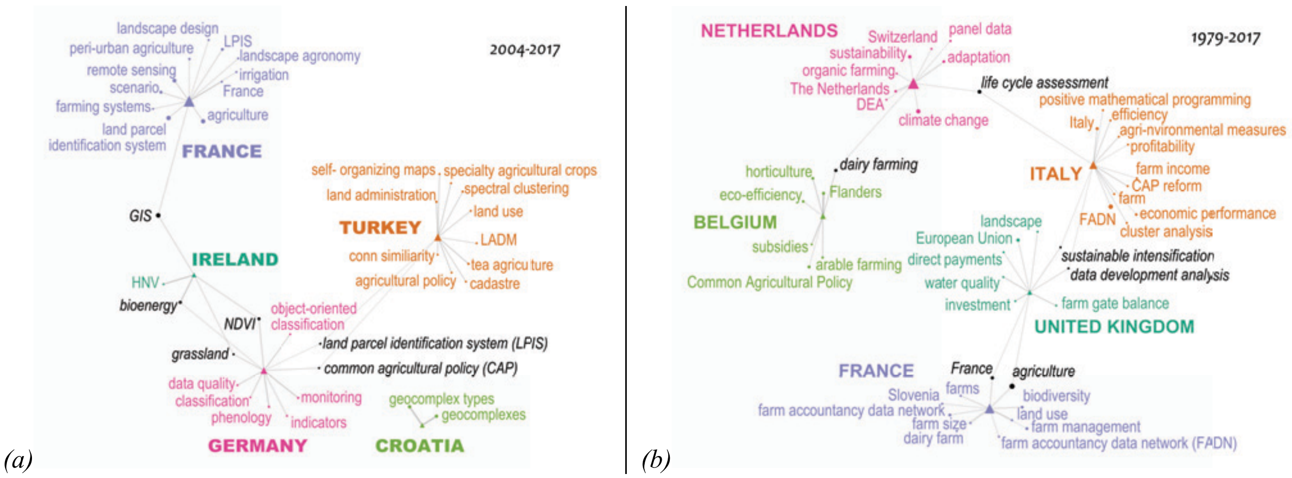


Fig. 1: Co-citation network. The 50 most cited keywords are considered to build a co-citation network with the 5 most frequent country in documents of the LPIS corpus (a) and FADN corpus (b). Node sizes scale with the number of citations received by keyword. Black labels highlight keywords associated with two Countries. Obtained using the CorText platform then manually improved for readability. Original networks are available here (a) http://bit.ly/2rvL5D4 and (b) http://bit.ly/2rgLd9f

Fig. 1: Rete di co-citazioni. Le 50 parole chiave più citate sono state considerate per costruire la rete di co-citazioni con i 5 Paesi più frequenti nei documenti dei corpora SIPA – sistema di identificazione delle parcelle agricole (a) e RICA – rete di informazione contabile agricola (b). La dimensione dei nodi è proporzionale al numero di citazioni ricevute. Le etichette nere evidenziano le parole chiave associate a due Paesi. Ottenuto usando la piattaforma CorText e adattato per migliorare la leggibilità.

Some authors has already identified the potential of coupling LPIS and FADN to scale the agro-environmental assessment from field to landscape (Dalgaard et al., 2009). Latruffe and Piet (2014) combined FADN and LPIS to evaluate the agricultural land fragmentation in Brittany, though being limited by the confidentiality constraints of the datasets. Although not developed to study agricultural landscapes, their contents could a priori make them suitable for a wide range of purposes. For instance, the RPG Explorer (Levavasseur et al., 2016) proposes a set of user-friendly modules which perform standardized analyses of LPIS allowing to retrieve crop sequences and to compute farm typologies. FADN data can complement LPIS analysis providing socio-economic indicators. Nevertheless, they also contain information about the cropland that have been recently explored to reconstitute cropping scheme (Vitali et al., 2012, 2016).

Conclusions

LPIS emerges as the fundamental pillar for the spatial characterization of cropland and grasslands. Nevertheless; it lacks of information about the farming practices, that could be provided by coupling it with FADN data (Bertaglia et al., 2016). In conclusion, we highlight the great opportunity to proceed on the coupling of LPIS data – mostly used at the crossroad of agronomy and ecology – with FADN data – insofar preferred by agricultural economists – to enhance the characterization of cropping systems at the regional level.

Acknowledgements
The work of the first author has been supported by the Chaire Agro-Machinisme et Nouvelles technologies, backed by UniLaSalle with the financial support from the Michelin Corporate Foundation, AGCO Massey-Ferguson, the Hauts-de-France Regional Council and the European Regional Development Fund (ERDF)

References

Benoît, M., Rizzo, D., Marraccini, E., Moonen, A.C., Galli, M., Lardon, S., Rapey, H., Thenail, C., Bonari, E., 2012. Landscape agronomy: a new field for addressing agricultural landscape dynamics. Landsc. Ecol. 27, 1385–1394. doi:10.1007/s10980-012-9802-8

Bertaglia, M., Milenov, P., Angileri, V., Devos, W., 2016. Cropland and grassland management data needs from existing IACS sources (EUR - Scientific and Technical Research Reports). European Commission.

Boiffin, J., Benoît, M., Le Bail, M., Papy, F., Stengel, P., 2014. Agronomie, espace, territoire : travailler « pour et sur » le développement territorial, un enjeu pour l'agronomie. Cah. Agric. 23, 72–83. doi:10.1684/agr.2014.0688

Bradley, D., Hill, B., 2016. Diversity and Innovation in the FADN Data Collection Systems in the EU-28. EuroChoices 15, 5–10. doi:10.1111/1746-692X.12137

Dalgaard, T., Kjeldsen, C., Jørgensen, M.S., Hutchings, N., Mogensen, L., Sahrbacher, A., Damgaard, M., Happe, K., Piorr, A., 2009. Scaling from Farm to Landscape 175–189. doi:10.1007/978-3-540-79470-7_10

Grandgirard, D., Zielinsky, R., 2008. Land Parcel Identification System (LPIS) Anomalies' Sampling and Spatial Pattern: Towards convergence of ecological methodologies and GIS technologies. (EUR - Scientific and Technical Research Reports).

Latruffe, L., Piet, L., 2014. Does land fragmentation affect farm performance? A case study from Brittany, France. Agric. Syst. 129, 68–80. doi:10.1016/j.agsy.2014.05.005

Leenhardt, D., Angevin, F., Biarnès, A., Colbach, N., Mignolet, C., 2010. Describing and locating cropping systems on a regional scale. A review. Agron. Sustain. Dev. 30, 131–138. doi:10.1051/agro/2009002

Levavasseur, F., Martin, P., Bouty, C., Barbottin, A., Bretagnolle, V., Thérond, O., Scheurer, O., Piskiewicz, N., 2016. RPG Explorer: A new tool to ease the analysis of agricultural landscape dynamics with the Land Parcel Identification System. Comput. Electron. Agric. 127, 541–552. doi:10.1016/j.compag.2016.07.015

Plieninger, T., Draux, H., Fagerholm, N., Bieling, C., Bürgi, M., Kizos, T., Kuemmerle, T., Primdahl, J., Verburg, P.H., 2016. The driving forces of landscape change in Europe: A systematic review of the evidence. Land Use Policy 57, 204–214. doi:10.1016/j.landusepol.2016.04.040

Ruiz-Martinez, I., Marraccini, E., Debolini, M., Bonari, E., 2015. Indicators of agricultural intensity and intensification: a review of the literature. Ital. J. Agron. 10, 74. doi:10.4081/ija.2015.656

Sagris, V., 2013. Land Parcel Identification System conceptual model: development of geoinfo community conceptual model (PhD thesis). University of Tartu (Estonia).

Tancoigne, E., Barbier, M., Cointet, J.-P., Richard, G., 2014. The place of agricultural sciences in the literature on ecosystem services. Ecosyst. Serv. 10, 35–48.

Vitali, G., Cardillo, C., Albertazzi, S., Della Chiara, M., Baldoni, G., Signorotti, C., Trisorio, A., Canavari, M., 2012. Classification of Italian Farms in the FADN Database Combining Climate and Structural Information. Cartogr. Int. J. Geogr. Inf. Geovisualization 47, 228–236. doi:10.3138/carto.47.4.1478

Vitali, G., Rizzo, D., Baldoni, G., Bazzani, G.M., Cardillo, C., Canavari, M., 2016. A national pedoclimatic characterization of cropping schemes based on FADN Italian data, in: Farm and Land System Dynamics in the Mediterranean Basin: Integrating Spatial Scales, from the Local to the Global One. Presented at the AgroMed International Conference, Avignon (FRA).

A METHODOLOGY FOR PROBABILISTIC ASSESSMENT OF ADAPTATION STRATEGIES: A CASE STUDY IN THE MEDITERRANEAN

UNA METODOLOGIA PER LA VALUTAZIONE PROBABILISTICA DELL'EFFETTO DELLE STRATEGIE DI ADATTAMENTO: UN CASO STUDIO NEL MEDITERRANEO

R. Ferrise*[1], M. Ruiz-Ramos[2], A. Rodríguez[2], I. J. Lorite[3], M. Bindi[1], T.R. Carter[4], S. Fronzek[4], T. Palosuo[5], N. Pirttioja[4], P. Baranowski[6], S. Buis[7], D. Cammarano[8], Y. Chen[5], B. Dumont[9], F. Ewert[10],T. Gaiser[10],P. Hlavinka[11,12], H. Hoffmann[10], J.G. Höhn[5], F. Jurecka[11,12], K.C. Kersebaum[13], J. Krzyszczak[6], M. Lana[13], A. Mechiche-Alami[14], J. Minet[15], M. Montesino[16], C. Nendel[13],J.R. Porter[16], F. Ruget[8], M. A. Semenov[17], Z. Steinmetz[18], P. Stratonovitch[17], I. Supit[19], F. Tao[4], M. Trnka[11,12], A. de Wit[19] and R. P. Rötter[20]

[1]*University of Florence, 50144 Florence, Italy*
[2]*Universidad Politécnica de Madrid, ETSIAgrónomos, 28040 Madrid, Spain,*
[3]*IFAPA Junta de Andalucía, 14004 Córdoba, Spain*
[4]*Finnish Environment Institute (SYKE), 00250 Helsinki, Finland*
[5]*Natural Resources Institute Finland (Luke), 00790 Helsinki, Finland*
[6]*Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4,20-290 Lublin, Poland*
[7]*INRA, UMR 1114 EMMAH, F-84914 Avignon, France*
[8]*James Hutton Institute, Invergowrie, Dundee, DD2 5DA, Scotland, United Kingdom*
[9]*Dpt. AgroBioChem & Terra, Crop Science Unit, ULgGembloux Agro-Bio Tech, 5030 Gembloux, Belgium*
[10]*INRES, University of Bonn, 53115 Bonn, Germany*
[11]*Institute of Agrosystems and Bioclimatology, Mendel University in Brno, Brno 613 00, Czech Republic*
[12]Global Change Research Institute CAS, 603 00 Brno, Czech Republic
[13]*Institute of Landscape Systems Analysis, Leibniz Centre for Agricultural Landscape Research (ZALF), 15374 Müncheberg, Germany*
[14]*Department of Physical Geography and Ecosystem Science, Lund University, 223 62 Lund, Sweden*
[15]*Université de Liège, Arlon Campus Environnement, 6700 Arlon, Belgium*
[16]*University of Copenhagen, 2630 Taastrup, Denmark*
[17]*Rothamsted Research, Harpenden, Herts, AL5 2JQ, UK*
[18]*RIFCON GmbH, 69493 Hirschberg, Germany*
[19]*Wageningen University, 6700AA Wageningen, The Netherlands*
[20]*TROPAGS, Department of Crop Sciences, Georg-August-Universität of Göttingen, Grisebachstr. 6, 37077 Göttingen, Germany*
*roberto.ferrise@unifi.it

Abstract
Uncertainty about future climate change impacts increases the complexity of addressing adaptation and evaluating risks at regional level. To provide useful information to decision makers, approaches are required for effectively quantifying climate impacts and the effect of adaptation options, managing inherent uncertainties and communicating the results. In this study, a probabilistic framework for evaluating the effect of feasible adaptation strategies for winter wheat in northern Spain under two future time periods was applied. The framework was based on coupling adaptation response surfaces and probabilistic projections of climate change to calculate the magnitude and the likelihood of the effect of selected adaptation strategies. Results indicated that a wide scope for adaptation exists when considering combined options. The most promising adaptation strategies were based on a combination of spring wheat, longer growing cycle, advanced sowing date and supplementary irrigation. This provided a virtually certain (likelihood >99%) positive adaptation response (i.e. increase in yield compared to the standard management), with a median yield increase up to 37%. Other feasible strategies were also found for winter wheat with supplementary irrigation (extremely likely positive response, i.e. >95%; median of adaptation response up to 22%) and for spring wheat under rainfed conditions (extremely likely positive response; median up to 20%).

Keywords: probabilistic projections; adaptation response surfaces; ensemble of models; wheat.
Parole chiave: proiezioni climatiche probabilistiche, superfici di risposta dell'adattamento, insieme di modelli, frumento.

Introduction

The projected climate change may negatively affect crops production, thus threaten future food and nutrition security. Appropriate adaptation options can alleviate detrimental effects of a warmer and drier climate as well as can better exploit favourable conditions. However, uncertainty about future climate change impacts increases the complexity of addressing adaptations and evaluating risks at regional level. This is especially true for rainfed cropping systems, for which even small discrepancies in precipitation projections can result in different impacts and therefore adaptation recommendations (Ruiz-Ramos et al., 2017). To allow stakeholder and policy makers taking the more appropriate decision, probability estimates to assess the seriousness of a projected impact are needed (Schneider, 2001). Accordingly, approaches are required for effectively quantifying climate impacts and the effect of adaptation options, managing inherent uncertainties and communicating the results.

In this study, a probabilistic framework for evaluating the effect of feasible adaptation strategies for winter wheat in Northern Spain, while taking into account uncertainty related to environmental conditions, crop models and climate projections was applied.

Materials and Methods

The study was conducted at Lleida, in northern Spain, for two representative actual soil profiles with contrating depth, texture, thus different soil water availability. An ensemble of 17 models was used for conducting a sensitivity analysis of the response of wheat crop under changed precipitation (P), temperature (T) and CO_2 air concentrations. The models were calibrated using observed phenological, above ground biomass and yield data and were applied to simulate crop performance under standard management and 35 different combinations of adaptation options. The standard management was defined as rainfed winter wheat (WW) with medium crop cycle sown on 29 October. The adaptation strategies tested were from the combination of the following single options: 1) removing vernalization requirements (Spring wheat, SW), 2) changing the duration of phenological phases (from -10% to +10%, 3) considering a moderate advance of the sowing date by -15 days as well as a delay of the sowing by 30 days, and 4) application of 40 mm of sI at flowering. All the simulations were performed under non-nutrient limiting conditions.

Figure 1 is a graphical representation of the probabilistic framework applied for evaluating the effect and the likelihood of feasible adaptation strategies. First, adaptations response surfaces (ARSs) were created. These are an extension of the concept of impacct response surfaces developed in Pirttioja et al. (2016). ARSs are bi-dimensional surfaces in which the effect of an adaptation option (e.g. changes in crop yield compared to the standard management) is plotted against two explanatory variables (e.g. changes in temperature and precipitation). Then, the likelihood of the effect of adaptations was calculated using ARSs and probabilistic projections (PP) of climate change. The latter are joint probabilities of changes in the same explanatory variables used for drawing the ARSs. Therefore, ARSs were constructed and climate PP superimposed. This allow to easily calculate the distribution of the effect of the adaptation options as well as the probability (likelihood) of exceeding a specific threshold.

In this study, the likelihood of having a positive response of the adaptations (i.e. increase in yield with respect to the standard management) was estimated. Further, the magnitude and the likelihood of having a positive recovery response was calculated. The recovery response is the ability of an adaptation options to maintain current yield levels (i.e. with standard management under present climate conditions). This was done by creating recovery response surfaces (RRSs) in T and P changes and then superimposing the PP.

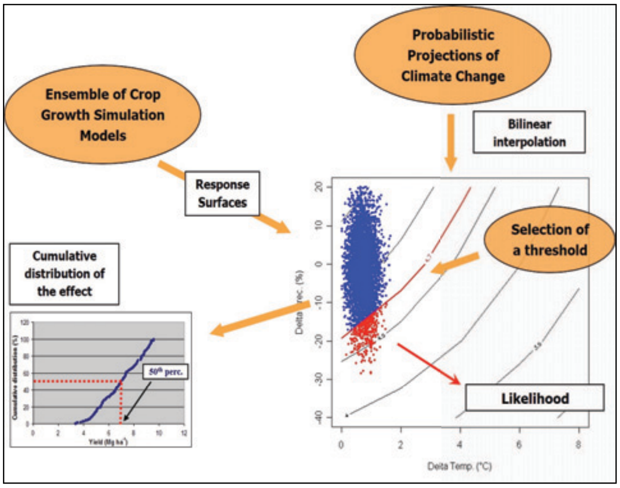


Figure 1: General framework for coupling adaptation response surfaces and probabilistic projections of climate change to estimate the likelihood and the magnitude of the effect of an adaptation option

Figura 1: Rappresentazione grafica del framework utilizzato per accoppiare le superfici di risposta dell'adattamento con le proiezioni climatiche probabilistiche

Results and Conclusions

Our analysis demonstrated that "business-as-usual", i.e. WW with standard cultivar and management, should be avoided in the future. Concerning single adaptation options, no single factor was able to overcome the detrimental effect of the complex interactions imposed by the P, T and CO_2 perturbations. The sole exception was sI, which proved to be useful even under the most severe perturbations, probably due to the high dependency of Mediterranean rainfed cropping systems on precipitation. The results indicated that a wide scope for adaptation exists when considering combined options (Tab 1). The most promising adaptation strategies were based on a combination of spring wheat, longer growing cycle, advanced sowing date and supplementary irrigation. This provided a virtually certain (likelihood >99%) positive adaptation response (i.e. increase in yield compared to the standard management), with a median yield increase up to 37%. Other feasible strategies were also found for winter wheat with supplementary irrigation (extremely likely positive response, i.e. >95%;

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

median of adaptation response up to 22%) and for spring wheat under rainfed conditions (extremely likely positive response; median up to 20%).

Tab. 1: Probabilistic assessment of the effect of some promising adaptation options in the shallow soil: Likelihood is the probability of having positive adaptation and recovery response; Median is the 50th percentile of the expected adaptation and recovery response.
Tabella 1: Valutazione probabilistica degli effetti di alcune strategie di adattamento per il suolo superficiale. Likelihood è la probabilità di avere delle risposte positive dell'adattamento o del recupero di resa; median è il 50° percentile della distribuzione dell'adattamento o del recupero di resa.

Shallow Soil				2020-2040 (447 ppm)				2040-2060 (522 ppm)			
				Adaptation		Recovery		Adaptation		Recovery	
	Water mgnt	Cultivar	Sowing date	Likelihood	Median (%)	Likelihood	Median (%)	Likelihood	Median (%)	Likelihood	Median (%)
WW	sI	Short	Earlier	1.00	8.1	0.98	10.0	1.00	7.4	0.95	10.5
		Std	Earlier	1.00	18.8	1.00	22.6	1.00	19.6	0.95	18.6
			Standard	1.00	20.2	1.00	22.2	1.00	22.4	0.97	20.4
SW	R	Short	Earlier	0.98	5.7	0.97	14.5	0.99	8.7	0.78	12.4
			Standard	0.88	5.8	0.86	10.3	0.99	9.0	0.78	7.3
		Std	Earlier	1.00	19.6	0.98	22.2	1.00	14.9	0.89	19.0
			Standard	1.00	11.3	1.00	21.8	1.00	15.0	0.97	22.2
		Longer	Earlier	1.00	13.8	0.96	13.5	1.00	15.7	0.92	10.8
	sI	Short	Earlier	0.98	6.7	0.89	11.3	1.00	9.7	0.79	7.8
			Standard	0.88	5.0	0.98	13.6	0.98	9.2	0.93	11.7
		Std	Earlier	1.00	30.6	1.00	27.4	1.00	37.5	1.00	27.1
			Standard	1.00	28.0	1.00	26.2	1.00	33.1	0.95	23.5
		Longer	Earlier	1.00	22.0	1.00	40.5	1.00	24.3	1.00	40.1
			Standard	1.00	12.2	1.00	26.3	1.00	14.9	1.00	27.0

The methodology proposed here can be a useful tool for planning and supporting decisions. ARSs may provide qualitative assessment of the performance of adaptations, since they can illustrate the different response of the effect to different climate perturbations. Then, coupling ARSs and PP integrates such information by providing quantitative values and informing on uncertainties

References

Pirttioja N., Carter T., Fronzek S., Bindi M., Hoffmann H., Palosuo T., Ruiz-Ramos, M., Tao F., Trnka M., Acutis M., Asseng S., Baranowski P., Basso B., Bodin P., Buis S., Cammarano D., Deligios P., M.-F. D., Doro L., Dumont B., Ewert F., Ferrise R., Francois L., Gaiser T., Hlavinka P., Jacquemin I., K.-C. K., Kollas C., Krzyszczak J., Lorite I.J., Minet J., Minguez M.I., Montesion M., Moriondo M., Müller C., Nendel C., Öztürk I., Perego A., Rodriguez A., Ruane A.C., Ruget F., Sanna M., Semenov M., Slawinski C., Stratonovitch P., Supit I., Waha K., Wang E., Wu L., Zhao Z., Rötter R. 2015. A crop model ensemble analysis of temperature and precipitation effects on wheat yield across a European transect using impact response surfaces. Climate Research 65, 87-105. doi: 10.3354/cr01322

Ruiz-Ramos M., Ferrise R., Rodríguez A., Lorite I.J., Bindi M., Carter T.C., Fronzek S., Palosuo T., Pirttioja N., Baranowski P., Buis S., Cammarano D., Chen Y., Dumont B., Ewert F., Gaiser T., Hlavinka P., Hoffmann H., Höhn J.G. J., F., K.C. K., Krzyszczak J., Lana M., Mechiche-Alami 2 7 A., Minet J., Montesino M., Nendel C., J.R. P., Ruget F., M.A. S., Steinmetz Z., Stratonovitch P., Supit I., Tao F., Trnka M., de Wit A., Rötter R.P. 2017. Adaptation response surfaces for managing wheat under perturbed climate and CO_2 in a Mediterranean environment. Agricultural Systems, *in press*. doi: 10.1016/j.agsy.2017.01.009

Schneider S.H. 2001. What is 'dangerous' climate change? Nature 411, 17-19. doi:10.1038/35075167

THE ROLE OF SOIL ORGANIC MATTER ON GREENHOUSE GAS EMISSIONS FROM DIFFERENT FERTILIZERS

RUOLO DELLA SOSTANZA ORGANICA NELLE EMISSIONI DI GAS SERRA DI DIVERSI FERTILIZZANTI

Leonardo Verdi[1]*, Marco Napoli[1], Marco Mancini[2], Mirjana Ljubojević[3], Anna Dalla Marta[1], Simone Orlandini[1]

[1] Dipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente, Università di Firenze, Piazzale delle Cascine 18, 50144, Firenze, Italy
[2] Fondazione per il Clima e la Sostenibilità, via Giovanni Caproni 8, 50145 Firenze, Italy
[3] Department for Fruit Growing, Viticulture, Horticulture and Landscape Architecture, Faculty of Agriculture, Trg Dositeja Obradovića 8, Novi Sad, Serbia
*leonardo.verdi@unifi.it

Abstract

Emissions from the use of fertilizers represent a serious issue for the sustainability of agricultural systems, also considering the increasing of human population and the world food demand. In the present experiment, we evaluated the role of soil organic matter on the emissions of greenhouse gasses after the application of different fertilizers as liquid fraction of digestate from pig slurries, compost from organic fraction of municipal solid wastes, and urea on bare soil in order to avoid the influence of the crop. The experiment was performed on twenty-four bare soil pots with two levels of organic matter (low and high). Emissions were directly monitored through the use of a static chamber system and a portable gas analyser. Results show that soil organic matter as well as the composition of the fertilizers affect greenhouse gasses emissions. In particular, after fertilization we observed an increase of greenhouse gasses emission both for organic and chemical fertilizers. An exception is represented by methane emissions that show higher values in correspondence of lower soil organic matter content. This is probably due to temporary anaerobic conditions caused by soil saturation and compaction observed after digestate (liquid) and compost (dry and milled) application. This, together with high levels of easily degradable carbohydrates and easily accessible nitrates, provides conditions for an overabundance in the denitrifier community, especially in the first 72h (from day 1 to 3).

Keywords: static chambers, nitrogen, fertilization management, sustainability
Parole chiave: camere statiche, azoto, fertilizzazione, sostenibilità

Introduction

Intensive agricultural systems in both plant and livestock production drastically increased the concentration of greenhouse gasses (GHG) as carbon dioxide (CO_2) methane (CH_4) and nitrous oxide (N_2O), as well as ammonia (NH_3) as the precursor of N_2O and main nitrogen loss trough volatilization. Deforestation and land use change for agricultural purposes led not just to the air CO_2 level increase, but also higher CH_4, N_2O and NH_3 atmospheric concentrations due to agricultural activities, including the overabundant and/or inappropriate use of fertilizers. It is well known that agricultural food-producing systems currently contribute to one-third of total anthropogenic GHG emissions that are assumed to increase with the increasing demand for agricultural products (Carlson et al., 2014). In order to keep such systems sustainable, future research must be focused on economically cost–efficient as well as environmental–friendly measures to mitigate climate gas emissions from agriculture. Pertinent literature addresses the emissions and solutions regarding different *in situ* soil and management conditions (Henault et al., 1998), application techniques (Carozzi et al., 2013), as well as fertilizer and manure type in laboratory conditions (Velthof et al., 2003). To the author's best knowledge there is a scarce literature regarding GHG emissions from *in situ* bare soil, addressing both the emissions and possible control of the major gases. Setting the experiment on bare soil allows to define its basic emission potential independently from the crop, enabling the expression of organic matter as one of the main factors affecting emissions from the soil, and derivation source.
Based on these considerations, the main goal of the study was to evaluate the role of the soil organic matter content on gasses emissions after fertilization with different fertilizers, including liquid fraction of digestate from pig slurries, compost from organic fraction of municipal solid waste (OFMSW) and urea, as mineral fertilizer.

Materials and Methods

The experiment was conducted on 9.5 litres pots, placed in the open field and exposed to the environmental conditions. Each pot was filled with 8 kg of a silty-clay soil from experimental fields of CREA-ABP located in Scarperia, Firenze (43°58'56" N, 11°20'53" E). The experiment was set on the bare soil in order to investigate the sole role of the organic matter without any crop interference. The soil was taken from the depth of 30 cm, including top and sub soil layer, mixed before filling the pots, in order to homogenise it. The experimental design consisted of two contrasting levels of soil organic matter – OM1 1.3% and OM2 4.3% - with four treatments. Treatments included two types of organic fertilizers (liquid fraction of digestate from pig slurries and compost from organic fraction of municipal solid waste) as well as one mineral fertilizer (urea), with

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

the non-fertilized pots as control treatment. The digestate was produced by 'Fattoria di Corte Marchesi De' Frescobaldi' farm (Florence, Italy, 43°58'29" N, 11°23'21" E), while the compost derived from composting plant of 'Alia Servizi Ambientali Spa' (Florence, Italy, 43°55'580.95'' N, 11°21'00.09'' E). The amount of each fertiliser varied according to its N content (Table 1), calculated on the base of a pre-defined quantity of 150 kg N/ha. GHG emission measurements were conducted three times in the first week (immediately after fertilization, after 48h and 96h) and once in the second week in order to investigate the emission trend. Experimental pots remained opened between the successive measurements to enable nitrogen volatilization, as these conditions would be the closest to the ones occurring naturally. CO_2, CH_4, N_2O and NH_3 emission rates were measured by means of a static chambers system (Parkin and Ventera, 2010) and a portable gas analyser XCGM 400 that use NDIR technology for CO_2, CH_4 and N_2O analysis and electrochemical technology for NH_3. Temperature inside the chambers and meteorological data (air temperature, wind speed and precipitation) were monitored continuously by thermocouples and an automatic meteorological station, respectively. Except for the first day, two hours prior to the measurements 10 mm of water were added to each pot for accelerating the beginning of the emissions process.

Table 1: Nitrogen content of three fertilizers
Tabella 1: Contenuto di azoto nei tre fertilizzanti

	Urea	Digestate	Compost
N content Total %	46	0.319	2.27
$N\text{-}NH_4^+$ %	-	0.284	0.15
$N\text{-}NO_3^-$ %	-	0.035	0.0013

Results and Discussion

In the present experiment, we investigated the role of soil organic matter on GHG emissions due to organic and mineral fertilizers applied on bare soil. Emissions data from each test are summarized in Table 2.

CO_2 EMISSIONS

Results show that an enrichment of soil OM content positively affects CO_2 emissions. As affirmed by Paustian et al. (2000) and Six (1999), CO_2 emissions dynamics from agricultural soil are affected by a wide range of factors. In this respect, OM represents one of the main factors due to its influence on soil respiration. In the present study, a higher soil OM probably increased soil respiration and consequently CO_2 emissions. Organic fertilizers (digestate and compost) produced higher emissions compared to urea. In particular, the highest emissions were registered for digestate also due to its composition, rich in water, that allows the infiltration into the soil. An enrichment of water content of soil combined to the mild air temperatures occurred probably encouraged the proliferation of soil microorganisms and consequentially soil respiration. However, we did not observe significant differences in digestate emissions behavior between OM1 and OM2.
Urea produced a higher level of CO_2 compared to compost, and the role of OM is evident. In fact, cumulative CO_2 emissions in OM2 were more than 3 times higher than in OM1.

CH_4 EMISSIONS

Results obtained from organic fertilizers (digestate and compost) showed that CH_4 had an opposite trend compared the others gasses monitored. In particular, organic fertilizers produced more emissions in OM1 than in OM2. As described by Le Mer and Roger (2001) also CH_4 emissions from soil are affected by many factors and in particular, a negative correlation between CH_4 emissions and C/N ratio was reported. In this respect, the composition of manure used to obtain the two levels of OM, which represent the 25% of total organic C, can partially explain the behavior of CH_4 emissions from organic fertilizers. In addition, the composition of organic fertilizers, rich in total organic C (34.5% and 25.6% for digestate and compost, respectively), may have reduced CH_4 emissions. In the case of urea, that did not provide organic C, the positive correlation between OM level and CH_4 emissions was confirmed.

N_2O EMISSIONS

From the observed results we can affirm that N_2O emissions are positively affected by the OM content of soil. For all tested fertilizers N_2O emissions in OM2 were higher than in OM1. In particular, digestate produced the highest emissions and this is probably due to its high water content that determine anaerobic conditions with consequent greater N_2O losses compared to the others fertilizers. Moreover, the higher amount of organic C available into the soil in OM2 probably encouraged the microorganisms activity and N degradation. Also, the high rate of readily available N compounds of digestate and the warm temperature occurred during the experiment (average of 28.4°) enhanced N losses in the first two weeks after fertilization. On the other hand, compost emitted a N_2O rate comparable with the control, probably due to its low water content. This result is in accordance with the findings of Dalal et al. (2010), confirming that the application of compost can be considered an efficient strategy to reduce N_2O emissions. Finally, concerning urea, its low water content reduces the risk of anaerobic conditions and the consequent N_2O emissions that are comparable with those of compost.

NH_3 EMISSIONS

NH_3 emissions were nearly five times higher in correspondence of OM2 than OM1 treated with urea. Again, this confirms that higher organic C content into the soil modifies the C/N ratio and encourages bacteria activity with greater degradation of N and NH_3 losses.

Organic fertilizers are an exception: digestate, in fact, showed the highest rate of NH_3 emissions. However, we observed no differences between emissions in the two OM levels. As digestate, also compost show comparable NH_3 emissions. This fact may mean that OM content of soil does not affect NH_3 volatilization dynamics.

Table 2: Gas emissions from each treatment for OM1 (1.3% organic matter content of soil) and OM2 (4.3% organic matter content of soil 1% organic matter content of soil) expressed as kg C or N per hectare in 26 days' period.

Tabella 2: Emissioni di gas nei diversi trattamenti per OM1 (contenuto di sostanza organica del suolo pari a 1.3%) e OM2 (contenuto di sostanza organica del suolo pari a 4.3%) espressi in kg di C o N per ettaro in un periodo di 26 giorni

	CO_2		CH_4		N_2O		NH_3	
	OM1	**OM2**	**OM1**	**OM2**	**OM1**	**OM2**	**OM1**	**OM2**
No-fertilizer	38,50	129,19	8.06	8.06	0.04	0.31	0.00	0.06
Digestate	604,12	679,75	15.07	12.65	0.96	7.65	0.61	0.59
Urea	67,04	206,67	8.95	11.17	0.09	0.29	0.09	1.15
Compost	29,22	169,35	9.62	8.38	0.03	0.38	0.26	0.54

Conclusions

This experiment was performed to evaluate the role of soil organic matter on the gas emissions that occur from soil after fertilization. The study focused on bare soil, allowing to understand the emissions dynamics without the influence of the plants. Based on the results, we observed that organic matter plays a key role on the emissions of GHG, generally enhancing the levels of gas emissions. However, results about CH_4 emissions of digestate and compost, which were higher in OM1 than in OM2, require further investigation with particular attention to the role of microorganisms population.

References

Carlson, K. M., Gerber, J. S., Mueller, N. D., O'Connell, C., & West, P. C., 2014. Current and Future Greenhouse Gas Emissions from Global Crop Intensification and Expansion. In AGU Fall Meeting Abstracts (Vol. 1, p. 0820)

Carozzi, M., Ferrara, R. M., Rana, G., & Acutis, M., 2013. Evaluation of mitigation strategies to reduce ammonia losses from slurry fertilisation on arable lands. Science of the Total Environment, 449, 126-133

Dalal R. C., Gibson I., Allen D. E., Menzies N. W., 2010. Green waste compost reduces nitrous oxide emissions from feedlot manure applied to soil. Agriculture, ecosystem and environment 136, 273-281

Henault, C., Devis, X., Page, S., Justes, E., Reau, R., & Germon, J. C., 1998. Nitrous oxide emissions under different soil and land management conditions. Biology and Fertility of Soils, 26(3), 199-207

Le Mer J., Roger P., 2001. Production, oxidation, emissions and consumption of methane by soils: a review. European journal of soil biology 37, 25-50

Parkin TB, Venterea RT (2010) USDA-ARS GRACEnet Project Protocols, Chapter 3. Chamber-Based Trace Gas Flux Measurements. (Replace original version of April 2003)

Paustian K., Six J., Elliott E. T., Hunt H. W., 2000. Management options for reducing CO_2 emissions froma gricultural soils. Biogeochemistry 48: 147-163

Six J., Elliott E. T., Paustian K., 1999. Aggregate and soil organic matter dynamics under conventional and no-tillage systems. Soil Science Society of America Journal 63:1350-1358

Velthof, G. L., Kuikman, P. J., & Oenema, O., 2003. Nitrous oxide emission from animal manures applied to soil under controlled conditions. Biology and Fertility of Soils, 37(4), 221-230

DOI 10.6092/unibo/amsacta/5692

REGULATORY PROBLEMS IN DEFINITION OF CONTAMINATED SOILS: THE AGRONOMIC APPROACH

PROBLEMATICHE NORMATIVE PER LA DEFINIZIONE DEI SUOLI CONTAMINATI: L'APPROCCIO AGRONOMICO

Massimo Fagnano[1*], Paola Adamo[1], Antonio Di Gennaro[2], Fabio Terribile [1]

[1] Dipartimento di Scienze Agrarie, Università di Napoli Federico II, Via Università, 100 780055 Portici, Napoli
[2] Risorsa SrL, Viale Raffaello, 15, 80129 Napoli
*fagnano@unina.it

Abstract

Italian environmental legislation highlighted several weaknesses in relation to the definition of the actually contaminated soils, mainly as regards agricultural soils. The first one is related to sampling methodologies (i.e setting up the sampling scheme and the depth of the soil layer to be sampled) aimed to perform the environmental characterization of potentially contaminated soils. The second weak point is the absence of specific references to the agricultural use of contaminated soils. In this paper we present a multidisciplinary approach for solving these weak points carried out in the frame of the LIFE11-ENV/IT/275 project and reported in the Ecoremed Handbook (Fagnano, 2017).
For the Environmental characterization we proposed a preliminary series of geophysical measurements to identify anomalies which would then be analysed with direct excavation of pits or soil profiles.

Keywords: contaminated soils; agricultural use; environmental characterization; agronomic approach.
Parole chiave: suoli contaminati, uso agricolo; caratterizzazione ambientale; approccio agronomico.

Introduction

The definition of contaminated soil is a two-step process. Firstly, we must compare the analytical data of a site with the table of screening values (SV). If some value exceeds the SV, then the site is defined potentially contaminated. In order for a site to be termed "contaminated" we must perform an analysis of health and environmental risks. The procedure as well as the tools available (e.g. Software Risknet 2.0 or ISPRA 2009), however, take into account only the direct risks for those who frequent the site and are therefore related to hours of exposure to contaminated soil particles that can reach the human target through inhalation, ingestion and skin contact. The risks for the environment linked to the leaching of contaminants in groundwater are also considered.
In the case of agricultural soils in addition to the direct risks, we need another step for assessing indirect risks for end users who could consume the products obtained on contaminated sites.
Analysis of Italian environmental legislation highlighted several weaknesses in relation to the definition of the actually contaminated soils, mainly as regards agricultural soils. The first one is related to sampling methodologies (i.e setting up the sampling scheme and the depth of the soil layer to be sampled) aimed to perform the environmental characterization of potentially contaminated soils. In Law Decree 152/06 there are no mandatory rules regarding rational sampling schemes or sampling layers. Normally reference is made to previous laws (Annex 2 to Ministerial Decree 471/99) which establish that 1-2 samples per hectare have to be taken and a composite sample of the 0-1 m layer has to be collected. Clearly, a soil sample 10 cm in diameter cannot be representative of an area of 10,000 m^2 and pollution levels, which are often higher in the top centimeters of soils, could be drastically underestimated if they were diluted in a 1 m layer.
The second weak point is the absence of specific references to the agricultural use of contaminated soils.
At this regards Art. 241 of the Single Environmental Text makes the following provision: a "*regulation on remediation, environmental restoration and emergency operative and permanent safety measures, of the areas for agricultural production and husbandry, was adopted by decree of the Minister for the environment and land and sea protection in concert with the Ministers for Industry, Health and Agriculture and Forestry policy*". The above regulation, after 11 years has not yet been adopted.
Currently, in Italy, agricultural soil pollution standards are based on total or pseudototal PTM content. It represents an excellent criterion to define the extent of metal contamination in soil, but it is of little value for the prediction of ecological impact. In agricultural soils, knowledge of PTM bioavailability is also required for a scientifically based evaluation since total metal content is not directly correlated to the effective absorption by plants. Finally the measurements of PTMs accumulation in plants can give the final assessment of the risks for health of consumers of the crops produced in such sites.
In this paper we present a multidisciplinary approach for solving these weak points carried out in the frame of the LIFE11-ENV/IT/275 project and reported in the Ecoremed Handbook (Fagnano, 2017). This approach was also reported in the regulation drawn up by a technical committee which included the presence of the working group of the Ministerial Directive of December 23, 2013 (Environmental Ministry, 2014).

Materials and Methods

Validation of the proposed methodologies was carried out in a 6 ha field situated in Giugliano in Campania (NA), sequestered from a criminal as it was used for disposal of industrial sludge rich in Cr and Zn.

For the Environmental characterization we proposed a preliminary series of geophysical measurements to identify anomalies which would then be analysed with direct excavation and sampling of pits or soil profiles.

Geophysical modelling provides generalized and nonunique solutions to questions concerning the geometry and physical organization of soil cover. Hence a well-conducted study generally requires complimentary geophysical surveys integrated with field survey and targeted sampling of different soil horizons.

The methodological approach involves the combined use of several indirect surveys to characterize contaminated or potentially contaminated sites:

- Automatic resistivity profiling (ARP);
- Frequency domain electromagnetic induction (Profilers EMP400 and DUAL-EM 642 S)
- Gamma-ray spectrometry (compact gamma surveyor – GF instruments);
- X-ray fluorescence (XRF) (Olympus Delta Professional Handheld XRF Analyzers)

The reliability of rapid low-cost methods (XRF) was assessed to design maps of contamination levels so as to guide a subsequent rational sampling scheme of the whole site area (6 ha in this case). XRF data were then compared with the data obtained in the same soil samples with the offical methods.

As regards the evaluation of the suitability of agricultural use of potentially contaminated soils, it is necessary to evaluate the bioavailability of MPT. Extraction with 1 mol L^{-1} ammonium nitrate is commonly used to determine the readily soluble and bioavailable content of PTMs in soil. In Germany, this procedure is recognized as official standard (DIN 19730, 1997) and is used to assess the risk of transfer of PTMs from the soil to plants in the German Federal Soil Protection and Contaminated Sites Ordinance (BBodSchV, 1999).

In each area defined as critical on the basis of the prevoius analyses, pairs of soil-vegetation samples have to be set up in order to assess variations in both the bioavailable fraction of PTEs in soil, and the accumulation of contaminants in plant organs. The vegetative sample must be collected from the plants present on the site. If the area is regularly cultivated, field crops must be collected and analysed to evaluate any potential hazards for consumers (EC Reg. 1881/2006); if the area is not cultivated, the wild species have to be sampled to evaluate the possible hazards, assimilating them to forage crops (EC Dir. 32/2002). For the contaminants not governed by legislation, health risk assessment can be made by estimating exposure of the population through the intake of the most commonly used foods in normal diets, of the ISS (2013) study, relating to the tolerable daily intake (TDI).

For monitoring the suitability of a site for the agricultural use the approach to follow is the so-called "worst case", which means growing a crop which under normal conditions is able to accumulate high concentrations of one or more PTEs in the more polluted hot spots of a site and analysing the edible parts of such crops. If it thus proves safe, we would consider that the site is free of contamination risk of the food chain.

Results and Discussion

SOIL CHARACTERIZATION

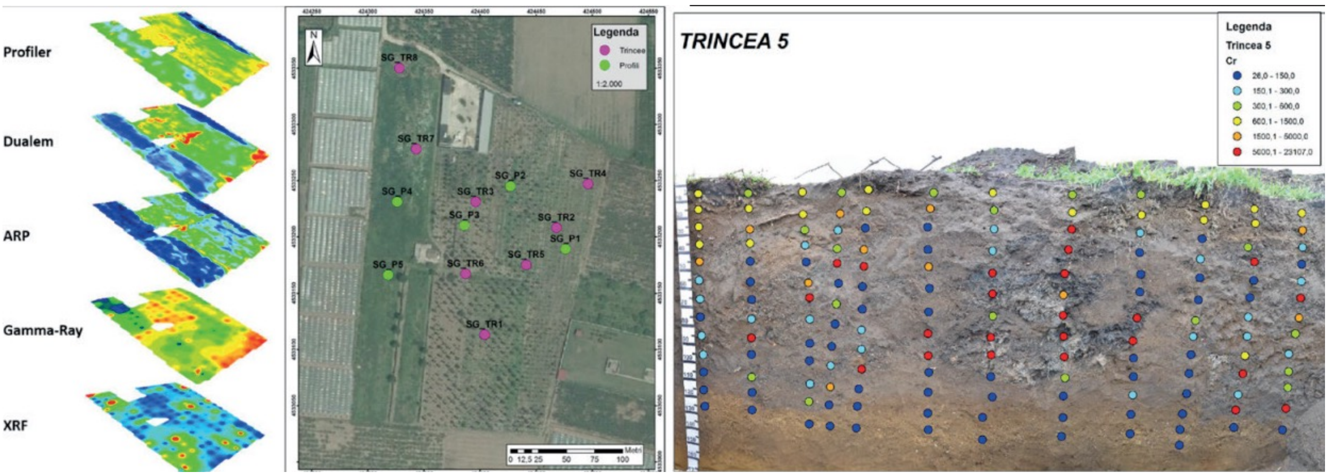


Figure 1. Identification of anomalous areas and example of a soil profile in which industrial sludge were found.

Figura 1. Identificazione delle aree anomale ed esempio di trincea in cui sono stati rinvenuti sversamenti di fanghi industriali.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

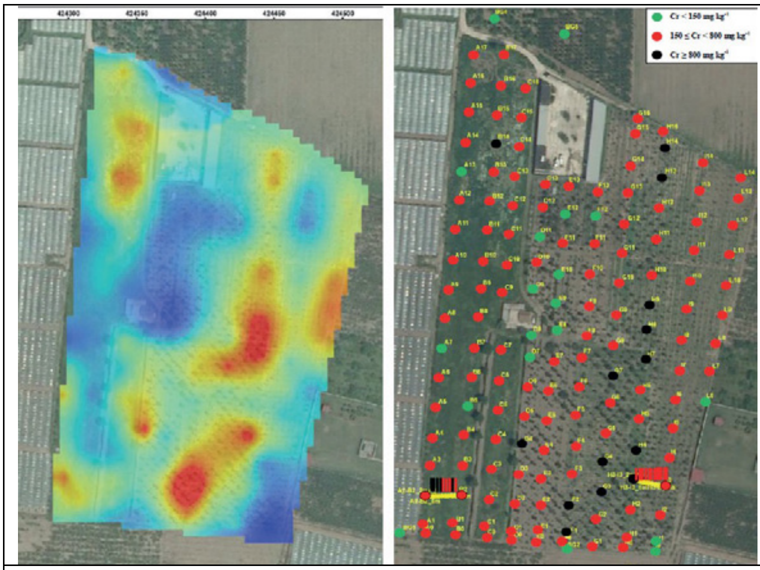


Figure 2. Levels of chromium as measured by XRF (left) and the official method of ICP-MS (right).
Figura 2. Livelli di cromo determinati con l'XRF (sinistra) e con l'ICP-MS (destra).

Opening a soil profile also allowed the stratigraphy and the presence of contaminated materials to be analyzed, thus making it possible to choose the layers most representing the form of contamination. For example, from the data gained from "Trench 5" it is evident that the most contaminated layers are only those between 50 and 80 cm: in this case the average sample of the 0-1 m layer, according to current legislation, would have underestimated the level of contamination.
Figure 2 shows that with a measurement campaign conducted with X-ray fluorescence (XRF), it was possible to identify, in a few days' work, the areas severely contaminated by chromium, on which then to perform direct sampling for analyses with the official methods.
The data obtained with the two methods resulted significantly correlated (R^2= 0.93 for Cr and 0.96 for Zn).

EVALUATION OF SUITABILITY TO AGRICULTURAL USE

Single chemical extractions revealed that Zn, although present on average at a lower total concentration, was more mobile and bioavailable than Cr. The readily bioavailable (extracted by 1 mol L^{-1} NH4NO3; DIN 19730, 1997) amounts of Cr were always much lower than those of Zn, which in some cases were higher than the trigger value of 2 mg kg^{-1}, adopted by some European countries in agricultural areas (Carlon, 2007). In the most contaminated soil samples, even the NH_4NO_3-extracted amounts of Pb, Cu and Cd were higher than the trigger values adopted by some European countries for agricultural areas (1 mg kg^{-1} for Cu, 0.1 mg kg^{-1} for Pb; 0.04 or 0.1 mg kg^{-1} for Cd). These findings were confirmed by the analyses of vegetables that showed low concentrations of Cr and high levels of Zn and Cu, but with values lower than the TDI. Instead accumulation of Pb in vegetables represented a higher risk for contamination of food-chain.

Conclusions

The proposed approach resulted much more appropriate and precise than current methods for the characterization of contaminated sites and also more economically sustainable because knowledge of detailed contamination geography enables site-specific remediation techniques to be performed and thus avoids treatment of non-contaminated soils.
The information obtained can then steer direct sampling (core samples to determine concentrations of contaminants with official analytical methods), thus reducing the number of samples and costs of analysis, and increasing the accuracy in delineating site-specific problems (e.g. volume of soil contamination).
The proposed method for assessing the suitability for the agricultural use, confirmed the uselessness of total content of PTM in the soils, highlighting an unexpected risk due to the presence of Pb (whose concentration was lower in this site) while allowing to exclude any risk due to Cr and Zn (whose total concentrations were very higher).
Finally, we should highlight the absolute need to improve existing legislation: the current formulation fails to guarantee proper characterization of the geospatial nature of contaminated sites and hence it is indeed very hard to ensure proper site restoration.

References

BBodSchV, 1999. Bodenschutz- und Altlastenverordnung [Federal Soil Protection and Contaminated Sites Ordinance]. 12 July 1999, Germany.

Carlon C., 2007. Derivation methods of soil screening values in Europe. EC-JRC, Ispra EUR 22805-EN, 306 pp.

DIN 19730, 1997. Bodenbeschaffenheit–Extraktion von Spurenelementen mit Ammoniumnitratlösung. Beuth Verlag Berlin.

Fagnano M., 2017 (Ed). Operative handbook for eco-compatible remediation of degraded soils. LIFE-Ecoremed.

ISPRA 2009. http://www.isprambiente.gov.it/it/temi/siti-contaminati/analisi-di-rischio.

ISS, 2013. http://www.iss.it/iasa/?lang=1&tipo=41.

Environmental Ministry, 2014. http://www.bonifiche.minambiente.it/contenuti%5Cgruppi%5Caree_agricole%5CREGOLAMENTO_A_MISE_SALUTE_E_MPAAF.pdf.

Risknet 2.0. http://www.reconnet.net/Risknet%202_download.html.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

EFFECT OF ORGANIC CONSERVATION AGRICULTURE ON N BALANCE: FIRST RESULTS OF THE SMOCA PROJECT

EFFETTO DI UN SISTEMA AGRICOLO BIOLOGICO CONSERVATIVO SUL BILANCIO DELL'N: PRIMI RISULTATI DEL PROGETTO SMOCA

Giacomo Tosti[1*], Daniele Antichi[2], Paolo Benincasa[1], Simona Bosco[3], Christian Frasconi[2], Luigi Manfrini[4], Andrea Onofri[1], Marcello Guiducci[1]

[1] Dipartimento di Scienze Agrarie, Alimentari e Ambientali - Università degli Studi di Perugia, Borgo XX Giugno 74, 06121 Perugia, Italy
[2] Dipartimento di Scienze Agrarie, Alimentari e Agro-ambientali – Università di Pisa, via del Borghetto 80, 56124 Pisa, Italy
[3] Istituto di Scienze della Vita, Scuola Superiore Sant'Anna, via S. Cecilia, 3 56127 Pisa, Italy
[4] Dipartimento di Scienze Agrarie, Università di Bologna, V.le Fanin 44, 40127 Bologna, Italy.
*giacomo.tosti@gmail.com

Abstract
The SMOCA (Smart Management Organic Conservation Agriculture) project aims at integrating conservation agriculture and organic farming in three of the most representative scenarios in Italy: (i) arable field crops, (ii) field vegetables, (iii) tree fruit orchards. Maximising the advantages of organic and conservative systems has been pursued through the "intensification" of the "ecological efficiency" through smart and advanced techniques.
Innovative machines for cover crops (CC) termination, minimum tillage, direct seeding/transplanting and physical weed control have been made "ex-novo" on purpose or optimized for each scenario. Following a common scheme, three different cropping systems were compared by each research unit:
- Integrated control (INT): conventional integrated farming system (herbicides and agrochemicals allowed, ordinary soil tillage, no CC use);
- Traditional organic (ORG): organic farming system which includes reduced soil tillage, the use of CC, preventive and direct non-chemical weed control methods;
- Advanced organic (ORG+): deep integration between organic farming and conservative techniques. It includes a permanent green cover of the soil, no-tillage, physical weed control, the use of CC as living or dead mulches.
The study of the overall sustainability of the three systems included the following aspects:
- agronomical (e.g. yield, N uptake, weed development, product quality, etc.);
- environmental and energetic (e.g. greenhouse gas emissions, C and N balance, LCA, etc.).
In the present contribution, the N balance and the relevant agronomic implications for the DSA3 research unit will be presented and discussed.

Keywords: processing tomato; durum wheat; vegetable production; horticulture; N use efficiency; leaching; sustainability.
Parole chiave: pomodoro da industria, frumento duro, orticoltura; efficienza d'uso dell'N, lisciviazione; sostenibilità.

Introduction

Organic farming systems are considered not compatible with conservation tillage mainly because of the reliance of conservative systems on herbicides, to control increasing weed pressure in absence of inversion tillage, and mineral fertilisers, in order to obtain satisfactory yields with a reduced mineralisation rate (Peigné et al., 2007). Consequently, the integration of organic and conservative systems can be achieved only if two major issues are addressed: the availability of specific versatile and efficient machines for non-chemical CC management, weed control and sod-seeding/planting (Sartori and Rota, 2007); and the optimisation of cropping systems in function of improved nutrient cycling and preventive weed control. Nitrogen management in low input and organic farming systems relies indeed to a great extent on preventive measures such as the introduction of legumes and CC in the crop rotation, and the adoption of conservative soil tillage techniques (Thorup-Kristensen et al., 2003). The high environmental and economic costs of N management only based on extra-farm fertilisers are not sustainable in the long term (Pimentel et al., 2005). Thus, several strategies are adopted in order to increase (i) N-self-sufficiency and (ii) N use efficiency at the plant, crop and whole rotation scales (Dresbøll and Thorup-Kristensen, 2014; Benincasa et al., 2017). The main objectives of this study were to test the performances of conservative crop production under organic farming conditions (ORG+), practiced with intensive use of CC and innovative machines and to assess the effect of such system on N leaching and soil N stock as compared to a traditional organic (ORG) and to a conventional integrated (INT) cropping system.

Materials and Methods

The field experiment was carried out in three consecutive years (2013/14, 2014/15 and 2015/16) at the experimental station of DSA3. Weather data were collected by an automatic meteorological station located inside the experimental site. The

DOI 10.6092/unibo/amsacta/5692

crop rotation implemented in PG consisted of processing tomato, *Lycopersicon esculentum* Mill. cv. PS1296) followed by durum wheat (*Triticum durum* Desf. cv. Dylan). In each experimental year, both crop were grown alternately in two adiacent fields. In a randomized blocks design with two replications for each field, three cropping systems (treatments) at increasing ecological intensification were compared: (i) integrated system with no CC and conventional tillage technique (INT), (ii) organic system with green manures and conventional tillage (ORG), and (iii) innovative organic system with CC and conservation tillage techniques (ORG+). Processing tomato was preceded by bare soil in INT and by an autumn sown CC mixtures (barley 25%:field pea 75%) in ORG and ORG+. CC were terminated by cutting and incorporating the biomass into the soil (ORG) or by using a roller crimper and leaving the biomass as dead mulch (ORG+). Both crops were transplanted/sown after traditional (harrowing/spading) soil preparation (INT and ORG) or after strip tillage/no-tillage (ORG+). Wheat N fertility management was fully based on external inputs in INT (160 kg N ha^{-1} in two split applications) and ORG (40 kg N ha^{-1} broadcasted at pre-sowing as poultry manure), while it was based on natural N-fixing process in ORG+ by adopting a temporary intercropping (Tosti and Guiducci, 2010) wheat-faba bean (*Vicia faba* L sub minor). N nutrition of processing tomato was managed by fertigation using synthetic input in INT (full dose of 150 kg N ha^{-1}) and organic fertiliser in ORG and ORG+ (variable rates calculated as the complement to 150 kg N ha^{-1} of the pea N accumulation observed in the preceding CC). During the crop cycle N leaching was measured with porous lysimeter cups (details can be found in Tosti et al., 2014 and 2016). Biomass, yield and N% (Kjeldahl) of the plant material were recorded at harvest. A simple N apparent balance for each system, year and crop was calculated as follows:

$$N_B = N_I - N_R - N_L$$

where N_B represents the positive or negative variation of total N in the soil (residues included) at the end of each cropping cycle, N_I is the N input (fertiliser + N derived from atmosphere), N_R is the N removed with crop yield and N_L is the N lost with drainage water in the deep watershed. Data were anlysed by using a linear mixed model where the year, treatment and crop species were included as fixed effect and the plot was included as random effect to account for repeated measures. Data analisys was performed by using the *lme*() function within the *nlme* library (Pinheiro et al., 2017) in the statistical software R (R Core Team, 2017).

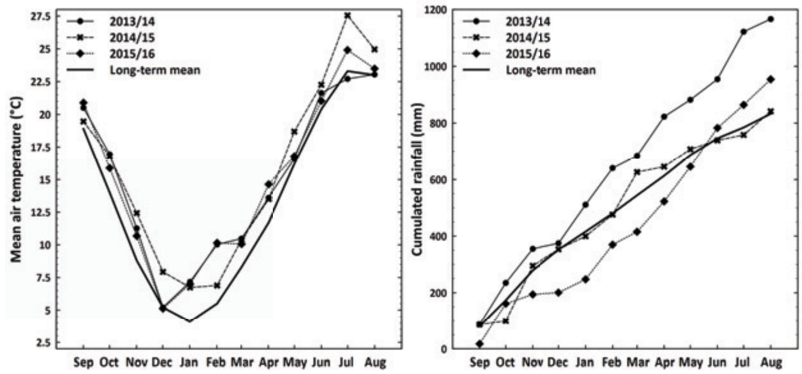


Fig. 1: Mean air temperatures (monthly values) and cumulated rainfalls recorded at the DSA3 experimental station during the 3-year experiment (2013-14, 2014-15 and 2015-16 comparing to the long-term mean over 1950–2015).
Figura 1: Temperatura media dell'aria (valori mensili) e precipitazioni cumulate registrate nella stazione sperimentale DSA3 durante l'esperimento triennale (2013-14, 2014-15 e 2015-16 rispetto alla media a lungo termine nel periodo 1950-2015).

Results and Discussion

WEATHER CONDITIONS

During the three years, mean air temperature was generally higher than the long-term mean (Fig. 1). Autumn and winter temperatures were particularly high during 2014/15. The amount of precipitation was variable during the experiment: cumulated rainfall were much higher (2013/14), similar (2014/15) or lower (2015/16) than the long-term mean. Thus drainage volumes were particularly high in 2013/14 and, due to a short period of intense rainfall in February/March, in 2014/15. On the contrary, drainage was low in 2015/16 because the autumn-winter period was unusually dry.

N APPARENT BALANCE

The interaction Year x Crop x Treatment was significant for both N_I ($p = 0.0120$) and N_R ($p = 0.0222$), so results are presented separately for each crop, year and treatment separated (Tab. 1). Considering wheat, N_I was constant in INT and ORG, while it varied in ORG+ depending on faba bean N accumulation. However, except for the third year, the N-fixing activity of the legumes supplied a low amount of N that was not different from the rate commonly supplied in ORG via

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

organic extra-farm source (poultry manure). N_I of processing tomato was kept rather constant across treatments, as fertigation technique allows an accurate management of the N dose with both organic or synthetic fertilizers. The main difference was that part of the total input was ensured in ORG and ORG+ by the N-fixing activity of the CC legume component (i.e. pea).

Tab. 1: N input (N_I) and N removed with crop yield (N_R) in the integrated (INT), traditional organic (ORG) and innovative organic (ORG+) systems during the 3-year experiment. Percentage values represent the amount of N derived from the atmosphere (via N-fixing activity of faba bean and pea) on N_I.
Tab. 1: N ingresso (N_I) e N rimosso con resa delle colture (N_R) nei sistemi integrato (INT), biologico tradizionale (ORG) e biologico innovativo (ORG +) durante i tre anni di sperimentazione. I valori percentuali rappresentano la quantità di N derivata dall'atmosfera (tramite l'attività di azoto-fissazione di fagiolini e piselli) su N_I.

		[illegible]		[illegible]	
		[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]		[illegible]	

Again, excepted for the third year, when both ORG and ORG+ performed quite bad, the N-fixing activity was better under ORG than ORG+ system, and that was mainly to be ascribed to the sod seeding that hampered the pea emergence. For both wheat and processing tomato, the N_R rankings among treatments was constant (i.e. INT>ORG>ORG+) across years. The higher N_I (100% extra-farm and synthetic N) of INT promoted higher yields and, as a consequence, higher N_R. The lower N_R of ORG+ was worsened by the higher presence of weeds compared to the other systems (data not shown).

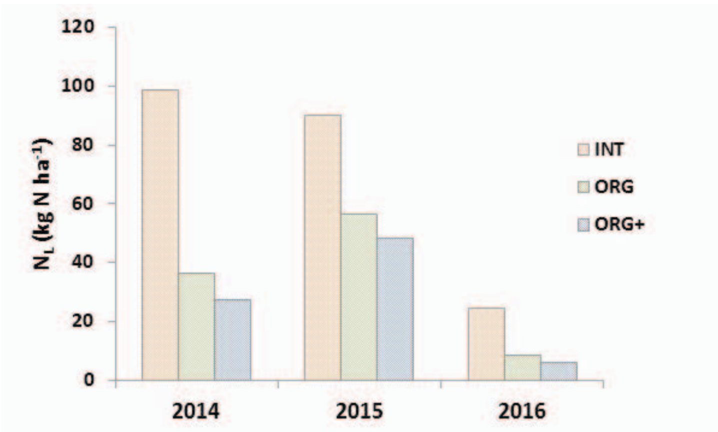


Fig. 2: N lost by leaching (N_L, kg N ha^{-1}) in the integrated (INT), traditional organic (ORG) and innovative organic (ORG+) systems during the 3-year experiment. SEM = 6.526.
Fig. 2: N persi per lisciviazione (NL, kg N ha^{-1}) nei sistemi integrato (INT), biologico tradizionale (ORG) e biologico innovativo (ORG +) durante i tre anni di sperimentazione. SEM = 6.526.

As expected, N_L was greatly influenced by the Year x Treatment interaction ($p = 0.0007$) (Fig. 2). The presence/absence of CC and the N rate were the most important factors that determined the N_L amount (Tonitto et al., 2006). The use of CC has strongly improved the ability of the agroecosystem to retain N and avoid that this resource is being lost by leaching. The biogeochemical cycles of carbon and N has been recoupled by the fertility building crop strategies (Gardner and Drinkwater, 2009), and, moreover, the conservation devitalization of the CC seemed to significantly decrease N_L compared to the traditional devitalization. However, a longer time span is needed in order to collect more reliable data on how this ecological service could be influenced. Concerning N_B, the Crop x Treatment interaction was significant ($p < 0.0001$). Wheat N_B was negative in all the three systems, while it showed important differences amongst treatment for processing tomato (Fig. 3). INT performance in terms of N_B was dramatically influenced by the high N_L in 2013/14 and the high N_R in 2014/15, thus both crops left a rather high debt in terms of N_B. Crop species had a contrasting effect in ORG and ORG+:

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA. Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

N_B was, in fact, negative in wheat and positive in processing tomato. As N_I and N_L were similar in ORG and ORG+, the lower N_B values in ORG have to be ascribed to the higher N_R as compared to ORG+. Even if the low N_R (i.e. yield) represents a weak point of ORG+, such system confirmed to be the most sustainable in terms of soil N fertility improvement. Research of innovative tools for weed and crop management should be a primary objective for coupling organic and conservation agriculture.

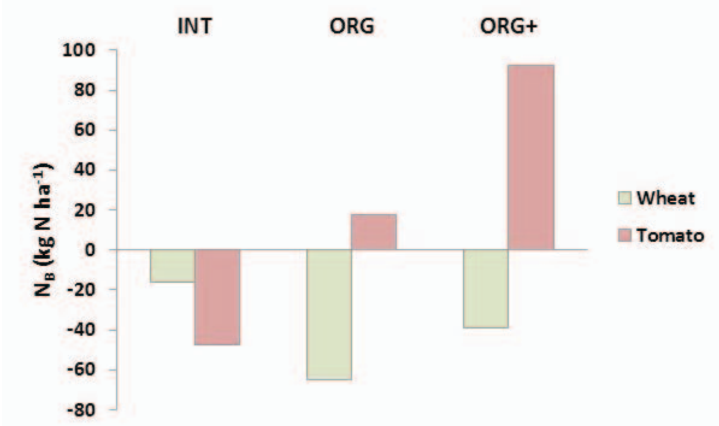


Fig. 3: N balance (N_B kg N ha^{-1}) in the integrated (INT), traditional organic (ORG) and innovative organic (ORG+) systems during the 3-year experiment. SEM = 9.615.
Fig. 3: Bilancio dell'azoto (NB kg N ha^{-1}) nei sistemi integrato (INT), biologico tradizionale (ORG) e biologico innovativo (ORG +) durante i tre anni di sperimentazione. SEM = 9.615.

Conclusions
N management could be improved strongly in organic systems by intensive use of fertility building crops, which also strongly reduced its losses to the environment. Conservation organic agriculture has proved to be an excellent system to build up the "N stock", but further research is needed in order to understand and deal with the implications of such system on cash and cover crops performance.

Acknowledgements
Research funded by MIUR FIRB 2013 – Project SMOCA (2014-2017) (Smart Management of Organic Conservative Agriculture). Project coordinator Christian Frasconi.
We wish to thank Dr. Marco Fernando Manco and Dr. Paolo Mucci for their support with the field activities.

References

Benincasa P., Tosti G., Guiducci M., Farneselli M., Tei F., 2017. Crop Rotation as a System Approach for Soil Fertility Management in Vegetables. In: Advances in Research on Fertilization Management of Vegetable (Francesco Tei, Silvana Nicola, Paolo Benincasa Editors). Springer International Publishing. doi: 10.1007/978-3-319-53626-2

Dresbøll, D.B., Thorup-Kristensen, K., 2014. Will breeding for nitrogen use efficient crops lead to nitrogen use efficient cropping systems? A simulation study of GxExM interactions. Euphytica 199, 97–117. doi:10.1007/s10681-014-1199-9

Gardner, J.B., Drinkwater, L.E., 2009. The fate of nitrogen in grain cropping systems: a meta-analysis of N-15 field experiments. Ecological Applications. 19:2167-2184.

Peignè J., Ball B.C., Roger-Estrade J., David C., 2007. Is conservation tillage suitable for organic farming? A review. Soil Use and Management 23, 129-144.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Seidel, R., 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience 55, 573–582.

Pinheiro J., Bates D., DebRoy S., Sarkar D., R Core Team, 2017. nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-131, https://CRAN.R-project.org/package=nlme.

R Core Team, 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Sartori L., Rota M., 2007. Valutazione tecnica ed economica: risultati di prove in campo. In Agricoltura Blu, a cura di Michele Pisante, 287-316, Edagricole.

Thorup-Kristensen K., Magid J., Jensen L.S., 2003. Catch crops and green manures as biological tools in nitrogen management in temperate zones. Adv. Agron. 79, 227-302.

Tonitto, C., David, M.B., Drinkwater, L.E., 2006. Replacing bare fallows with cover crops in fertilizer-intensive cropping systems: A meta-analysis of crop yield and N dynamics. Agric. Ecosyst. Environ. 112, 58–72. doi:10.1016/j.agee.2005.07.003

Tosti, G., Benincasa, P., Farneselli, M., Tei, F., Guiducci, M., 2014. Barley-hairy vetch mixture as cover crop for green manuring and the mitigation of N leaching risk. Eur. J. Agron. 54, 34–39. doi:10.1016/j.eja.2013.11.012

Tosti, G., Farneselli, M., Benincasa, P., Guiducci, M., 2016. Nitrogen Fertilization Strategies for Organic Wheat Production: Crop Yield and Nitrate Leaching. Agronomy Journal 108, 1–12. doi:10.2134/agronj2015.0464

Tosti, G., Guiducci, M., 2010. Durum wheat-faba bean temporary intercropping: Effects on nitrogen supply and wheat quality. Eur. J. Agron. 33, 157–165. doi:10.1016/j.eja.2010.05.001

TRICHODERMA INOCULATION CAN IMPROVE YIELD AND QUALITY OF LEAFY VEGETABLES UNDER DIFFERENT N AVAILABILITY CONDITIONS

EFFETTO DEL TRICHODERMA SU PRODUZIONE E QUALITA' DI ORTAGGI DA FOGLIA IN FUNZIONE DELLA DISPONIBILITA' AZOTATA

Nunzio Fiorentino, Youssef Rouphael, Armando De Rosa, Eugenio Cozzolino, Vincenzo Cenvinzo, Maria Giordano, Laura Gioia, Sheridan Woo, Massimo Fagnano

Dipartimento di Agraria, Università di Napoli, Via Università 100, 80055, Portici
*nunzio.fiorentino@unina.it

Abstract

N fertilizer excess can cause the accumulation of high levels of nitrate in leafy vegetables, mainly when grown under reduced light levels, exposing consumers to important health risks. Appropriate agronomic practices can limit nitrate accumulation in vegetables and increase their quality, while producing optimal yields with low N inputs. In this work we report the results of two greenhouse experiments aimed at testing the effect of two *Trichoderma* strains (*T. harzianum* T22 and *T. virens* GV41) on lettuce and rocket quality under different N availability conditions. Both strains resulted in higher lettuce marketable yields (+19%) under optimal fertilization compared to the no inoculated control, while *T.virens* GV41 resulted in higher yields (+34% on the average) for both crops under low N availability conditions. Trichoderma inoculation with both strains enhanced total ascorbic acid in lettuce compared to the control and also in rocket at optimal and very high levels of nitrogen.

Keywords: *Trichoderma*; lettuce; rocket; nitrate; ascorbic acid
Parole chiave: *Trichoderma*, lattuga; rucola; nitrati; acido ascorbico

Introduction

Nitrate is the main nitrogen (N) source for most vegetables and a significant number of them, in particular leafy vegetables, require large quantities of nitrate fertilizer for ensuring maximum yield (Marschner, 1994). Balancing the amount of N required for optimum growth and development while minimizing the nitrate losses in surface and ground water represents a major sustainability challenge, since many vegetable growers are dealing with higher fertilizers costs, as well as restrictions and regulations imposed by several European countries. One of the most important and innovative approaches to tackle this important challenge is to use naturally derived biostimulants, which are gaining importance globally (Colla and Rouphael 2015). As defined by du Jardin (2015), plant biostimulants (PBs) correspond '*to any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients conten*t'. Trichoderma is a genus of saprotrophic fungi that have also been reported to promote plant growth, in addition to their biocontrol activities, acting by either the production of antimicrobial compounds or the parasitism of fungal plant pathogen (Lopez-Bucio et al., 2015). Some *Trichoderma* strains have a predominant biostimulant action, that make them interesting for their use in vegetables crop production (Lopez-Bucio et al., 2015). Two greenhouse experiments, one on lettuce (*Lactuca sativa* L.) and the other on rocket (*Diplotaxis tenuifolia* L) were carried out to assess the effectiveness of two *Trichoderma* strains under different N availability conditions. Inoculated and non inoculated plants were compared in terms of yield, yield components and nutritional quality of these two important and representative leafy vegetables.

Materials and Methods

Two consecutive experiments were conducted in the 2016 growing season from February 2nd to March 31st (experiment 1) and from June 13th to July 11th (experiment 2) in a 240 m^2 polyethylene greenhouse located in Portici (Campania region, Southern-Italy). In experiment 1 *Lactuca sativa* var. iceberg cv. Silvinas (lettuce) was transplanted in double rows with a density of 11 pt m^2, while in experiment 2 *Diplotaxis tenuifolia L* (rocket) was sowed with a density of 3000 seed m^{-2}.

In both experiments, an optimal fertilization (100N) of 90 kg N ha^{-1} for lettuce and 60 kg N ha^{-1} for rocket was compared to a non-fertilized control (0N) and an excess N-dose (200N) of 180 kg N ha^{-1} for lettuce and 120 kg N ha^{-1} for rocket. Two biostimulants containing a spore suspension (1×10 sp ml^{-1}) of different *Trichoderma* strains (*T. harzianum* T22 and *T. virens* GV41, labelled as T1 and T2, respectively) were compared to a non-inoculated control (T0). Biostimulant application to lettuce was done at transplanting (root dip) and during the crop cycle (24 days after transplanting, by watering with 50 ml $plant^{-1}$), while a seed treatment was done for rocket. A split-plot design with 3 replicates (randomized blocks) was adopted with fertilization (3 levels) as main factor and *Trichoderma* inoculation (3 levels) as sub-factor. The same experimental layout (blocks and plots) was adopted in both experiments.

Marketable and unmarketable yield were measured on 1 m^2 reference area within each plot 60 days after transplanting for lettuce and 30 days after seeding for rocket.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

In both experiments, the dried leaf tissues were finely ground in a mill (IKA, MF10.1, Germany) to pass through a 0.5-mm sieve. Nitrate were extracted from 250-mg samples with deionized water at 80 °C in a shaking water bath for 10 min. The resulting solution was filtered, diluted, and analyzed by ion chromatography (ICS-3000, Dionex, USA). An IonPac AG11-HC guard column and IonPac AS11-HC analytical column were used (Dionex) for nitrate determination. The total ascorbic acid defined as ascorbic acid (ASA) and dehydroascorbate (DHA) acid was assessed by spectrophotometric detection on fresh plant tissues as reported by Kampfenkel et al. (1995). The absorbance of the solution was measured at 525 nm, and data were expressed as mg of ascorbic acid on 100 g fresh weight. All data were subjected to ANOVA and means separated according to LSD test ($p<0.05$).

Results and Discussion

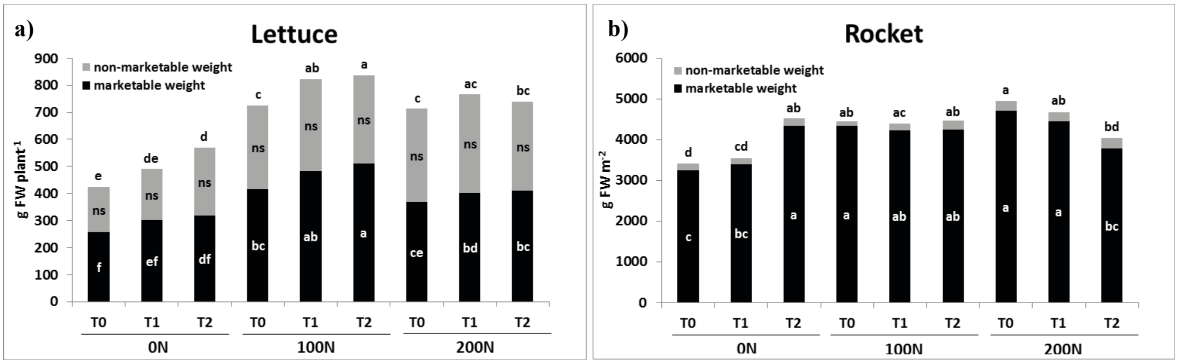


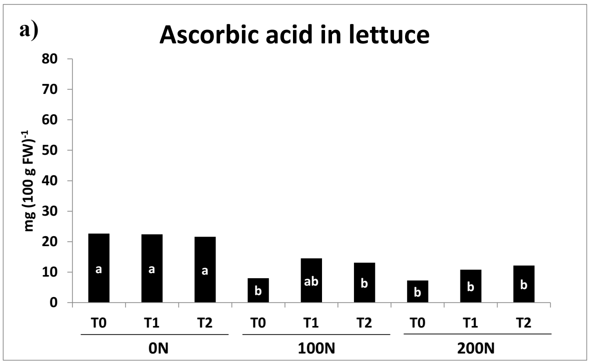
Figure 1. Effect of fertilization doses and biostimulants on lettuce (a) and rocket (b) marketable (black bars) and non-marketable (grey bars) yield. 0N: non-fertilized control; 100N: 90 and 60 kg N ha^{-1} for lettuce and rocket, respectively; 200N : 180 and 120 kg N ha^{-1}for lettuce and rocket, respectively; T0: non-inoculated control; T1: biostimulant containing T. harzianum; T2: biostimulant containing T.virens. Different letters within each column indicate means different at p<0.05. Letters at the top of the bars are referred to total yield. n.s: not significant.

Figura 1. Effetto della fertilizzazione e dei biostimolanti sulla produzione commerciale (barre in nero) e sullo scarto (barre in grigio) di lattuga (a) e rucola (b). 0N: non concimato; 100N: 90 and 60 kg N ha^{-1} per lattuga e rucola, rispettivamente; 200N: 180 and 120 kg N ha^{-1} per lattuga e rucola, rispettivamente; T0 non inoculato; T1 biostimolante contenente T. harzianum; T2: biostimolante contenente T.virens. Lettere differenti indicano medie differenti per ciascuna variabile (p<0.05). Le lettere posizionate all'estremità alle barre sono riferite alla produzione totale. n.s: non significativo

Biostimulants containing *Trichoderma* positively affected lettuce (Fig.1a) and rocket (Fig.1b) yield compared to T0 in non fertilized plots, while yield response to biostimulants varied between the two crops when fertilizers were applied. In absence of external N inputs (0N), T2 increased total yield by 34% for both lettuce and rocket, respectively; marketable yield followed the same pattern for rocket while no effect was recorded for lettuce with an average commercial weight of 292 g FW plant^{-1}. These results are probably due to the positive effects of *Trichoderma* in enhancing root N uptake under sub optimal conditions (Marschner, 1994). No increase in yields was recorded for both crops when an excess N dose was applied.

No biostimulant effect was recorded for rocket under optimal N supply (100N), while an average increase was recorded in lettuce total (+14%) and marketable (+19%) yield compared to 100N-T0. The excessive N dose (200N) was not different from 100N-T0 for both crops. In addition 200N significantly suppressed biostimulant effect on rocket marketable yield with values lower than T0 (4707 vs 3786 g FW m^{-2} for 200N-T0 vs 200N-T2, respectively), while values recorded for lettuce with 200N-T2 (409 g FW plant^{-1}) were found significantly lower than 100N-T2 (509 g FW plant^{-1}). The different response of the two crops to biostimulants in fertilized plots was probably due to the length of the growth cycle who allowed a more marked effect in lettuce (60 days cycle) than in rocket (30 days cycle). A different root-Trichoderma interaction in the two tested crops cannot be excluded.

The nitrate content was not significantly influenced by biostimulant and N applications. Generally, nitrate accumulating leafy vegetables belong to the families of *Brassicaceae*, *Chenopodiaceae*, and also *Asteraceae* (Santamaria, 2006). This was also the case in the present study, where the highest nitrate accumulating leafy crop was rocket (3251.2 g kg^{-1} DW on the average), a known hyper-accumulator species (Santamaria et al. 2002) belonging to the family of *Brassicaceae*, whereas the values were lower in lettuce (1614.2 g kg^{-1} DW on the average). On the whole, values were below the maximum threshold of nitrates (2500 mg NO_3^- kg^{-1}) imposed by Commission Regulation (EC) No 1881/2006 for lettuce as well as for rocket (6000 mg NO_3^- kg^{-1} FW in summer-grown rocket or 7000 mg NO_3^- kg^{-1} FW in winter-grown rocket).



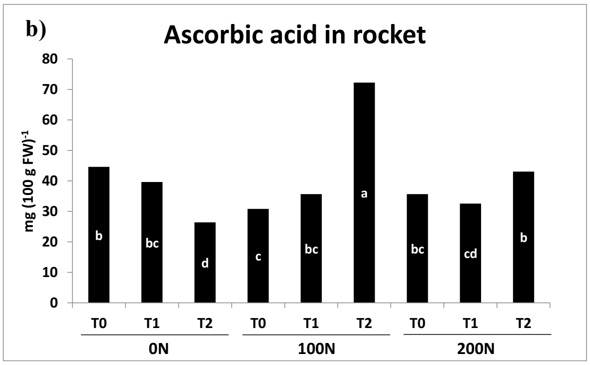


Figure 2. Effect of fertilization doses and biostimulants on Ascorbic acid content in lettuce (a) and rocket (b) leaves. 0N: non-fertilized control; 100N: 90 and 60 kg N ha^{-1} for lettuce and rocket, respectively; 200N : 180 and 120 kg N ha^{-1}for lettuce and rocket, respectively; T0: non-inoculated control; T1: biostimulant containing T. harzianum; T2: biostimulant containing T.virens. Different letters indicate means different at p<0.05.

Figura 2. Effetto della fertilizzazione e dei biostimolanti sul contenuto di Acido ascorbico nelle foglie di lattuga (a) e rucola (b). 0N: non concimato; 100N: 90 and 60 kg N^{1}ha^{-1} per lattuga e rucola, rispettivamente; 200N : 180 and 120 kg N ha^{-1} per lattuga e rucola, rispettivamente; T0 non inoculato; T1 biostimolante contenente T. harzianum; T2: biostimolante contenente T.virens. Lettere differenti indicano medie differenti (p<0.05).

Many leafy vegetables are regarded as a good source of vitamin C. The total ascorbic acid (AA) content, including ascorbic and dehydroascorbic acid, of the two leafy vegetables tested varied widely (figure 2). In experiment 1 the total ascorbic acid of lettuce ranged from 7.2 to 22.6 mg 100 g^{-1} FW whereas in experiment 2 the total ascorbic acid ranged from 2.4 to 72.7 mg 100 g^{-1} FW. In both experiments, the application of biostimulant and N doses affected significantly the total ascorbic acid content. In experiment 1, the absence of N application exhibited the highest total ascorbic acid values irrespective of *Trichoderma* inoculation. Under optimal N supply (100N) the inoculation of T1 improved significantly the quality of lettuce leaves in comparison to T2 and non-inoculated plants. Finally, in rocket the application of 100N combined with inoculation with T2 could be considered an effective and sustainable way to biofortify the leaf quality of rocket since the total ascorbic acid was two-fold compared to the other treatments.

Conclusions

Recommended N doses for leafy vegetables allow the highest marketable yield, while an excessive N fertilization does not provide any yield benefit. Biostimulants containing *Trichoderma* can significantly increase yields in crops with a medium length cycle as lettuce when recommended N dose is applied. Our results also demonstrated that specific *Trichoderma* strains can enhance the nutritional quality of both leafy vegetables (i.e. higher total ascorbic acid content). Nitrate accumulation in lettuce and rocket leaves may not be a problem in Mediterranean cropping systems even when an excessive N dose is applied, meaning that in some soils with high N native availability the risk of contamination of groundwater could be the main concern instead of food security.

References

G. Colla, Y. Rouphael, 2015. Biostimulants in horticulture. Scientia Horticolturae 196, 1–2.

P. du Jardin P, 2015. Plant biostimulants: definition, concept, main categories and regulation. Scientia Horticolturae 196:3–14

J. Lopez-Bucio, R. Pelagio-Flores, A. Herrera-Estrella, 2015. Trichoderma as biostimulant: exploiting the multilevel properties of a plant beneficial fungus. Scientia Horticulturae 196: 109-123.

H. Marschner, B. Dell, 1994. Nutrient uptake in mycorrhizal symbiosis. Plant Soil, 159: 89-102.

P. Santamaria, A., Elia, F. Serio, 2002. Effect of solution nitrogen concentration on yield, leaf element content, and water and nitrogen use efficiency of three hydroponically-grown rocket salad genotypes. Journal of Plant Nutrition, 25, 245–258.

P. Santamaria, 2006. Nitrate in vegetables. Journal of the Science and Food and Agriculture, 86, 10–17.

DOI 10.6092/unibo/amsacta/5692

PHENOLOGICAL LONG-TERM TREND IN MAIZE IN RESPONSE TO TEMPERATURE CHANGES IN NORTHEAST ITALY

ANDAMENTI DELLA FENOLOGIA DEL MAIS NEL LUNGO TERMINE IN RISPOSTA AL CAMBIAMENTO DELLE TEMPERATURE IN NORD ITALIA

Antonio Berti[1], Alessandra Bonammano[1], Carmelo Maucieri[1*], Maurizio Borin[1]

[1] Dipartimento di Agronomia Animali Alimenti Risorse Naturali e Ambiente, Università di Padova, Viale dell'Università 16, 35020, Legnaro (PD)
*carmelo.maucieri@unipd.it

Abstract

Using data on maize phenology collected during 2005-2007 in a network of 6 stations scattered over the Veneto plain (NE Italy), linear regression, hyperbole and piecewise were used to identify the best fitting for the relationship BBCH versus ΣGDD. Piecewise gave the best performance. The response of the maize phenology to thermal sum was described by two lines with different slopes, having an angular coefficient of 0.07 from sowing to BBCH 70 (beginning of fruit development) and 0.03 from BBCH 70 to harvest. On the basis of the piecewise equation, the ΣGDD were calculated for the corresponding selected BBCH stages (09, 39, 60, 73, 83, and 89). These values have then been used to reconstruct the long-term (1956-2007) evolution of phenology considering that long-period temperature trend was characterized by a breakpoint in 1990, with the average temperature of April-October being 17.5 °C prior to 1990 and 18.8 °C in the following sub-period. Due to the increase of average temperature an anticipation of about 10 days was already estimated at stage 09 and on average, the growing cycle duration was shortened by 9 days.

Keywords: maize; climate changes; phenology.
Parole chiave: mais; cambiamenti climatici; fenologia.

Introduction

A rising air temperature trend has been found around the world during the last decades with a general increase in growing season length and this trend is predicted to accelerate in the future (Tao et al., 2006). The relationship between air temperature changes and variations in the timing of phenological stages of cultivated plants plays a key role for crop management. In fact, changes in the appearance of phenophases could be of great economic importance, because the efficacy of agronomic techniques differs in relation to the phenological stage at which they are applied. To predict crop responses to climate change, it is necessary to know how crops have responded to changes in the past. Unfortunately, only a few phenological records are of sufficient length to show any response to natural climate variability, not only across Europe but also in Italy. For this purpose a regional phenological network was created in Veneto Region, Northeast Italy, during 2005-2007 in order to support farm management at local scale and obtain data for agro-environmental studies. This network concentrated on the most important crops of the Region: maize, winter wheat and grapes.
The aim of this study is to analyze the response of maize phenology to temperature at regional scale and then reconstruct the phenological trend during 1956-2007.

Materials and Methods

Maize (FAO 500 and FAO 600) phenological data collected by the regional network during 2005-2007 were combined with temperature data to analyze the relationship between BBCH stages describing phenology and thermal sum. The phenological network consisted of seven sites well scattered over the plain in the Veneto region where an observation field was selected in each site to monitor the phenological phases. Each maize growth stage was recorded based on the BBCH scale. Daily mean air temperature in the period April-October 2005-2007 were recorded through arpav stations. The relationship between BBCH stages describing phenology and thermal sum has been used to identify the Growing Degree Days (GDD) corresponding to the most significant growth stages. Using these values, the long-term (1956-2007) evolution of phenology has lastly been reconstructed. In each location and year the thermal sum (ΣGDD) was calculated setting the base temperature at 8 °C (Cicchino et al., 2000). For both FAO class 500 and FAO classes 600 BBCH values were used to calculate linear regressions between BBCH and ΣGDD. The same phenological dataset was then used to identify the best equation, among linear, hyperbole and piecewise models, to describe the relationship between FAO classes and ΣGDD. The best equation was then used for a further analysis to identify the GDD at which the most important phenological stages were reached. The daily air temperature data of the 1956-2007 period from six representative weather stations of Veneto region were averaged and seasonal mean temperature was calculated for every year. These data were used to analyze the time trend with linear regression and also applying a discontinuity analysis to investigate if and when there was a breakpoint in the temperature series. In order to reconstruct the maize phenological cycles from 1956 to 2007 a theoretical sowing date has been calculated for each year and site assuming that the sowing occurred on the first day of the year after

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

at least ten consecutive days with a daily mean temperature higher than 10°C (Stone et al., 1999). Afterwards, the ΣGDD corresponding to the selected phenophases was used to identify the Julian date of the appearance of the main development stages in every year and location to obtain the time series.

Risults and Discussion

Average maximum and minimum temperature in Veneto region, in the period 1956-2007, were 16.8° and 6.8°C respectively with the most marked change in air temperature occurred at the end of the 1980s. The linear regressions between BBCH and ΣGDD were significant for both FAO classes but the F-test on the regressions was not significant between classes. The piecewise analysis gave the best fitting of the observed data showing that the crop phenology response to thermal sum is characterized by two lines with different slopes (Figure 1), confirming that the linear approach to the thermal sum is not completely realistic for maize (Streck et al., 2008). The change of slope takes place around BBCH 70 (beginning of fruit development), suggesting that the early stages of the growing cycle are more sensitive to air temperature (Wang et al., 2008). On the basis of the piecewise equation, the following ΣGDD were identified for the corresponding BBCH selected stages: 61 for BBCH 09, 468 for BBCH 39, 753 for BBCH 60, 1044 for BBCH 73, 1378 for BBCH 83 and 1578 for BBCH 89.

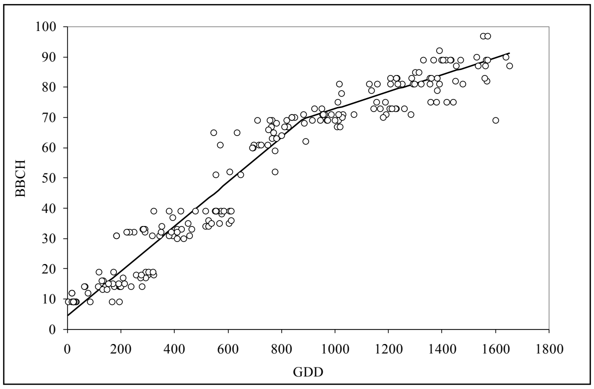


Fig.1: Piecewise regression between BBCH stage and GDD for all the phenological data.
Fig.1: Regressione piecewise tra gli stadi fenologici BBCH e la somma termica

During 1956-2007 two sub-periods with different temperatures can be identified with a breakpoint around 1990. The average temperature was 17.5 °C prior 1990 and 18.8 °C in the following sub-period. Taking the 1990 breakpoint, the seasonal mean temperature for every meteorological location was calculated for the two sub-periods ante and post breakpoint. Due to the temperature increase, the theoretical sowing date showed a progressive anticipation (1.1 day every 10 years). On average, all BBCH stages were reached earlier after the breakpoint. In particular an anticipation of about 10 days was already clear at stage 09 and was constant until stage 60. Since stage 60 (beginning of flowering) is recognized as the critical phase for water stress, its anticipation by 10 days might lead to the irrigation season being anticipated in dry years or to a reduction in the seasonal irrigation demand if there is sufficient rainfall in the spring. Afterwards the earlier appearance became more marked during the final stages (21 days at the end of the growing cycle) and this implies an earlier harvest. On the average, the growing cycle duration shortened by 9 days almost all due to a reduction in the duration of the 73-89 inter phase. As expected, the reduction in growing cycle duration was more marked in the locations where the higher temperature increases were detected and on average the seasonal increase of 1 °C shortened the cycle by 16 days.

Conclusions

Early sown FAO class 500 cultivars and late sown 600 of maize had a similar response to the thermal sum. The response of BBCH values to the thermal sum was characterized by a discontinuous model composed of two lines with different slopes. The efficacy of temperature in the stimulation of plant development is higher in the vegetative-early reproductive phases. This study showed an increase in temperatures across the Veneto plain during the period 1956-2007 with a breakpoint year of the mean temperature during the maize growing season (April to October) around 1990. Considering the average trend of the simulations, the increased temperatures shortened the ripening phase and reduced the length of the growing season by 9 days. Although these simulations of the adaptation of maize phenology in relation to changed temperature do not consider the possible effects of changes of cultivar over the years, the results suggest that the anticipation and shortening of phenophases might lead to practical consequences, such as the modification of irrigation management and harvest date.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

References

Cicchino, M., Rattalino, Edreira, J.I., Otegui, M.E., 2000. Heat Stress during Late Vegetative Growth of Maize: Effects on Phenology and Assessment of Optimum Temperature. Crop Sci., 50, 1431-1437.

Stone, P.J., Sorensen, I.B., Jamieson, P.D., 1999. Effect of soil temperature on phenology, canopy development, biomass and yield of maize in a cool-temperate climate. Field Crops Res., 63, 169-178

Streck, N. A., Lago, I. Fernandes, G. L., Samboranha, F. K., 2008. Simulating maize phenology as a function of air temperature with a linear and a nonlinear model. Pesq. Agropec. Bras., 43, 449-455 .

Tao, F., Yokozawa, M., Xu, Y., Hayashi, Y., Zhang, Z., 2006. Climate changes and trends in phenology and yields of field crops in China, 1981–2000. Agr. For. Meteorol., 138, 82-92

Wang, H.L., Gan, Y.T., Wang, R.Y., Niu, J.Y., Zhao, H., Yang, Q.G., Li, G.C., 2008. Phenological trends in winter wheat and spring cotton in response to climate changes in nortwest China., Agr. For. Meteorol. 148, 1242-1251

DATAMETEONOW REALTIME STORM TRACK VALIDATION PLATFORM

DATAMETEONOW PIATTAFORMA DI NOWCASTING TEMPORALI CON VALIDAZIONE REALTIME

Michele De Rosa[1] , Gabriele Ghibaudo*[2], Cristian Rendina[3], Stefania Roà[4]

[1] Geo-K Srl satellite remote sensing.Via del Politecnico 1, 00133 Roma
[2,] CEO LRC Servizi srl powering Datameteo.com, Via Piave 4/c 12022 Busca CN
[3,4] Meteorologo LRC Servizi srl powering Datameteo.com, Via Piave 4/c 12022 Busca CN

[1]info@geok.co [2,3,4]info@datameteo.it

Abstract
DatameteoNOW Storm Track is one of the component of MeteoBrowser 2, our new 2D-3D geolocated content delivery system that can display all types of real-time weather information, high resolution weather model maps, fire and weather alerts. The extensive family of our weather data services (data, forecast, sat, webcams) offered, combined into a single web-based product platform with the addition of the Storm Tracking capability, is a milestone for the nowcasting. This feature, interfaced with an innovative realtime output validation system, is able to calibrate and validate the outputs at the same time.

DatameteoNOW Storm Track è uno dei componenti di MeteoBrowser 2, il nostro nuovo sistema geolocalizzato di distribuzione di contenuti 2D-3D in grado di visualizzare tutti i tipi di informazioni meteorologiche in tempo reale, mappe da modelli meteo ad alta risoluzione, allerte ed avvisi meteo. L'integrazione di questo prodotto di nowcasting, sviluppato con GEOK nella filiera di offerta meteorologica, rappresenta una pietra miliare nel settore del nowcast, interfacciato con un innovativo sistema di validazione realtime, in grado di validare gli output e minimizzare gli errori della sorgente satellitare utilizzata.

Parole chiave: nowcasting temporali, evoluzione breve termine temporali, previsione temporali, fulminazioni
Keywords: storm track nowcasting, storm short-term forecast, satellite t-storm scanning, lightning

Introduction
La piattaforma Storm Track permette la rilevazione, il monitoraggio e la previsione della convezione all'interno di una cella, utilizzando una combinazione di canali satellitari dal visibile all'infrarosso. L'algoritmo funziona con i canali satellitari per rilevare la base (individuazione iniziale) e la sommità delle nubi (Kolios e Feidas, 2010), approssimando l'oggetto convettivo ad una forma convessa.
La piattaforma al momento copre la zona esaminata dai satelliti Meteosat (Europa, Africa, Eurasia).

Fig.1: Attuale area di copertura del servizio Strom Track Browser che utilizza i satelliti Meteosat.
Fig.1: Actual Strom Track Browser Area Coverage.

L'innovazione del progetto e il contenimento dei costi, delle risorse informatiche e delle tempistiche di elaborazione, rendono il prodotto altamente scalabile e configurabile.
La piattaforma consente la rilevazione, il monitoraggio e la previsione della convezione all'interno di una cella, definendo la forma, la dimensione e l'evoluzione delle nubi, con un'intuitiva combinazione di colori (il **giallo** indica la fase di innesco**,** l'**arancio** la crescita**,** il **blu** la fase matura, il **viola** la sua dissipazione). Una recente innovazione è stata quella di integrare

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

nella piattaforma il dato di **fulminazione** proveniente da reti di parti terze, sia a fine di **validazione**, sia di incremento dell'**accuratezza**. (Fig. 2)

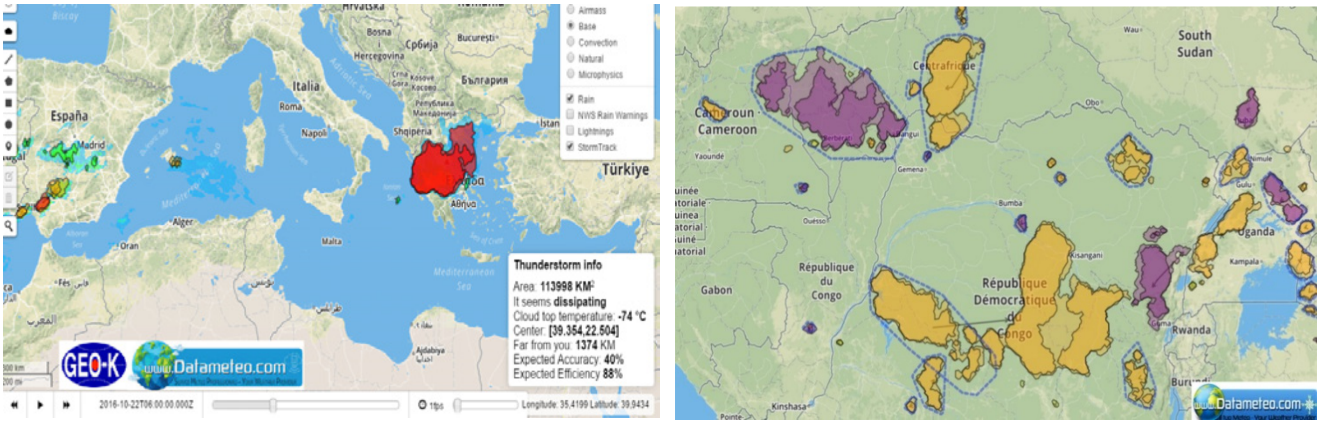


Fig. 2: a) Rappresentazione del potenziale convettivo con una intuitiva scala di colori e tracking delle celle. b) Dettaglio della rappresentazione del potenziale convettivo con una intuitiva scala di colori e tracking delle celle. Le linee tratteggiate rappresentano la prevista evoluzione della cella temporalesca.
Fig. 2: a) Image showing the convective cells potential put in evidence by an intuitive color scale and the T-storm tracking. B) Image showing the convective cells potential details put in evidence by an intuitive color scale and the T-storm tracking. The dashed lines are the cell forecasted evolution.

Materials and Methods

L'algoritmo, oltre ad un'intuitiva visualizzazione, propone la possibilità di conoscere per ogni cella attiva alcune importanti informazioni di tipo numerico quali: area di sviluppo in km^2, centroide della stessa, temperatura della sommità della nube in °C, distanza dal punto della propria geolocalizzazione. Due indici statistici completano il quadro dei dati disponibili (Fig. 3).

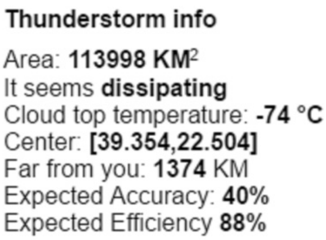


Fig. 3: Output numerici della piattaforma disponibili per ogni cella attiva rilevata dal sistema di Storm Tracking.
Fig. 3: Numerical output available for each convective cell detected by the Storm Tracking platform.

Gli indici statistici che indicano l'Accuratezza ed Efficienza attesa (Expected Accuracy and Efficiency) non sono tanto utili a livello di validazione, ma sono interessanti per la calibrazione stessa dell'algoritmo. Infatti gli stessi danno un'idea dell'accuratezza (non statistica assoluta) come parametro di riferimento di detect della cella convettiva, in una data ora e luogo, rispetto ad una base statistica.
Lo stesso dicasi in linea generale per l'efficienza attesa. Questo indice ci fornisce un parametro di "reattività dell'algoritmo" nel rilevare la cella convettiva in una determinata posizione spazio-temporale.
Con l'aumentare degli archivi di dati a disposizione, confrontabili con i report realtime, saremo in grado di operare dei training mirati sull'algoritmo, al fine di predisporre delle calibrazioni stagionali.
Un ampio studio di validazione su di una vasta regione (Fig.4) che divide l'Europa in 10 sub-regioni, è disponibile con dati che vanno dal 22 Giugno 2015 al 13 Luglio 2016. I dati del mese di Dicembre 2015 sono stati esclusi per problemi di elaborazione.
La sorgente utilizzata per la validazione è stata la rete di fulminazione ATDNET con il dato di fulminazione rilevato in una finestra da 5 minuti prima sino a 10 minuti dopo la finestra dello Slot del dato Meteosat aggiornato ogni 15 minuti. La tipologia di fulminazione considerata è quella dei fulmini C-G, ovvero cielo-terra.

Fig. 4: Area oggetto del processo di validazione con Europa divisa in 10 sub-regioni.
Fig. 4: Area for validation process divided in 10 sub-regions.

Come piattaforma per la validazione è stato utilizzato il tool MET (Meteorological Evaluation Tool), che è universalmente utilizzato per la validazione nell'ambito della modellistica meteorologica. Qui sotto viene sintetizzato nel digramma il processo di uniformazione, controllo e validazione.

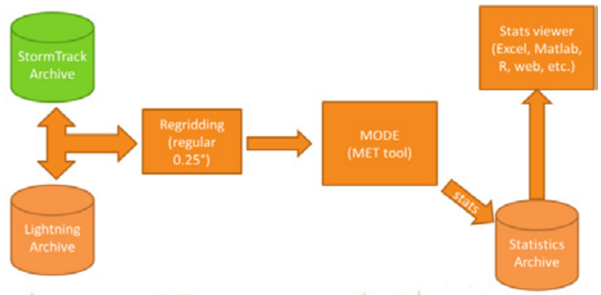


Fig. 5: Diagramma che illustra il processo di uniformazione, controllo e validazione del dato.
Fig. 5: Diagrams showing the validation check approach used.

Al fine di meglio rappresentare il processo di validazione abbiamo scelto di utilizzare due tipologie di indicatori:
- Probability of Detection (POD), cioè la capacità dell'algoritmo di individuare una cella convettiva;
- False Alarm Ratio (FAR) l'ammontare di allarmi relativi a celle convettive non correttamente rilevate.

Forecast	Observation		Total
	O=1 (e.g. "Yes")	O=0 (e.g. "No")	
f = 1 (e.g., "Yes")	n_{11}	n_{10}	$n1. = n_{11} + n_{10}$
f = 0 (e.g., "No")	n_{01}	n_{10}	$n0. = n_{01} + n_{00}$
Total	$n_{.1} = n_{11} + n_{01}$	$n_{.0} = n_{10} + n_{00}$	$T = n_{11} + n_{10} + n_{01} + n_{00}$

Fig. 6: Indici oggetto del processo di validazione: Probability of Detection (POD), False Alarm Ratio (FAR).
Fig. 6: Validation Index: Probability of Detection (POD), False Alarm Ratio (FAR).

- Probability of detection (POD)

$$POD = \frac{n_{11}}{n_{11}+n_{01}} = \frac{n_{11}}{n_{.1}}$$

- False alarm ratio (FAR)

$$FAR = \frac{n_{10}}{n_{11}+n_{10}} = \frac{n_{10}}{n_{1.}}$$

Results and Discussion

Grazie al lavoro di validazione si sono potute analizzare le performance del sistema DatameteoNOW Storm Track: in presenza di attività convettiva da moderata ad intensa, l'apparato si è dimostrato un ottimo rilevatore di celle temporalesche. Questo si evince dal fatto che la differenza dall'indice POD (capacità dell'algoritmo di individuare una cella convettiva) e del FAR (ammontare di allarmi relativi a celle convettive non correttamente rilevate) sia sempre positiva durante i mesi estivi nelle ore centrali del giorno, periodo in cui si presentano maggiormente precipitazioni convettive.

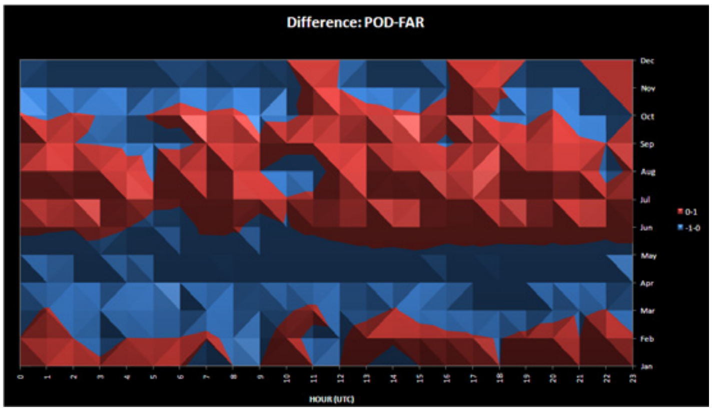


Fig. 7: Differenza tra l'indice POD e FAR sull'Italia.

Fig. 7: POD-FAR difference on Italy.

Average POD	Average FAR	Region
0,89	0,14	ALPS
0,79	0,16	BALTIC
0,82	0,19	CENTRAL EUROPE
0,72	0,20	EASTERN EUROPE
0,84	0,10	IBERIAN PENINSULA
0,64	0,44	EUROPE
0,83	0,21	FRANCE
0,77	0,14	GREECE & ALBANIA
0,75	0,17	ITALY
0,74	0,12	BALKANS
0,78	0,24	NORTHERN EUROPE

Fig. 8: Indici medi POD e FAR su diverse aree europee.
Fig. 8: Average Index POD and FAR on European Regions.

In generale
• FAR>=POD, ma bisogna ricordare che la maggior parte degli allarmi relativi a celle convettive non correttamente rilevate (FAR) si verifica in presenza di bassa convezione e mancanza di attività elettrica. Per limitare questo errore si è integrato il sistema con reti di rilevamento della fulminazione.
Si notino i buoni andamenti (alto POD e basso FAR) su Italia e Alpi. Score più bassi sull'Europa Settentrionale, probabilmente dovuta alla mancanza di attività di fulminazione e ad una bassa risoluzione satellitare.

Conclusions

Riassumendo DatameteoNow Storm Track è stato oggetto di un'ampia validazione, con più di 20.000 immagini satellitari analizzate. Questo processo ha permesso di ottenere risultati lusinghieri, che dimostrano la valenza del prodotto, la sua flessibilità ed usabilità. Per questo si è deciso di rendere il processo di validazione incrementale ed aggiornato realtime. Questo ci permetterà di avere informazioni sempre aggiornate sulle prestazioni, al fine anche di testare nuove soluzioni integrate, come quella dell'utilizzo della fulminazione IC (Intra-Cloud), indice del potenziale della nube convettiva.
Questi fulmini possono essere utili per integrare le informazioni dei canali satellitari, eliminare i falsi positivi ed interfacciare nuovi indici sul potenziale convettivo della cella.

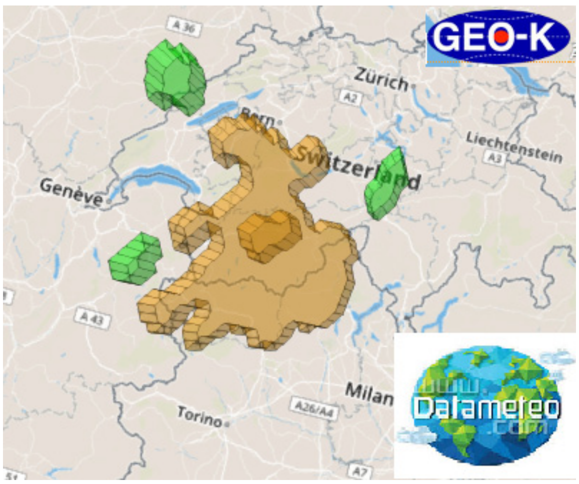


Fig. 9: Particolare della possibile rappresentazione 3D di una cella convettiva in evoluzione.
Fig. 9: 3D representation of T-storm convective cells.

Sviluppi sul fronte prettamente agrometeorologico saranno:

- L'estensione della capacità di previsione dell'evoluzione della cella temporalesca ai prossimi 60 minuti;
- L'integrazione di nuovi indici sul rischio potenziale della cella evolutiva (Severity Index), collegabili anche con le variabili precipitative;
- L'ampliamento della copertura con utilizzo di altri satelliti come Himawari, etc..

Queste evoluzioni renderanno questo strumento sempre più preciso, integrabile e scalarmente disponibile su tutto il globo terrestre, con risoluzioni inferiori a 3 Km per pixel e con frequenze di aggiornamento che variano dai 5 minuti sull'Europa ai 15-30 minuti sul resto del globo terrestre attualmente coperto, Il tutto con lo stesso standard di individuazione, validazione e presentazione del dato.

References

Busacca S. (2013) Hail Forecasting in Italy: A validation to a model approach
De Rosa M (2015) Tracking of thunderstorms based on the Meteosat Second Generation images.
Fierro (2012) A cloud-scale lightning data assimilation technique implemented within the WRF-ARW model.
Falco A, Rendina C, Gabriele G (2016) Meteobrowser 2 Interactive weather platform user manual
Kolios S, Feidas H.(2010). A warm season climatology of mesoscale convective systems in the Mediterranean basin using satellite data. Theor. Appl. Climatol. 102: 29–42.

SNOW AS A WATER RESOURCE AND ITS CLIMATOLOGY (NASA-ESA DATABASE)
NEVE COME RISORSA IDRICA E SUA CLIMATOLOGIA (ARCHIVIO NASA-ESA)

Andrea Spisni[1], Valentina Pavan[1], Martina Collina[2], Valentina Ciriello[2], Luca D. Sapia[1], Vittorio Marletto[1]

[1] Arpae Emilia - Romagna – Servizio Idro Meteo Clima, viale Silvani 6, 40122, Bologna (BO)
[2] Università di Bologna – DICAM, Scuola di Ingegneria e Architettura, Viale del Risorgimento, 2, 40136 Bologna
aspisni@arpae.it

Abstract
Snow represents an important winter water reserve that can recharge aquifer and can give water to the agriculture during summer time, mitigating drought periods. In regions, like Emilia-Romagna, where the presence of snow is not excessive, remote sensing images are the only solution to know how much snow has fallen down to the ground. In fact, due to the lack of specifying staff and suitable tools, often snow data is not available or is untrustworthy; therefore, simplicity of finding and processing of the information from satellite data could be a possible new way to do analysis. In this study, snow data is processed from remote sensing images detected by Modis-Terra (NASA) within of product Climate Change Initiative (Esa-Cci). This product represents 8-Day aggregation of snow presence; it refers to the years 2000-2012 and gives the probability of snow presence on a Global 500m grid.
Aim of this study was to show a short analysis of the snow distribution at regional level and how this information could be incorporated inside of snow reports. Since 2005 Arpae does snow reports detected from remote sensing and since 2017 the anomaly of the presence of the snow has been added on it. This one allow knowing how distribution and quantity of snow has changed.

Keywords: remote sensing image analysis, climate change, snow distribution, probability snow presence, anomaly.
Parole chiave: analisi immagini satellitari, cambiamenti climatici, distribuzione della neve, probabilità presenza neve, anomalia.

Introduction
Snow is an important water reserve that can feed groundwater reserve and provides water to agriculture during the summer, mitigating drought periods. At the same time, its presence on the ground during the spring period is of paramount importance for civil protection alert bulletins as its contribution added together to the expected or observed rains, increasing the risk of floods and avalanches. Since 2005 Arpae has a snow monitoring bulletin done by satellite analysis [1] and since 2017 the integration of the snow cover climate data. The snow climatology used is the snow cover produced in the Climate Change Initiative (Esa-Cci) [2] from satellite data collected by Modis-Terra (Nasa). The climate refers to the period 2000-2012 and it shows the aggregate snow cover probabilities at weekly level at 500 m spatial resolution. The study shows an analysis of the distribution at the regional level and how this information can be incorporated into the snow report. The study area covers the macro areas of civil protection and is about 25225 kmq.

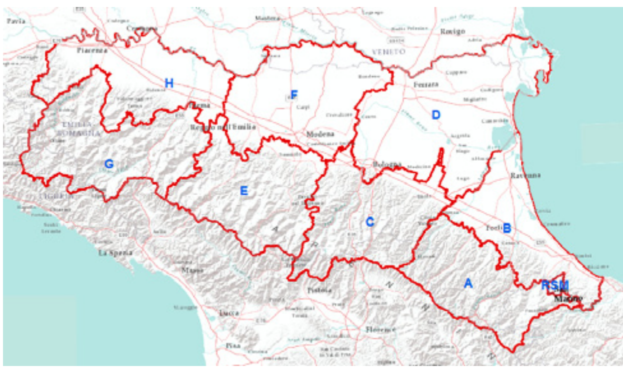


Fig. 1: Macro areas of civil protection of Emilia-Romagna at the closure of river basins
Fig. 1: Macro aree di protezione civile dell'Emilia-Romagna alla chiusura dei bacini idrografici

Materials and methods
The Esa-Cci Snow Occurance data set covers the entire globe and has been reprocessed from the Nasa level 3 data encoded as MODIS / Earth Snow Cover 8-Day L3 Global 500m Grid: MOD10A2 [3] (Hall and Riggs, 2016) over the period 2000-2012. This product represents the 8-day aggregation of snow presence. Subsequently, the Esa-Cci team worked to mediate across the available database, making a weekly average snow cover.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

In this analysis, only mountain macro areas and aggregate regional data are considered. These areas were subdivided according to the altimetric bands Srtm Cgiar (Jarvis et al., 2008), processed to a minimum of 25 ha. Table 1 shows the extent of the orographic areas corresponding to the whole region.

Zone Attribute	H max	kmq
DSM 1	150	13146.50
DSM 2	300	2186.75
DSM 3	600	4123.25
DSM 4	1000	4071.50
DMS 5	1500	1513.25
DSM 6	2000	183.50
DMS 7	2500	0.50

Tab. 1: Distribution of altimetric zones of aggregate macro areas
Tab. 1: Distribuzione delle fasce altimetriche delle macro aree aggregate

Results and discussion
The graph describes the trend of the Emilia-Romagna snow cover extension during the years 2000 to 2012. From Figure 2, which shows the likelihood of snow on the ground for the different altimetric zones, it is clear that the region presents limited snow cover, which can only become continuous in ridge areas, above 1500 m asl, and only in the most snowy years of the average. In these areas, snow cover is likely to occur in the months between December and April, while in the months from mid June to September the probability of this event will drop to zero.

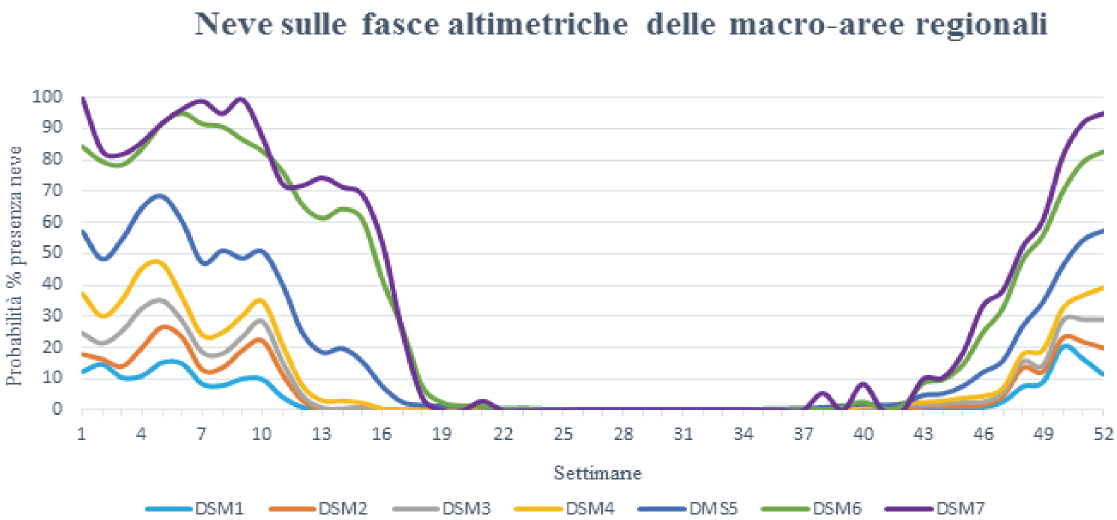


Fig. 2: Snow percentage distribution about all the altimetric zones of aggregate macro areas

Fig. 2: Distribuzione percentuale neve su tutte le fasce altimetriche delle macro aree aggregate

Comparing the average probability for the mountain macro areas in the different altimetric zones, it can be noted that in the winter months the Romagna Apennines (macroarea A) and in the ones closest to the highest mountains in the region (Monte Cimone and Monte Cusna, macroarea E) the temporal variability of snow cover probability is lower than the other mountain areas of the region. This feature may be due to the fact that in other mountainous areas it is less likely that weather conditions are such as to bring the temperature down to 2 m below or around 0 ° C in a part of the territory for several weeks in a row. For sites with a height between 1000 and 1500 m above sea level, snow cover was only detected in just over 50% of the cases between December and March and the presence of snow cover was never detected between July and September. In the other months the snow cover has been present only in a few years and is often limited to days or weeks immediately following a snowy event. For areas below 1000 m above sea level, the presence of snow is limited to days following a snowy event. In these areas, the frequency of such events increases as the altitude increases, while their distribution over the year is quite independent of the quota, and runs from October to early June: moving a cold front may lead to lowering sudden

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

temperatures up to values close to 0 ° C, even in the plain, and associated with snowfall with consequent deposition of mantle. At altitudes up to 150 m above sea level, this is more likely to occur in December, while in the hill the higher chance of observing snow on the ground occurs in February.
These climatic considerations obviously refer only to the years covered by the data analyzed here. In an analysis of overall thickness of the mantle in a group of historical observation stations in the region (De Bellis et al, 2010), there was a significant relationship between the variability of the regional snow cover and winter temperatures. Their analysis in regional climate atmospheres (Marletto et al., 2016) has shown significant trends towards higher values suggesting a possible downward trend in snow events. This phenomenon, added up to summer droughts, the sharp fall of the snowy precipitation of the last few years, to the reduction of the extension of the alpine glaciers due to the high summer and autumn temperatures, leads to accentuated and prolonged lean of Apennine rivers and Po, which feeds the Emilia Romagna Channel, that provide irrigation water to the Romagna area. This can lead to severe irrigation problems in Emilia-Romagna during the summer season.
Snow climates can be integrated into the snow report, thus providing the indication of where the snow might be present on the basis of the available observations and highlighting negative and / or positive anomalies.
Since climatology reports only the probability of presence for a given week, while the bulletin identifies the snow at a precise date, it has opted to define the probable snow cover by climates by selecting pixels with a probability greater than 66% (third percentile, Figure 3 represented by blue lines).

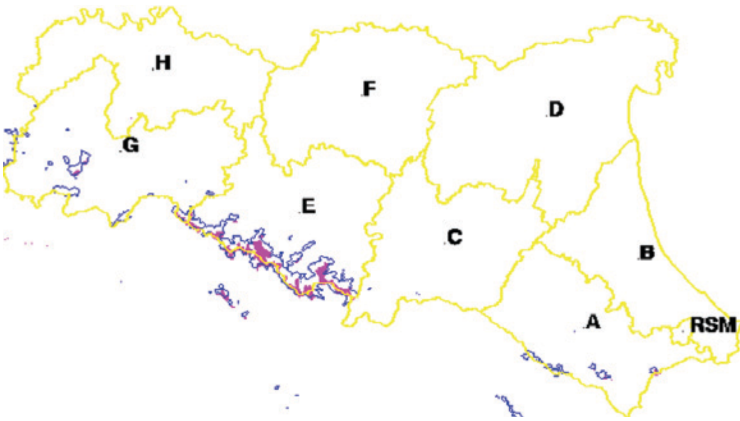


Fig. 3: Integration of snow probability (macro areas are reported in yellow, current snow in a given date in magenta and probability snow ≥ 66% of the week including the snow detection date in blue)

Fig. 3: Integrazione della probabilità neve (in giallo sono riportate le macro aree, in magenta la neve presente ad una determinata data ed in blu la probabilità neve con soglia ≥ 66% della settimana che include la data di rilevamento della neve)

Conclusions
Satellite imagery is the only alternative to map the spatialization of snow on the ground. The Esa-Cci Snow Occurance climatic database, albeit on a limited time frame, allows easy use of snow probability information for a given area. This climatology can be supplemented with Arpae snow bulletins, thus providing an indication of the presence of snow in relation to the climate.

Bibliography
De Bellis A., Pavan V. e Levizzani V., 2010: Climatologia e variabilità interannuale della neve sull'Appennino Emiliano-Romagnolo. Quaderno Tecnico Arpae-Simc n° 19

Hall, D. K. and G. A. Riggs. 2016. MODIS/Terra Snow Cover 8-Day L3 Global 500m Grid, Version 6. subset h18v04. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: http://dx.doi.org/10.5067/MODIS/MOD10A2.006

Jarvis A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT), available from http://srtm.csi.cgiar.org

Marletto V., Antolini G., Pavan V. e Tomozeiu R., 2017: Atlante climatico dell´Emilia-Romagna (edizione 2017). Ed. Arpae-Simc

Web reference
[1] https://goo.gl/PvK8e7
[2] http://maps.elie.ucl.ac.be/CCI/viewer/index.php
[3] http://nsidc.org/data/MOD10A2

BIVARIATE ANALYSIS OF THE DURATION AND SEVERITY OF WATER STRESS IN OLIVE

ANALISI BIVARIATA DELLA DURATA E DELLA SEVERITÀ DEL DEFICIT IDRICO DELL'OLIVO

Lorenzo Vergni[1], Bruno Di Lena[2], Enrico Maria Lodolini[3]

[1] Dipartimento di Scienze Agrarie, Alimentari ed Ambientali, Università degli Studi di Perugia, Borgo XX Giugno 74 Perugia
[2] Regione Abruzzo Centro Agrometeorologico Regionale - Scerni (Ch)
[3] Centro di ricerca Olivicoltura, Frutticoltura e Agrumicoltura, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, via di Fioranello 52 Roma
*lorenzo.vergni@unipg.it

Abstract

In this work, the joint probabilities and return periods of two characteristics - Duration, D (days) and Severity, S (mm) - of the simulated water stress in olive orchards were modelled by a two-dimensional copula. First, the precipitation and temperature daily time series of some stations in central Italy were used in input to a "bucket" soil water balance model to simulate the corresponding dynamics of the soil water (SW) available for olive. Then, by applying the theory of runs to SW, with a threshold equal to the crop critical point, the water stress events were identified and characterized in terms of D (days) and S (mm). This last variable is given by the sums of the daily evapotranspiration deficit during the corresponding water stress event. A 2-parameter Gamma distribution was fitted to both D and S, whilst their dependence structure was modelled by a Student's t copula.

Finally, the stations considered were compared in terms of joint probabilities and joint return periods for D and S, thus enabling the evaluation and the characterization of the risk of water stress related to olive in different areas.

Keywords: risk of water deficit, copula functions, joint probabilities, return periods

Parole chiave: rischio di deficit idrico, funzioni copula, probabilità congiunte, tempi di ritorno

Introduction

As many other natural hazards, the crop water stress has a typical multivariate nature, i.e. it is characterized by the contemporary presence of multiple characteristics correlated with each other (e.g. duration, severity, peak, areal extension, etc.). In this situation, a risk analysis based on a traditional univariate approach may lead to misleading, inadequate or incomplete interpretations of the phenomenon.

The problem of the probabilistic joint analysis of two or more random correlated variables can be effectively solved by the copula functions (Nelsen, 1999), which have been widely applied in the last decade in the economical and hydrological contexts. Copulas are functions that join univariate probability distributions to form multivariate probability distributions, enabling to model the dependence structure among random variables independently of their marginal distributions (Joe, 1997). In this work, the joint probability and return periods of two characteristics of water stress related to olive orchards (Duration, D and Severity, S) have been modelled by a two-dimensional copula. The case study refers to some stations of the Umbria and Abruzzo regions. The climatic data were used to estimate the dynamics of the available soil water and to derive the characteristics of water stress D and S. The definition of a copula model for D and S allowed to derive the joint probabilities and the joint return periods and to perform a comparative analysis among the considered localities.

Materials and Methods

The climatic data (daily precipitation, and minimum and maximum daily temperature) for the stations considered were obtained from both the Italian National Hydrographic and Oceanographic Service and the Regional Hydrographic Services. The length of the available time series and some summary statistics for the stations selected are given in Tab. 1.

Daily reference evapotranspiration ET_0 was estimated by the Hargreaves and Samani equation (Allen et al., 1998), using only daily minimum and maximum temperature. The estimation reliability of this equation was considered adequate for the purposes of the study. The meterological data where used in input to a "bucket" soil-water balance model to simulate the daily dynamics of the available water for the olive orchards. The soil water balance model follows the scheme suggested in the FAO 56 paper (Allen et al., 1998). In particular, daily precipitation amounts lower than 5 mm were not considered effective and larger amounts were reduced by 20%. For simplicity'sake, a 1-m soil depth with 20 % of crop available water (Total Available Water, TAW= 200 mm) was assumed for all the stations. The olive crop coefficients for the calculation of the non-stressed crop evapotranspiration (ET_m) were retrieved from the FAO 56 guidelines and a threshold level of 0.25 TAW was adopted as critical point (beginning of water stress, i.e. actual evapotranspiration $ET_a < ET_m$).

The hydrological balance model has been applied continuously throughout the time series starting from an initial condition of full recharge of the soil water (i.e. SW_{ini}=TAW), thus enabling the simulation of the soil water (SW, mm) dynamics. The water deficit events were identified by applying the Theory of Runs (Yevevich, 1967) to the time series of SW, using the threshold level of 0.25 TAW (50 mm): a water stress event was indentified by a continuos period in which SW < 0.25 TAW. Each event has a duration D (numer of consecutive days in which $ET_a < ET_m$) and a severity S (sums of the deficits ET_m-ET_a during the event). The mean value of D, S and of the number of water stress events per year is given in Tab.1

Station	Time series	Annual precipitation (mm)	Number of rainfall events > 5mm	Reference evapotranspiration (mm)	Olive maximum evapotranspiration (mm)	D (days)	S (mm)	Water stress events per year
Chieti	1951-2015	777.1	40.0	893.7	475.3	40.3	35.1	1.7
Scerni	1951-2015	765.0	40.2	935.6	497.7	44.6	43.1	1.9
Penne	1951-2012	830.8	44.7	945.3	502.7	30.3	24.3	1.9
Spoleto	1951-2015	991.1	54.1	1074.0	571.1	32.9	33.5	2.2
Gubbio	1951-2015	1007.4	56.9	1016.1	540.2	27.5	27.4	1.9
Orvieto	1951-2015	818.1	46.2	1092.0	580.5	49.0	65.8	2.1
Todi	1951-2015	824.2	47.0	1060.3	563.8	38.3	43.5	2.4

Tab. 1: Mean values of some agrometeorological variables for the stations considered.
Tab. 1: Valori medi di alcune variabili agrometeorologiche per le stazioni considerate

The first step of the analysis consisted in the identification of adequate marginal distributions for the random variables considered. The variable D is a discrete variable, but this is an artefact dependent on the application of discrete (daily) soil water balance. Therefore it was assumed that both D and S are continuous random variables. Several 2-parameter continuous distributions have been considered for the description of D and S and their goodness of fit was compared in terms of RMSE (Vergni et al., 2016).
The most suitable copula model was selected by applying both subjective (graphical) and objective methods. The first was based on the analysis of the scatter plots of pseudo-observations plotted together with random pairs of cumulative probabilities generated from a given copula model. The objective evaluation was based on the Cramer-Von Mises statistics, S_n (Genest and Remillard, 2008) whose p-value was calculated by a bootstrap approach based on 1000 repetitions (Vergni et al., 2015). The R package "Copula" (Hofert et al., 2017) was used for the calculations.
Therefore, the complete models (copula + marginal distributions) were used to estimate: the joint probabilities P ($D \leq d$, $S \leq s$); the conditional probabilities (P<=S|D>=d'), i.e. the cumulative probability of S given D has already reached a certain threshold d', the joint return periods (years) for the condition D≥d and RS≥rs.

Results and Discussion

The gamma distribution showed a better goodness of fit in comparison to other tested distributions (Exponential, Weibull) in terms of RMSE and it was therefore selected as marginal distribution for both D and S. The corresponding shape and scale parameters were estimated by the L-moments approach (Hosking, 1990).
Different copula functions were tested to describe the dependence structure between the correlated variables D and S. The best choice was represented by the Student's t-copula whose parameter was estimated by the method of inversion of Kendall's tau and the degrees of freedom were optimized by minimizing the statistic S_n (Vergni et al., 2015).
The complete copula model (dependence structure + marginal distributions) allowed to obtain the estimation of the joint probability P($D \leq d$, $S \leq s$). A graphical example of this information is given in the perspective graphs of Fig. 1 for the Orvieto (Fig. 1a) and Gubbio (Fig. 1b) stations, which are characterized by very different climatic conditions (drier in Orvieto than in Gubbio, Tab.1). This determined the different shape of the perspective graphs.

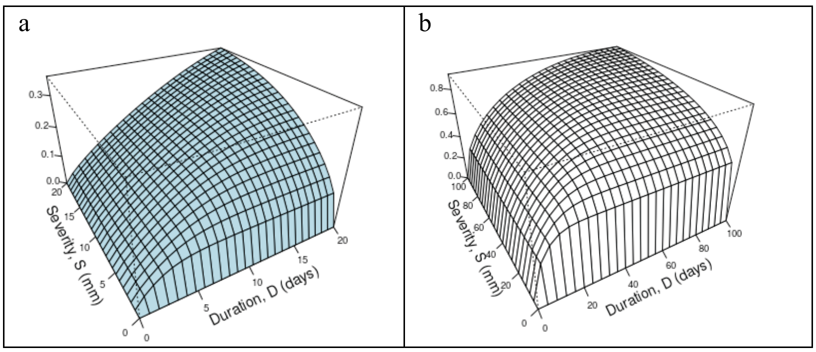


Fig. 1: Joint probabilities P ($D \leq d$, $S \leq s$ for two exemplificative stations (a: Orvieto; b: Gubbio).
Fig. 1: Probabilità congiunte P ($D \leq d$, $S \leq s$ per due stazioni di esempio (a: Orvieto; b: Gubbio).

Another example of the results attainable from this type of analysis is shown in Fig. 2, which shows the conditional cumulative probability of S given the duration has reached at least 90 days. The shape of the curves indicates that, in this circumstance, the expected severity is higher for Umbria than Abruzzo stations. Very similar probabilities were observed for Spoleto and Gubbio stations. Fig. 3a and 3b show, respectively, the pairs (D, S) having 5-year and 20-year return periods (condition $D \geq d$ and $S \geq s$) for olive in the stations considered. The stations characterized by less favourable meteorological conditions (Tab. 1) exhibit in Fig. 3 curves more distant from the axes origin (e.g. Orvieto and Todi). For example, the curve for the 5-year return period in Orvieto is similar to that of Gubbio for a 20-year return period. It is interesting to notice that the two stations Spoleto and Gubbio, characterized by very similar mean

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

values of D and S (Tab.1) and similar conditional probabilities (Fig. 2), are not so similar if compared in terms of return periods (Fig. 3). This is a consequence of the higher frequency of stress events in Spoleto (Tab. 1). Moreover, it can be also noticed that some curves intersect (e.g. Penne and Gubbio, Spoleto and Chieti): of course these are stations characterized by similar conditions, but the water stress events have a different characterization in terms of D and S. This type of information is only attainable from a joint probabilistic analysis of D and S.

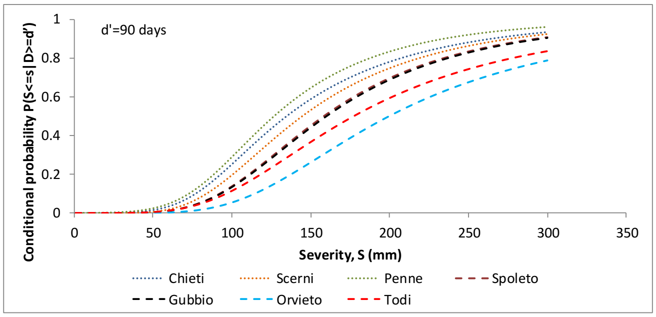


Fig. 2: Conditional probabilities (P<=S|D>=90 days) in some stations of Abruzzo (dotted lines) and Umbria (dashed lines).

Fig. 2: Probabilità condizionate (P<=S|D>=d') in alcune stazioni di Abruzzo (linee punteggiate) e Umbria (linee tratteggiate).

Conclusions

The use of multivariate probabilistic models is becoming common in hydrological studies. In this paper, a bivariate risk analysis of the Duration and Severity of water stress in olive has been illustrated in relation to some stations of Umbria and Abruzzo regions. This preliminary work was mainly addressed to illustrate the potentiality of this type of approach. The next step will be to improve the model's reliability through its calibration and validation with actual crop data. In this context it would be interesting to explore the possibility to introduce other variables in the joint analysis. For example, taking into account that the sensitivity to water stress varies with the phenological stage of olive, the date of occurrence of the water stress could be a useful variable in a 3D copula model.

a b

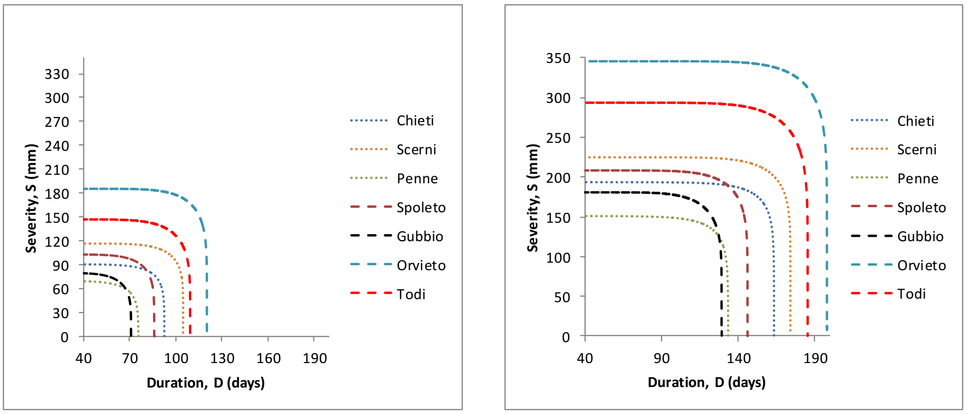


Fig. 3: pairs (D, S) having a 5-year (a) and 20-year (b) return periods (condition D ≥ d and S ≥ s) for olive in some stations of Abruzzo (dotted lines) and Umbria (dashed lines).

Fig. 3: coppie (D, S) aventi tempi di ritorno 5 (a) e 20 (b) anni (condizione D ≥ d e S ≥ s) in alcune stazioni di Abruzzo (linee punteggiate) e Umbria (linee tratteggiate).

References

Allen RG, Pereira LS, Raes D, Smith M (1998). Crop evapotranspiration. Guidelines for computing crop water requirements. Irrigation and drainage paper 56, FAO, Rome.

Genest C., Remillard B., (2008). Validity of the parametric bootstrap for goodness-of-fit testing in semiparametric models, Ann. I. H. Poincare-Pr., 44, 1096–1127.

Hofert M., Kojadinovic I., Maechler M. Yan J. (2017). Copula: Multivariate Dependence with Copulas. R package version 0.999-16 URL https://CRAN.R-project.org/package=copula

Hosking JRM (1990). L-moments: analysis and estimation of distributions using linear combinations of order statistics. J R Stat Soc Ser B 52:105–124.

Joe H. (1997). Multivariate model and dependence concepts. Chapman and Hall, London.

Nelsen R. B. (1999). An introduction to copulas, Springer, New York.

Todisco F., Mannocchi F., Vergni L., (2013). Severity–duration–frequency curves in the mitigation of drought impact: an agricultural case study Nat Hazards 65:1863–1881.

Vergni L., Todisco F., Mannocchi F. (2015). Analysis of agricultural drought characteristics through a two-dimensional copula Water Resources Management 29 (8) 2819–2835.

Vergni L. Todisco F., Di Lena. B., Mannocchi F. (2016). Effect of the North Atlantic Oscillation on winter daily rainfall and runoff in the Abruzzo region (Central Italy). Stoch Environ Res Risk Assess, 30 (7) 1901–1915.

Yevjevich V. (1967). An objective approach to definitions and investigations of continental hydrologic droughts. Hydrology paper No. 23. Colorado State University, Fort Collins.

A PRELIMINARY STUDY ON THE PHYSIOLOGY OF SOME SANGIOVESE CLONES, IN RELATION TO THE ROOTSTOCK AND THE ENVIRONMENTAL CONDITIONS

UNO STUDIO PRELIMINARE SULLA FISIOLOGIA DI ALCUNI CLONI DI SANGIOVESE, IN RELAZIONE AL PORTAINNESTO E ALLE CONDIZIONI AMBIENTALI

Paolo Valentini[1]*, Rita Perria[2]

[1]Laboratorio di Ricerca per la Viticoltura Arezzo, [2]Centro di Ricerca per la Viticoltura Conegliano
*paolo.valentini@crea.gov.it

Abstract

The purpose of this study was to investigated the effect of rootstock on chlorophyll fluorescence in 5 clones of Sangiovese, in water stress conditions. Chlorophyll fluorescence has been used to monitor the photosynthetic performance of plants non-invasively, this study represents to possible for specific applications of chlorophyll fluorescence for tolerance to environmental stress. The test have been carried out in July 2010 and 2011, in different weather conditions. The differences to the photosynthetic process is manifested by alteration of photosystem, in particular the curves of transients, the K-band and therefore altered the Oxygen Evolving Complex and the limitation in the electron transport. The results highlights the rootstock effect.

Keywords: *Vitis vinifera*, rootstock, Sangiovese, transient.
Parole chiave: *Vitis vinifera***,** portinnesto, Sangiovese, transient.

Introduzione

L'impiego dei portinnesti in viticoltura non è più considerato come mezzo agronomico di lotta alla fillossera ma anche come strumento capace di influire sulla fisiologia del nesto. Nei confronti del portainnesto quindi sono sorte delle aspettative più ampie che riguardano il suo adattamento all'ambiente, all'attività vegetativa, all'estrinsecazione dei processi fisiologici quali l'efficienza assimilativa e fotosintetica (Scalabrelli *et al*. 2002). Il portainnesto è un mezzo per regolare l'attività vegeto-produttiva della vite; questa affermazione risulta più aderente alla realtà in considerazione delle mutazioni climatiche di cui siamo testimoni ed artefici. Resta molto da capire su come cambi la tolleranza dei portinnesti in funzione delle modalità con cui lo stress idrico si manifesta.
Lo scopo del presente studio è quello di capire quali sono i comportamenti fisiologici indotti dallo stress idrico prendendo in esame un aspetto molto particolare della fisiologia della pianta, e cioè la funzionalità dei fotosistemi, in diverse condizioni ambientali, determinata tramite la misura dell'emissione della fluorescenza. L'energia luminosa assorbita dalle foglie viene trasferita verso i centri di reazione dei fotosistemi II e I (PSII e PSI), utilizzata per alimentare le reazioni fotochimiche. Una parte dell'energia assorbita, non è catturata dai centri di reazione ed è dissipata sottoforma di calore, un'altra frazione di energia, pur raggiungendo il centro di reazione non riesce ad essere trasferita all'accettore di elettroni e per questo viene riemessa in forma di fluorescenza, corrispondente in condizioni normali, a circa il 3-5 % della luce totale assorbita. Condizioni di stress della pianta, dovuti sia a fattori abiotici che a incidenza di malattie, inducono un aumento della fluorescenza aumentano e quindi una riduzione dell'efficienza foto sintetica.
Le prove sono state svolte sul Sangiovese, il vitigno a bacca nera più coltivato in Italia (Istat, 2010), con la maggior penetrazione nelle superfici a DOC e DOCG dell'Italia centrale, da qui l'importanza di una sempre maggiore conoscenza del comportamento del vitigno, dei suoi innumerevoli cloni e dell'interazione fra i cloni e i diversi portinnesti in condizioni climatiche in continuo mutamento.
Scopo di questo lavoro è quello di evidenziare le alterazioni rilevabili dallo studio delle curve di estinzione e determinare quali parametri fluorimetrici, indicano una condizione di stress della pianta, ed eventuali differenze dovute all'interazione fra clone e portainnesto.

Materiali e metodi

Le misurazioni fluorimetriche hanno riguardato piante del vitigno Sangiovese appartenenti a 5 cloni diversi ed innestate su due portinnesti: i cloni R10, VCR4, e Janus 10 innestati su 1103 Paulsen; VCR23 e VCR30 innestati su S.O.4 (Selezione Oppenheim 4). Le piante osservate fanno parte della collezione situata presso il CREA-Vic di Arezzo; sono state messe a dimora nel 2002, sono allevate a spalliera con una potatura a cordone speronato; il sesto d'impianto è di m 0.90x2.70; il vigneto è inerbito. Il terreno è pianeggiante, limoso, con poco scheletro e di difficile drenaggio.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Tab.1:Characteristics of grape rootstock
Tab. 1: Caratteristiche dei portinnesti

	Resitenze	Sensibile	Media	Resistente	Vigoria
1103 Paulsen Berlandieri x Riparia	Siccità			X	vigoroso
	Calcare attivo			X	
	Carenza potassio	X			
	Carenza magnesio			X	
Sel. Oppenheim 4 Berlandieri x Riparia	Siccità	X			media
	Calcare attivo		X		
	Carenza potassio			X	
	Carenza magnesio	X			

Le misure fluorimetriche

I fotoni che colpiscono la superficie della foglia vengono catturati dai complessi antenna e trasferiti ai Centri di Reazione per attivare la fase luminosa del processo fotosintetico. In alcuni casi si può avere un eccesso di fotoni, cioè la foglia non è in grado di trasformare completamente l'energia luminosa in energia chimica. Le cause possono essere molteplici: eccesso di luce o cause fisio-ambientali che deprimono l'efficienza delle catene di trasporto degli elettroni e del PSII in particolare. La fluorescenza rimane su livelli modesti quando la fotosintesi decorre regolarmente . L'incremento dell'emissione di fluorescenza indica una riduzione dell'efficienza della fotosintesi (Lichtenthaler et al., 1988) In tutti questi casi la luce in eccesso viene smaltita come calore oppure come fluorescenza. Il fluorimetro è uno strumento che riesce a misurare questo esubero di energia e tramite la misurazione in un brevissimo lasso di tempo produce una curva di estinzione della fluorescenza, chiamata "transient" con cui è possibile stabilire una serie di parametri che danno una misura dell' efficienza del fotosistema II (c.d. PSII). Inoltre confrontando due transient è possibile capire in quale tratto della catena di trasporto degli elettroni si verifica la disfunzione.
Proprio questo particolare confronto è stato fatto per capire quali effetti hanno le condizioni ambientali sul comportamento delle piante prese come oggetto di questo lavoro. In pratica per ogni clone sono state effettuate delle misurazioni (tab. 3) a cadenza settimanale per tutto il mese di luglio, sia nel 2010 che nel 2011.
Per le misurazioni fluorimetriche è stato impiegato il fluorimetro "Handy PEA" della Hansatech instruments.

Tab. 2 Date of surveys
Tab. 2 Date dei rilievi

RILIEVO	DATA 2010	DATA 2011
1°	2 luglio	30 giugno
2°	6 luglio	6 luglio
3°	15 luglio	13 luglio
4°	21 luglio	22 luglio
5°	28 luglio	26 luglio

Le curve relative alla prima sessione di misure sono considerate quelle caratteristiche delle piante prive di stress ambientali (piante non trattate/piante prima del trattamento). Le curve ottenute dalle successive misurazioni sono state considerate come provenienti da piante che hanno subito un trattamento. Questa considerazione è necessaria perché il confronto dei transients si basa proprio sulle differenze tra prima e dopo il trattamento. In questo caso il trattamento è l'azione del calore e dello stress idrico sopportato dalle piante. Le curve che si ottengono sono chiamate Δ-curve e vengono realizzate sottraendo al valore della fluorescenza delle piante trattate, quello delle piante non trattate (in questo caso il valore della fluorescenza delle piante prima dell'esposizione delle stesse agli agenti ambientali); i grafici sono descritti da un asse orizzontale in cui sono riportati i tempi in scala logaritmica. L'asse delle ordinate indica invece le unita di fluorescenza.

Risultati e Discussione

Di seguito vengono illustrati i risultati ottenuti dalle elaborazioni delle curve di estinzione della fluorescenza, distinguendo le annate e i portinnesti. Inoltre viene riportato un grafico termo-pluviometrico riferito al mese di luglio con dati giornalieri, per entrambe gli anni considerati.

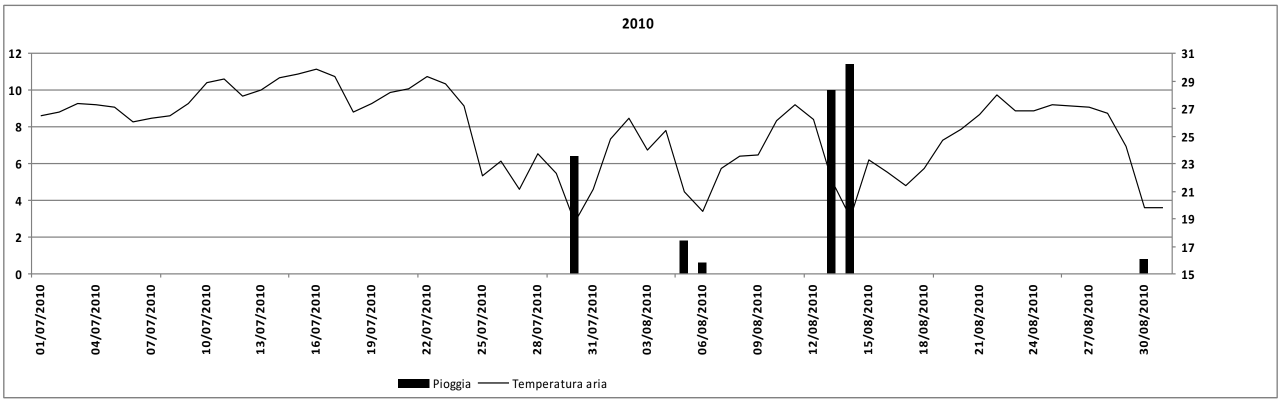


Fig. 1: July-august 2010: rainfall and mean temperature
Fig.1: luglio-agosto 2010: piovosità e temperature medie

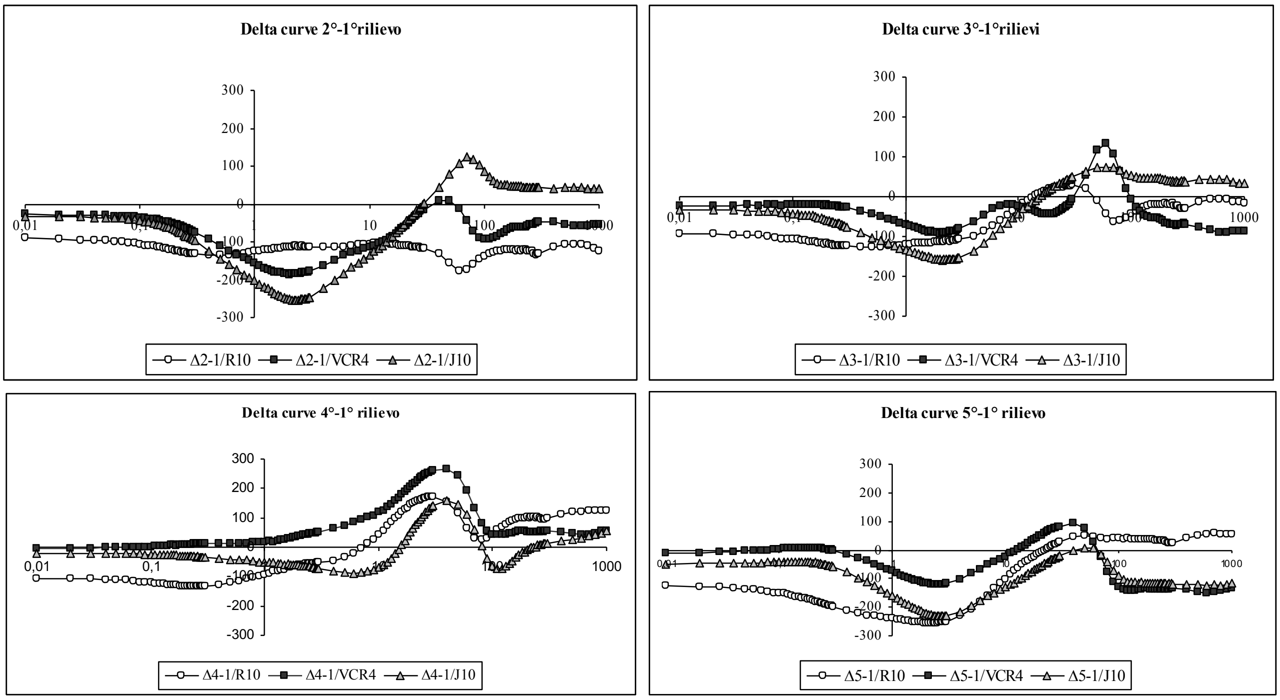


Fig. 2: 2010: ΔV curve of grapes grafted on 1103 Paulsen
Fig. 2: 2010 :Curve ΔV delle viti innestate su 1103 Paulsen.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

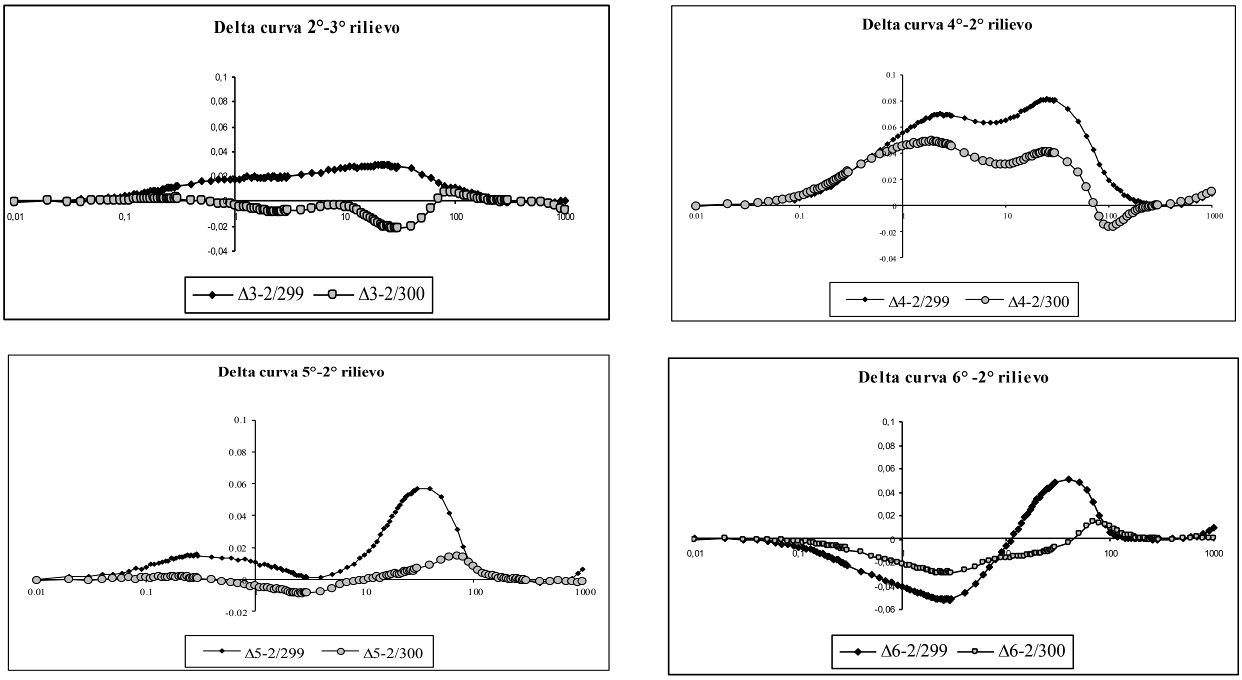


Fig. 3: 2010: ΔV curve of grapes grafted on SO4
Fig. 3: 2010 : Curve ΔV delle viti innestate su SO4.

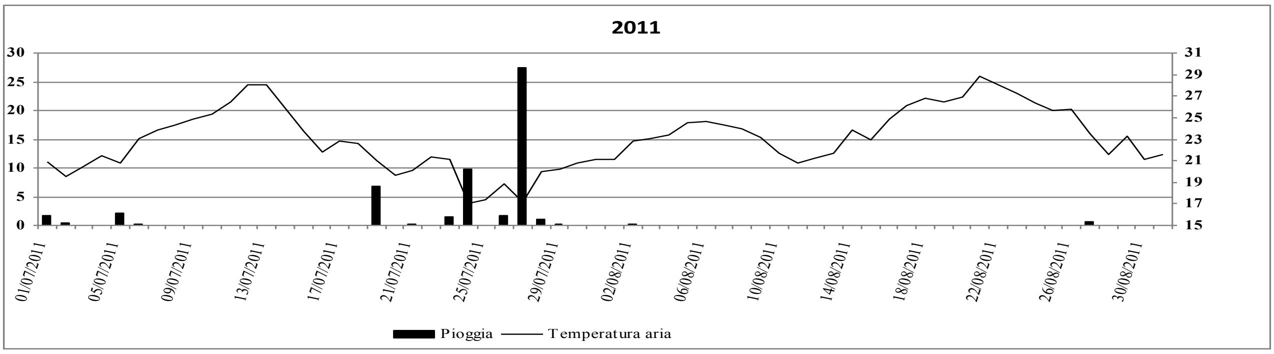


Fig. 4: July-august 2011: rainfall and mean temperature
Fig.4: Luglio-agosto 2011: piovosità e temperature medie

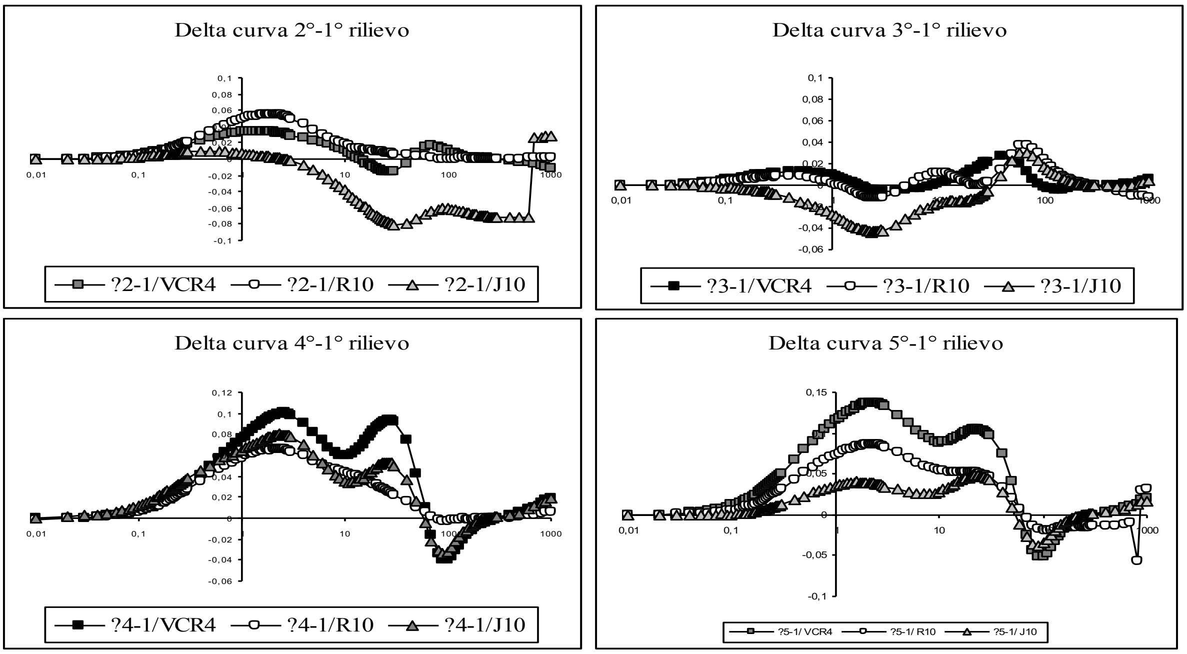


Fig. 5: 2011: ΔV curve of grapes grafted on 1103 Paulsen.
Fig. 5: 2011 :Curve ΔV delle viti innestate su 1103 Paulsen

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

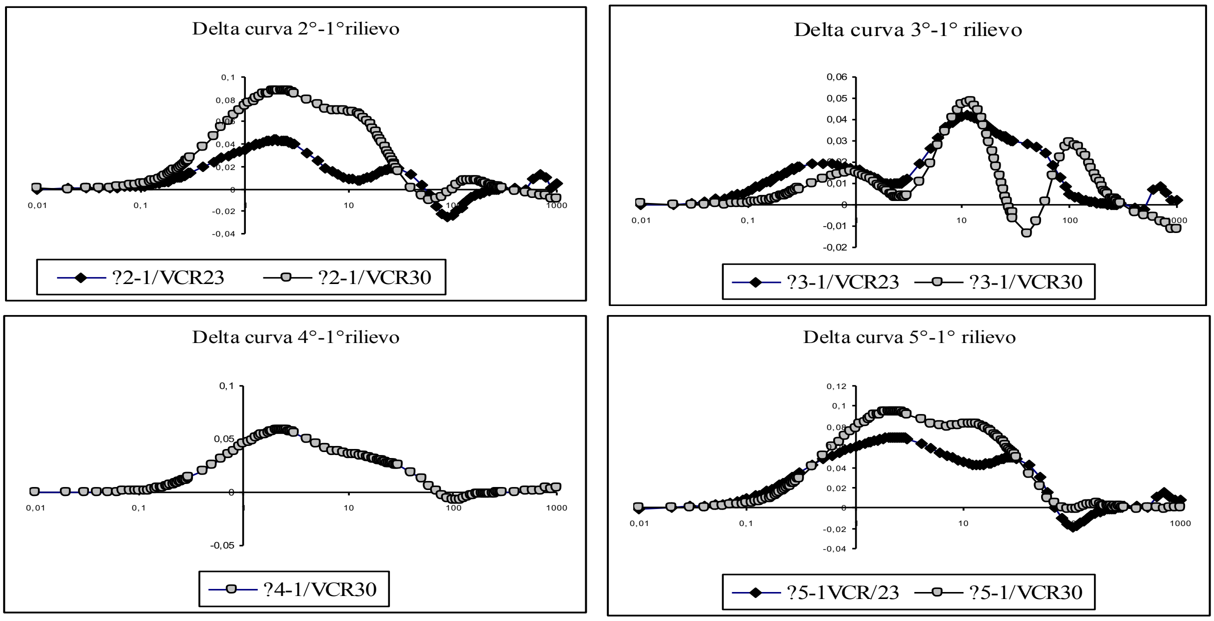


Fig. 6: 2011: ΔV curve of grapes grafted on SO4
Fig. 6: 2011 :Curve ΔV delle viti innestate su SO4.

Il mese di luglio 2010 decorre senza piogge fin quasi alla fine: il 29 si verifica una pioggia di modesta entità preceduta però da un breve periodo di temperature medie comprese tra 19 e 23 °C, decisamente modeste per il periodo considerato. Le temperature medie, dall'inizio del mese fino al giorno 24 invece sono comprese tra i 29 e i 32 °C.

Passando ad analizzare le curve ΔV si osserva che le traiettorie per il Paulsen 1103 sono sostanzialmente tutte simili tra loro. Si nota che: 1) le curve sono prevalentemente nel territorio negativo del grafico e assumono valori positivi (stress) solamente nei punti di massimo; 2) il punto di minimo si raggiunge subito dopo i 2 s x 10^{-3}; 3) da questo punto in poi la curva vira verso l'alto e raggiunge il punto di massimo all'incirca all'istante 30 s x 10^{-3} (punto I del transient); 4) i tre cloni di Sangiovese osservati presentano traiettorie delle curve ΔV omogenee nella forma e parallele nell' andamento.

Per il portinnesto Selezione Oppenheim 4 (S.O.4), bisogna premettere che i grafici sono stati realizzati utilizzando come termine di paragone i dati del 2° rilievo. Per tale portainnesto si ha una differente situazione: 1) le curve hanno una collocazione variabile; 2) presentano due minimi e due massimi; il primo punto di massimo si verifica nell'intervallo di tempo tra 0,2 s x 10^{-3} e 2,5 s x 10^{-3} e quasi sempre in territorio positivo, segnalando che con tale portainnesto si va in stress moderato anche nella fase fotochimica.

Il mese di luglio del 2011 ha avuto un decorso piovoso e con basse temperature: infatti si sono avuti otto eventi piovosi con 52 mm di acqua in totale, e temperature medie intorno ai 17 °C. Analizzando i grafici ΔV , si osserva che in entrambe le tesi dei portinnesti le curve tendono ad assumere una conformazione a "M" presentando due punti di massimo e due punti di minimo. La parte iniziale delle curve ΔV è parallela all'asse orizzontale ma già si trova in campo positivo; il primo punto di massimo si evidenzia all'istante 2,5 Sx10^{-3} mentre il secondo punto di massimo si verifica all'incirca a 30 Sx10^{-3}. Nell'istante 2 Sx10^{-3} finisce la fase fotochimica: durante questa fase l'accettore primario QA viene ridotto una sola volta (Bussotti et al. 2012). Abbiamo segnalato che da questo momento in poi la curva ΔV tende verso l'alto fino a raggiungere un punto di massimo in un lasso di tempo compreso tra 30 e 70 Sx10^{-3}; questo intervallo che nel transient corrisponde alla fase J-I, interessa la riduzione dell'insieme dei plastochinoni; in particolare il punto I (20 Sx10^{-3}) rappresenta la completa riduzione di QB. Da qui in poi segue la riossidazione del plastochinone da parte del citocromo. Il punto di massimo della curva ΔV si realizza durante l'intervallo del transien IP, in cui gli accettori finali di elettroni vengono ridotti (NADP e ferrodossina).

L'effetto dello stress idrico si manifesta soprattutto nella regione I-P del transient indicando una disfunzione nel ridurre gli accettori finali oltre il PSI (Oukarroum et al., 2009). Tale situazione è, forse, da attribuire alla scarsa dotazione di carbonio sottostomatico, causata dalla chiusura degli stomi (Oukkarroum et al.,2007).

Per quanto riguarda il portainnesto S.O.4, la situazione descritta dai grafici è più complessa: le curve dei due cloni seguono traiettorie simili, assimilabili alla conformazione ad "M". Nel quarto rilievo non è stata effettuata l'osservazione sul clone VCR23.

CONCLUSIONI

I dati ottenuti non sono sufficienti per illustrare i rapporti fisiologici che intercorrono tra i portainnesti e i cloni, in relazione alle condizioni ambientali; l'argomento deve essere ulteriormente indagato. Quello che si può dire è che in condizioni di stress idrico, come quelle che si sono verificate nel 2010, i due portinnesti hanno comportamenti diversi: nei cloni innestati su 1103Paulsen si osserva che l'andamento delle curve ΔV assumono una conformazione ed "onda",

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

con un decorso in campo negativo del grafico fino a raggiungere un minimo subito dopo la fine della fase fotochimica. La curva poi sale e raggiunge un massimo tra i 30 e i 70 $Sx10^{-3}$, in campo positivo, evidenziando un rallentamento nella riossidazione del plastochinone ad opera del citocromo; questo rallentamento è possibile sia dovuto alla carenza di CO_2 nelle camere sottostomatiche, come si deduce dalla letteratura sull'argomento. Per i cloni innestati su S.O.4 si ha una situazione iniziale diversa: nelle prime sessione di rilievi fluorimetrici la curve ΔV assumono una conformazione a "M" decorrendo fin dall'inizio in campo positivo e quindi segnalando uno stress fin dalle prime fasi del transient. Questa situazione si verifica anche nel 2011 e anche per i cloni su 1103P con condizioni ambientali opposte.
Queste considerazioni inducono a pensare che l'andamento ad "onda" delle curve ΔV sia da ascrivere a situazioni di stress idrico mentre la conformazione a "M" di dette curve sia una condizione di stress generico che la pianta manifesta con disfunzioni del Fotosistema II (PSII) fin dalle prime fasi di tale processo fisiologico.

Bibliografia

Scalabrelli, G., G. Ferroni, and G. Di Collalto. "Effetto del portinnesto sull'attività vegeto-produttiva del "Sangiovese" nella zona di produzione del vino DOC Morellino di Scansano." *AGGIORNAMENTO SULL'ATTIVITÀ SPERIMENTALE PER LA VALORIZZAZIONE ED IL RINNOVAMENTO DELLA VITICOLTURA DELLA PROVINCIA DI GROSSETO n 2* (2002): 61.

Intergovernmental Panel on Climate Change (IPCC). (2013)

Tombesi, Sergio, Stefano Poni, and Alberto Palliotti. "Stress idrico in Vitis vinifera: variabilità delle risposte fisiologiche intraspecifiche e loro potenziale sfruttamento nella mitigazione degli effetti dei cambiamenti climatici." *ITALUS HORTUS* 23/1 (2016): 45-53.

Lichtenthaler, H. K., & Rinderle, U. (1988). The role of chlorophyll fluorescence in the detection of stress conditions in plants. CRC Critical Reviews in Analytical Chemistry, 19(sup1), S29-S85.

Bussotti, F., Kalaji, M. H., Desotgiu, R., Pollastrini, M., Łoboda, T., & Bosa, K. (2012). Misurare la vitalità delle *piante per mezzo della fluorescenza della clorofilla* (Vol. 137). Firenze University Press.

Oukarroum, A. EL Madidi S, Schansker G, Strasser RJ (2007) Probing the responses of barley cultivars (Hordeum vulgare L.) by chlorophyll a fluorescence OLKJIP under drought stress and rewatering. *Environ Exp Bot*, *60*, 438-446.

Oukarroum, A., Schansker, G., & Strasser, R. J. (2009). Drought stress effects on photosystem I content and photosystem II thermotolerance analyzed using Chl a fluorescence kinetics in barley varieties differing in their drought tolerance.*Physiologia Plantarum*, *137*(2), 188-199.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

INFLUENCE OF THERMAL GRADIENT ON THE DYNAMICS OF GROWTH AND DEVELOPMENT OF EMMER IN GARFAGNANA
INFLUENZA DEL GRADIENTE TERMICO SULLE DINAMICHE DI CRESCITA E SVILUPPO DEL FARRO IN GARFAGNANA

Anna Dalla Marta[1]*, Marco Mancini[1], Stefano Cecchi[2], Giada Brandani[1], Gianni Licheri[1], Simone Orlandini[1]

[1] Dipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente, Università di Firenze, Piazzale delle Cascine 18, 50144, Firenze
anna.dallamarta@unifi.it
[2] Fondazione per il Clima e la Sostenibilità, via Giovanni Caproni 8, 50145 Firenze.

Abstract
Emmer (*Triticum dicoccum* Sch.) is a traditional crop of Garfagnana (Tuscany, Central Italy), where the typical environmental characteristics and a low-input agronomic management favored the development of a local variety. The cultivation area is located at an altitude ranging from about 300 to almost 1200 m a.s.l. characterized by a significant thermal gradient affecting the biological cycle of the crop. The aim of the research, is to assess the influence of such climatic variability in Garfagnana emmer growth and development. Results showed that the altitude and temperature are the most effective variables able to regulate the crop dynamics. In particular, we found that growing degree days calculated with a base temperature of 5 °C is significantly related to the phenological phase of the crop, showing how emmer thermal demand is lower compared to modern wheat varieties. Also, dry mater accumulation and plant height showed that emmer is able to grow even under extreme and marginal conditions. Further analysis will be performed at harvest in order to investigate the productivity of the three crop biotypes (mutico, semi-aristato and aristato) under the different environmental conditions considered.

Keywords: growing degree-days; *triticum dicoccum*; mountain farming; phenology; dry biomass.
Parole chiave: sommatorie termiche; *triticum dicoccum*; agricoltura di montagna; fenologia; biomassa secca.

Introduction
In Garfagnana the cultivation of emmer (*Triticum dicoccum* Sch.) it's always been related to the food tradition, to the point that in 1996 the PGI (Protected Geographical Indication) "Farro della Garfagnana" is obtained for the local production. Health benefits of emmer, and of ancient cereals in general, are partially attributed to the phytochemical composition of ancient grains and to the presence of some elements, such as slow release carbohydrates and proteins, able to ensure a high nutritional value (Dinelli et al. 2007). Such characteristics have been lost in new cereal varieties due to the strong genetic selection driven by the obtainment of high yields and improved technological properties. This led to varieties that, in order to express their potential in terms of yield and quality, require the use of intensive agricultural systems that use large energy inputs with consequent environmental impact and high production costs. For such reasons emmer almost disappeared due to its low yields, but its cultivation is maintained in marginal and mountain areas, of limited extension and low fertility, that were not suitable for more productive cereals. Garfagnana is one of these areas, where the typical environmental characteristics and a low-input and traditional agronomic management favored the maintenance of an ancient local variety. Emmer populations cultivated in the region are genetically very variable and mainly represented by three biotypes (mutico, semi-aristato and aristato) of *Triticum dicoccum* Sch characterized by different grain properties. The crop covers a relatively small area (200 ha) but the growing conditions are also very variable. In fact, a wide range of altitude from about 300 to more than 1200 m a.s.l. determines a strong variability in the growth and development of emmer, mainly due to a significant thermal gradient affecting the biological cycle of the crop (Porter et al.,1999; Bonhomme, 2000; Dalla Marta et al., 2011; Guasconi et al., 2011). The aim of the present research is to assess the influence of such climatic variability in Garfagnana emmer growth and development under traditional low-input farming management. In fact, to the aim of preserving a broad genic pool, it is necessary to provide for seed production systems that can safeguard this important biodiversity, and for which the effect of the environment is fundamental on the maintenance of the three main biotypes.

Materials and Methods
The experiment started in October 2016 in 9 experimental fields located in Garfagnana, ranging from an altitude of 350 to almost 1200 m. Soils are from deep (100-150 cm) to moderately deep (50-100 cm) with medium to fine texture.
The agronomic technique is the one normally adopted by local farmers, very simple and low-input. Soil tillage consists of a surface ploughing (25-30 cm) in August-September followed by a harrowing just before sowing. Sowing (90-150 kg/ha of dressed grain) is carried on in late September-early October, one month earlier over 800 m of altitude, by means of seeders, centrifugal fertilizer spreaders, or more often, manually. Then, harrowing is used to bury the grains into the soil. Fertilization is not applied, only manure is exceptionally used if available in the farm. The farming system commonly adopted is a 5-6 years rotation including 2-3 years of emmer followed by 2-3 years of grass (alfalfa, clove, ryegrass, etc.) used for in-farm hay production. Summary information for the experimental fields are reported in Table 1.

FARM N.	ALTITUDE (m)	SOWING DATE	SEED RATE (kg/ha)	SOWING METHOD	POSITION IN THE ROTATION
F1	349	10/11/16	150	rows	**E** - E - E - A -A - A - A
F2	399	10/10/16	90	rows	E - **E** - F - (F)
F3	464	15/10/16	125	broad casting	E - **E** - (E) - M - M - M
F4	516	05/11/16	140	broad casting	**E** - E - M - M - M
F5	534	20/10/16	90	rows	**E** - E - F - (F)
F6	659	20/10/16	130	broad casting	E - **E** - E - M - M - M
F7	676	20/09/16	120	broad casting	E - E - **E** - F - (F)
F8	820	05/10/16	110	broad casting	E - E - M - M - M
F9	1198	25/10/16	130	broad casting	E - **E** - E - M - M - M

Tab.1: Agronomic information of experimental fields: F=field; E= emmer; A= alfalfa; F= fallow; M = meadow.
Tab. 1: dati agronomici relativi ai campi sperimentali: F=campo; E= farro, A= erba medica; F= maggese; M= prato.

The first sampling was carried on on May 12. Four samplings of 0,25 m^2 were collected in each field and the following data are measured: phenological phase (BBCH), plant height (cm), number of leaves and, after drying for 24 hours at 105 °C dry biomass (g/m^2). Meteorological data are collected by 9 thermoigrometric stations (HOBO® PRO series Onset, USA), one specifically installed in each field the study area. Temperature data are used for calculating the degree days accumulaton with different thresholds (0, 5, 6, 7 and 8 °C) in order to find the most suitable for the determination of flowering, and to investigate the effect of the altitude on the phenology dynamics of emmer. To this aim, simple and multiple regression analysis are carried on.

Results and Discussion
The simple linear regression between the altitude of the field and the phenological stage of the sampled emmer showed that the two parameters are significantly related (R^2= 0,908). In the same way, also crop growth is strongly related with altitude (R^2= 0,534) confirming its effect on the crop growth and development (Fig. 1).

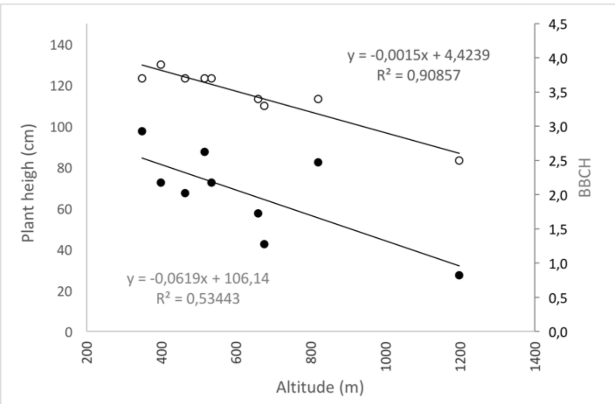


Fig.1: Linear regression between altitude (m) of the field and plant height (cm) and phenological stage (BBCH).
Fig.1: Regressione lineare tra la quota dei campi sperimentali (m) e l'altezza delle piante (cm) e la fase fenologica (BBCH).

Considering that the main variable showing a gradient with altitude is air temperature, that is also the driving variable of crop development, growing degree days (GDD) are calculated and plotted against the phenological phase measured in the different fields. In order to find the best indicator, different base temperatures are tested (GDD_0, GDD_5, GDD_6, GDD_7 and GDD_8 °C) and degree days are accumulated starting from the sowing date to the day of the sampling. The most suitable base temperature is 5 °C as demonstrated by the determination coefficient (R^2= 0,709; P<0,001) (Fig. 2).

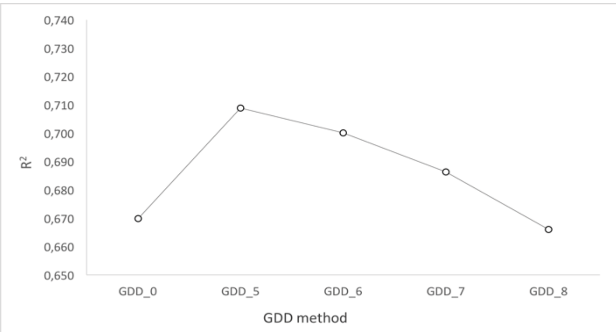


Fig.2: Trend of the determination coefficient (R^2) between emmer phenological phase and growing degree days calculated with different base temperatures.
Fig.2: Andamento del coefficiente di determinazione (R^2) tra la fase fenologica del farro e le sommatorie termiche calcolate con diverse temperature di base.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

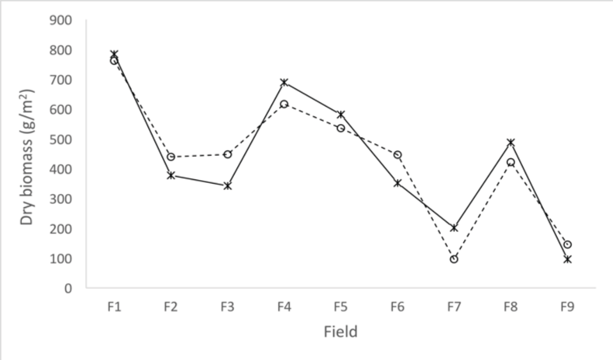


Fig.3: Dry biomass accumulation (g/m^2) observed (solid line) and estimated through the multiple linear regression equation (dotted line).
Fig.3: Biomassa secca accumulata (g/m^2) osservata (linea continua) e stimata con l'equazione di regressione multipla (linea tratteggiata).

In partiuclar, the multiple regression implemented showed an increasing effect of altitude, sowing density and GDD_5, which together explain a significant part of the plant growth variability (R^2=0,935) (Fig. 3).

Conclusions

In this research, the effect of the environment (altitude and temperature gradient) and the sowing density on the emmer growth and development is investigated. The nine fields are located at different altitudes ranging between 350 to almost 1200 m a.s.l. with a consequent variation in air temperature. Preliminary results showed that both altitude and temperature strongly affect emmer phenology. In particular, the GDD with a base temperature of 5 °C seems to be the most related to the phenology dynamics, showing the adaptation of emmer to lower temperature compared to modern wheat varieties. On the other hand, dry matter accumulation is the result of more complex interactions between environment and sowing density. In fact, both factors affect the crop tillering, but in an opposite way and with different intensity. In particular, the manual method of sowing (broad casting) provide an inhomogeneous but complete cover of the soil which probably depends more on its irregular distribution rather than on a high sowing density.

These preliminary results highlight that emmer growth and development is strongly affected by the environmental conditions, but also that the crop is well adapted to the marginal areas in which is cultivated. Further analysis will be performed in order to determine the effect of the variables considered on the final yield.

Acknowledgments

Attività in parte svolte nell'ambito del progetto misura 16.2 "FAGADOP", PSR 2014/2020 Regione Toscana. Si ringraziano la Garfagnana COOP Alta Valle del Serchio e la Fondazione Cassa di Risparmio di Firenze per il supporto fornito.

References

Dinelli G., Benedettelli S., Marotti I., Bonetti A., Ghiselli L., Segura-Carretero A., (2008). Functional properties of wheat: phytochemical profiles of old and new varieties. X Congress of the European Society for Agronomy, Bologna (Italy) 15-19 September: 415-416.

Bonhomme, R. 2000. Bases and limits to using 'degree day' units. Eur. J. Agron. 13: 110.

Porter, J. R. and Gawith, M. 1999. Temperatures and the growth and development of wheat: a review. Eur. J. Agron. 10: 23-36.

Mc Master, G.S., Green, T.R., Erskine, R.H., Edmunds, D., Ascough II., J.C., 2012. Spatial interrelationships between wheat phenology, thermal time and terrain attributes. Agron. J. 104 (4), 1110-1121.

Dalla Marta A., Grifoni D., Mancini M., Zipoli G., Orlandini S. (2011). The influence of climate on durum wheat quality in Tuscany, Central Italy. International Journal of Biometeorology, 55, 87-96. (1.813).

Guasconi F., Dalla Marta A., Grifoni D., Mancini M., Orlando F., Orlandini S. (2011). Influence of climate on durum wheat production and use remote sensing and weather data to predict quality and quantity of harvest. Italian Journal of Agrometeorology – 3/2011, 21-28.

APPLICATION OF THE DAYCENT BIOGEOCHEMICAL MODEL TO ASSESS GHG-EMISSIONS FROM AN SWISS GRASSLAND

APPLICAZIONE DEL MODELLO BIOGEOCHIMICO DAYCENT PER VALUTARE LE EMISSIONI DI AZOTO DA UN PASCOLO ALPINO

L. Brilli[*1], K. Fuchs[2], L. Merbold[3], C. Dibari[4], G. Argenti[4], R. Ferrise[4], M.Moriondo[1], S. Costafreda-Aumedes[4], M. Bindi[4].

[1] IBIMET-CNR, Via Madonna del Piano 10, 50019 Sesto Fiorentino (Fi), Italy
[2] ETHZ, Department of Environmental Systems Science, 8092 Zürich, Switzerland
[3] Mazingira Centre, International Livestock Research Institute, 00100 Nairobi, Kenya
[4] University of Florence, DiSPAA, Piazzale delle Cascine 18, 50144 Firenze, Italy.

[*] Lorenzo Brilli, l.brilli@ibimet.cnr.it

Abstract
Grassland systems are one of the main source of greenhouse gases (GHG), particularly nitrous oxide (N_2O) and methane (CH_4). This makes grassland systems great contributors to global warming. Management practices, soil types and climatic conditions are the main drivers influencing the magnitude of GHG emissions, therefore assessing their interaction is essential in order to identify practices that lead to GHG emission reductions. Biogeochemical process-based models are a powerful tools to overcome known constraints of field experiments, i.e. high costs, limited range of practices, etc.. On this basis, the process based model DAYCENT, widely applied worldwide on grassland sites, has been applied for estimating the emission of the major N trace gases (i.e. N_2O, NO flux, etc.) and CH_4 considering different management options.

Keywords
Grassland modelling, DAYCENT, Mitigation, N fluxes
Parole chiave
Modellistica dei pascoli, DAYCENT, Mitigazione, Flussi di N

Introduction
Grasslands are known to be one of the main source of greenhouse gases (GHG), particularly nitrous oxide (N_2O) and methane (CH_4). These fluxes are closely linked with management practices, soil types and climatic conditions (Soussana et al., 2004). Understanding the role played by these systems as contributors to global warming has been widely addressed through several experiments (e.g. Allard et al., 2007; Soussana et al., 2007). The scouting of all possible interactions between management practices, soil types and climatic conditions may indeed allow to open new perspective for limiting grasslands contribution to global warming and, at the same time, maintaining a sustainable level of production. This scouting, however, is sometimes limited by constraints, particularly in field experiments and include high costs, defined but static experimental designs and covering only few management practices. These constraints can be overcome using process-based models. Process-based models have been applied widely on several ecosystems worldwide, can reproduce ecosystems soil-plant-atmosphere dynamics, thus providing indication for understanding the role played by grassland systems to global warming (Chen et al., 2008; Seijan et al., 2011). In this work, the DAYCENT model has been applied in a Swiss grassland over a period of three years (2003-2005) in order to assess the effect of different fertilizer types (i.e. ammonium nitrate, urea and manure) and amount (50 kg N ha^{-1}) on the harvested biomass and the relative Nitrogen (N) content and emission of the major N trace gases (i.e. N_2O, NO flux, etc.) and CH_4.

Materials and Methods
Study area: The test site is a permanent grassland located in Chamau (Switzerland, 47°12'36.8" N and 8°24'37.6" E) at 393 m asl, and is part of a former ETH Research Station. The typical management of the grassland consists of few days of grazing with sheep per year, and regular (up to 6 times a year) application organic fertilizer, decadal ploughing and more frequent oversowing besides the regular harvests (up to 6 times a year).
Experimental design: Five (5) fertilizer application and five (5) harvest dates to simulate grazing with residues removal per year- were hypothesized based on typical grassland management. The fertilizer scenarios included: *i)* AMN, using 50 kg N ha^{-1} per fertilizer application as ammonium nitrate; *ii)* URE, using 50 kg N ha^{-1} as urea; *iii)* MAN, using 50 kg N ha^{-1} as manure (C:N=30). Fertilization and harvest dates changed across the years (Tab. 1)
Model description and application: DAYCENT, the daily time step version of the biogeochemical model CENTURY (Parton et al., 1994, 1998), was designed to simulate soil C dynamics, nutrient flows (N, P, S), and trace gas fluxes (CO_2, CH_4, N_2O, NO_x, N_2) between soil, plants and the atmosphere (Parton et al., 1998, del Grosso et al., 2001a). The model takes

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

different agronomic practices (tillage, mowing, fertilization) into account driving C-dynamics, the effects of elevated CO_2 and other consequences of global change on net primary production, transpiration rate, and C:N ratio in biomass. Based on these features, DAYCENT can be considered a tool highly suitable at simulating the GHG mitigation potential of different management activities in grasslands (De Gryze et al., 2010).

Results and Discussion

The DAYCENT model was a priori calibrated over an Swiss grassland within the project "Robust models for assessing the effectiveness of technologies and managements to reduce N_2O emissions from grazed pastures" (M4P, 2014-2017), under the auspices of the Global Research Alliance for Agricultural Greenhouse Gases – Integrative Research Group. Then, the model was applied to evaluate the effect of different type (i.e. ammonium nitrate, urea and manure) and amount (50 kg N ha^{-1}) of fertilizer on the harvested biomass and the relative Nitrogen (N) content (Fig. 1).

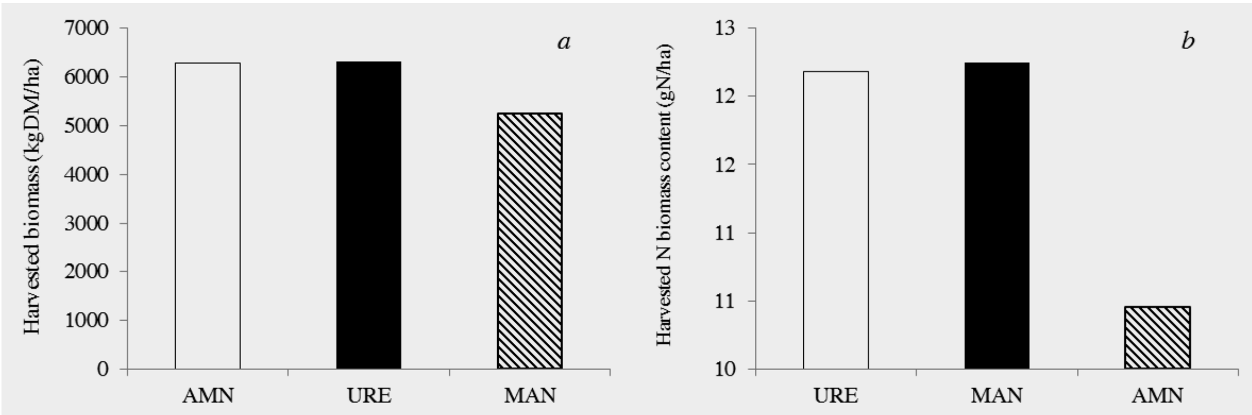


Fig.1 – Histograms of total three-years average harvested biomass (kg DM ha^{-1}*) and three years harvested biomass N content (g N* m^{-2}*) over the period 2003-2005 for the ammonium nitrate, urea and manure scenarios.*
Fig.2 - Istogrammi della biomassa media annua (kg DM ha^{-1}*) e del contenuto di N (g N* m^{-2}*) per il periodo 2003-2005 per gli scenari di fertilizzazione rispettivamente con ammonio nitrato, urea e letame.*

In figure 1a no substantial differences in the three-years average harvested biomass have been observed when ammonium nitrate (6272.8 kg DM ha^{-1}) and urea (6320 kg DM ha^{-1}) were applied. By contrast, using manure a decrease of about 17% has been observed. This more efficient vegetation response using inorganic fertilization may be probably due to the climate conditions of the area. More specifically lower temperature may have decreased the manure decomposition thus providing lower N availability for vegetation. A similar pattern has been observed also for the N content in the harvested biomass (Fig. 1b), where the highest values were found using ammonium nitrate (12.17 g N m^{-2}) and urea (12.25 g N m^{-2}), whilst the lowest using manure (10.45 g N m^{-2}, i.e. -14.4% on average).

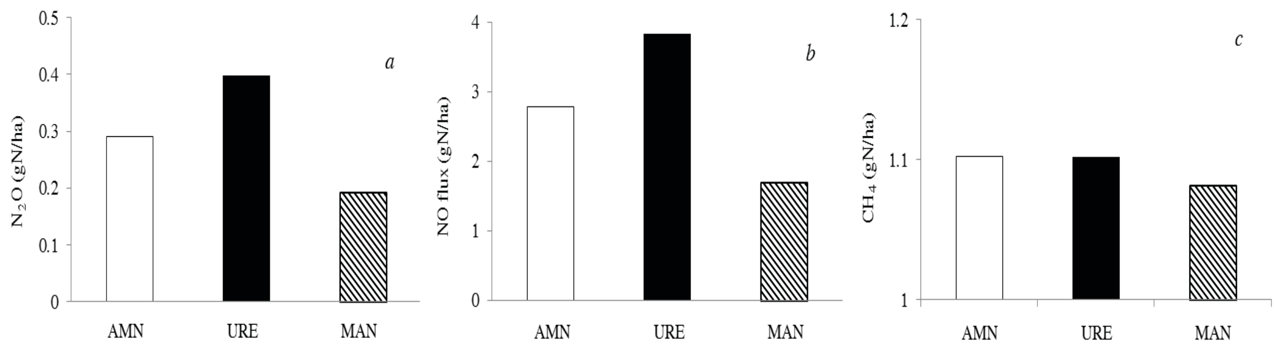


Fig.2 – Histograms of cumulated the major N trace gases (i.e. N_2O*, NO flux, etc.) and* CH_4*.over the period 2003-2005 for the ammonium nitrate, urea and manure scenarios.*
Fig.2 - Istogrammi del cumulato totale relativo ai gas serra investigati (N_2O*, NO flux e* CH_4*) nel periodo 2003-2005 per gli scenari di fertilizzazione rispettivamente con ammonio nitrato, urea e letame.*

Concerning N_2O emissions (Fig. 2a) the highest values were found using urea (0.39 g N m^{-2}) whilst the lowest using manure (0.19 g N m^{-2}). A similar pattern was observed also for NO flux (Fig.2b), where the highest emissions were observed using urea (3.8 g N m^{-2}) whilst the lowest using manure (1.7 g N m^{-2}). These results significantly diverge with literature, since manure is well known to increase soil N_2O emissions by stimulating nitrification and denitrification processes. These unexpected results may be due to the low efficiency of DAYCENT in reproducing manure either the effect of low temperature over the alpine grassland. The joint effect of these two modelling limitations may have decreased the simulated nitrification and denitrification processes, thus strongly reduced the N emissions from manure. The ability of a process-based model at correctly reproduce a specific type of fertilizer should be considered fundamental for assessing N trace gas emissions. The impacts of several type of fertilizer on GHG emissions are linked to the type of fertilizer used as well as to a wide number of soil properties including moisture content, texture, pH, source of organic amendments and the C and N contents of amendments. Therefore, limitations at reproducing specific type of fertilizer and/or the joint effect with specific climate conditions (I.e. low temperature) may decrease the suitability of a process based model for investigating on GHG dynamics. Concerning CH_4 emissions, no huge differences using all fertilizer types (Fig.2c) were found. The level of emissions are in line with those reported in the most recent literature (Louro et al. 2016, Jones et al., 2017) that analysed GHG fluxes responses to inorganic and organic fertilization in grazed areas.

Conclusions

Our results show that DAYCENT is a suitable tool to model pasture growth as well as to analyse N content in harvested biomass. Due to its ability at reproducing several management options such as grazing, cutting, fertilization, tillage and irrigation, the model can be used to assess GHG emissions under different scenarios and to improve nitrogen use efficiency. However, limitations due to bias in nitrogen partitioning or nitrification/denitrification rate over specific conditions may reduce the suitability of the model at reproducing specific grassland scenarios (i.e. limitations at representing specific type of fertilizer or geographical areas, etc). Nevertheless, field experiments providing initial soil data and high-frequency GHG flux data should be incentivized since this may allow to test C-N processes of models under different conditions, and subsequently lead to better model performances and/or implementation.

Acknowledgments

This work was developed by the project "Robust models for assessing the effectiveness of technologies and managements to reduce N_2O emissions from grazed pastures" (M4P, 2014-2017), under the auspices of the Global Research Alliance for Agricultural Greenhouse Gases – Integrative Research Group (http://globalresearchalliance.org/research/integrative). Kathrin Fuchs and Lutz Merbold were supported by the Swiss National Science Foundation under the 40FA40_154245 / 1 grant agreement.

References

Allard V., Soussana J.F., Falcimagne R., Berbigier P., Bonnefond J.M., Ceschia E., D'hour P., Hénault C., Laville P., Martin, C., Pinarès-Patino C. 2007. The role of grazing management for the net biome productivity and greenhouse gas budget (CO_2, N_2O and CH_4) of semi-natural grassland. Agriculture, Ecosystems and Environment, 121: 47–58.

Chen D.L., Li Y., Grace P., Mosier A.R. 2008. N_2O emissions from agricultural lands: a synthesis of simulation approaches. Plant Soil, 309:169-189.

Jones S. K., Helfter C., Anderson M., Coyle M., Campbell C., Famulari D., Di Marco C., van Dijk N., Tang Y. S., Topp C. F.E., Kiese, R., Kindler, R., Siemens, J., Schrumpf, M., Kaiser, K., Nemitz, E., Levy, P. E., Rees, R. M., Sutton, M. A., Skiba U. M. 2017. The nitrogen, carbon and greenhouse gas budget of a grazed, cut and fertilised temperate grassland. Biogeosciences, 14:2069-2088.

Louro A., Cárdenas L.M., García M.I., Báez D. 2016. Greenhouse gas fluxes from a grazed grassland soil after slurry injections and mineral fertilizer applications under the Atlantic climatic conditions of NW Spain. Science of the Total Environment, 573:258-269.Seijan, V., Lal, R., Lakritz, J., Ezeji, T. 2011. Measurement and prediction of enteric methane emission. International Journal of Biometeorology, 55:1-16.

Signor D., Cerri C.E.P., Conant R. 2013. N_2O emissions due to nitrogen fertilizer applications in two regions of sugarcane cultivation in Brazil. Environmental Research Letters, Volume 8, Number 1.

Soussana J.F., Loiseau P., Vuichard N., Ceschia E., Balesdent J., Chevallier T., Arrouays D. 2004. Carbon cycling and sequestration opportunities in temperate grasslands. Soil Use Management, 20:219-230.

Soussana J.F., Allard V., Pilegaard K., Ambus C., Campbell C., Ceschia E., Clifton-Brown J., Czobel S., Domingues R., Flechard C., Fuhrer J., Hensen A., Horvath L., Jones M., Kaspe, G., Martin C., Nagy Z., Neftel A., Raschi A., Baronti S., Rees R.M., Skiba U., Stefani P., Manca G., Sutton M., Tuba Z., Valentini R. 2007. Full accounting of the greenhouse gas (CO_2, N_2O, CH_4) budget of nine European grassland sites. Agriculture, Ecosystems and Environment, 121:121–134.

Yao Z., Wei Y., Liu C., Zheng X., Xie B. 2015. Organically fertilized tea plantation stimulates N_2O emissions and lowers NO fluxes in subtropical China. Biogeosciences, 12:5915–5928.

EFFECT OF AIR TEMPERATURE ON OLIVE PHENOLOGY: PRELIMINARY RESULTS OBSERVED IN VAL D'ORCIA.

EFFETTO DELLA TEMPERATURA DELL'ARIA SULLA FENOLOGIA DELL'OLIVO: PRIMI RISULTATI OSSERVATI IN VAL D'ORCIA.

Ada Baldi[1*], Martina Petralli[1], Stefano Cecchi[2], Carolina Fabbri[2], Giada Brandani[2], Marco Mancini[2], Simone Orlandini[1]

[1] Dipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente, Università di Firenze, Piazzale delle Cascine 18, 50144, Firenze
[2] Fondazione per il Clima e la Sostenibilità, Via Caproni 8, 50144, Firenze
*ada.baldi@unifi.it

Abstract
The development and application of decision support systems in agriculture is a concrete step toward a more sustainable production, and a response to climate change which is imposing the adoption of effective adaptation and mitigation strategies. In this context, the objective of this study is to develop a decision-making tool for the optimization of olive (*Olea europea* L.) management in terms of nutrient supply (foliar application) and crop protection.
To this aim, phenological dynamics of olives were monitored in Val d'Orcia (Central Italy) under different environmental conditions in order to assess their influence on the growth and development of olive tree. The preliminary results highlighted that Frantoio and Leccino cultivars are more precocious than Moraiolo in achieving bud development, but not differences exist between the cultivars in the occurrence of inflorescence emergency. Beside the cultivar, we also observed an influence of temperature on the appearance and development of buds.

Keywords: *olea europea* L.; growing degree days (GDD); bud development; inflorescence emergency, agrometeorology.
Parole chiave: *olea europea* L.; sommatoria termica (GDD); ripresa vegetativa; mignola; agrometeorologia.

Introduction
Plant phenology is one of the most important bio-indicators, since its trends can provide helpful spatial and temporal information regarding ongoing climate changes (García-Mozo et al., 2011). Many studies highlighted the insensitivity of floral maturation of olive (*Olea europea* L.) to day length but a remarkable response to temperature (Mancuso et al., 2002; Bongi et al., 2002); for this reason, olive is considered a useful indicator of increasing temperature for the Mediterranean region, where it is one of the most cultivated crops (Osborne et al., 2000; Orlandi et al., 2008).
The thermal requirement of olive at flowering have been well investigated in order to assess and forecast the yield and the timing of pollen release and airborne pollen concentration, being olive pollen one of the principal causes of allergies in the Mediterranean basin (Moriondo et al., 2001). However, only a little information is available about the thermal requirement for the other phenological stages occurrence (Mancuso et al., 2002; Pérez-López et al., 2008). Knowing how the temperature influences the whole phenological cycle of olive could be decisive for forecasting and optimizing crop management strategies like foliar fertilization, phytosanitary treatments, and olive fly control. The aim of this study is to develop a decision-making tool useful to introduce precision farming techniques in olive orchards in Val d'Orcia area (Tuscany, Italy).

Materials and Methods
The study was carried out in Val d'Orcia, a hilly area located in the south inland of Tuscany and characterized by a typical Mediterranean climate.
Air temperature and olive phenological growth stages were monitored from 1st January 2017 (Bonofiglio et al., 2008) to 18th May 2017 in 4 olive orchards, located at different quota from 246 to 506 m above sea level (Table 1), in order to assess the influence of temperature on the olive tree growth and development. The olive orchards were managed with the same cultivation techniques and composed by plants of Leccino, Moraiolo and Frantoio cultivar with similar age and dimensions (330-350 plants ha^{-1}).

Olive orchard	m a.s.l.	UTM East	UTM North
A	246	32T 709440	32T 4762056
B	418	32T 713275	32T 4765521
C	481	32T 709979	32T 4766841
D	506	32T 710406	32T 4767081

Table 1: Monitored olive orchards.
Tabella 1. Oliveti monitorati.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Minimum and maximum air temperature data were collected hourly by 4 air temperature sensors (HOBO® PRO series Temp/RH Data Logger, Onset Computer Corporation, Pocassette, MA, USA) with a naturally ventilated solar radiation shield.
Phenological stages were monitored every 2 weeks during January and February 2017 and every 2 days from March to May on 10 olive trees for each cultivar in each orchard. Plants were selected randomly at a short distance (less than 500 meters) to the air temperature sensors, and exposed to similar condition.
Air temperature data was used to calculate the growing degree days (GDD) by the following formula: GDD = Σ (T m – T threshold) where "T m" is the daily mean temperature and "T threshold" is the minimum temperature for olive biothermic accumulation (Bonofiglio et al., 2008). For "T threshold" 7.5 °C (GDD_7.5) (Bonofiglio et al., 2008) and 10 °C (GDD_10) (Mancuso et al., 2002) were considered in order to evaluate which better fits with our observation in the study area. GDD were used to identify the days of the year (DOY) in which the bud development (foliar buds start to swell and open, BBCH_01) and inflorescence emergency stages (flower cluster totally expanded, BBCH_55) were reached.
To date, no data are available about the response of olive three to the ongoing warming in Val d'Orcia. In order to estimate the DOY of occurance of BBCH_01 and BBCH_55 phenological stages over the last 20 years the calculated GDD_7.5 and GDD_10 for 2017 were taken as a reference and applied to the data collected by a weather station of the Regional Hydrological Service of Tuscany, located in the middle of the study area.

Results and Discussion
From the 1st of January 2017 to 18th of May 2017 air temperature showed the same trend in all the monitored olive orchards (Figure 1), with a regular increasing until the end of March and from the end of April. In the middle of April, a strong decrease of temperature was observed (of almost 10 °C). GDD showed differences between sites (Table 2), with a total amount of 46.8 °C and 73.3 °C between the coolest (D) and the hottest (A) olive orchard, respectively in GDD_10 and GDD_7.5.

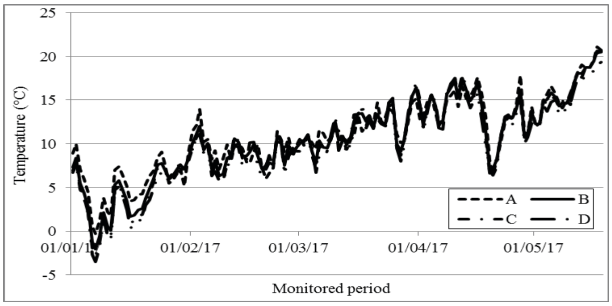


Figure 1: Air temperature trend in Val d'Orcia from the 1st of January 2017 to 18th of May 2017 in the 4 monitored olive orchards.
Figura 1: Andamento della temperatura dell'aria in Val d'Orcia, dal 1 gennaio 2017 al 18 maggio 2017, nei 4 oliveti monitorati.

Site	GDD_10	GDD_7,5
A	298,2	538,5
B	290,3	516,2
C	290,0	510,9
D	251,4	465,2

Table 2: GDD accumulation in the 4 observed olive orchards in Val d'Orcia from the 1st of January to the 18th of May 2017. [GDD was calculated with a base temperature of 7.5 °C (GDD_7.5) and 10 °C (GDD_10)].
Tabella 2: Gradi giorno accumulati dal 1 gennaio 2017 al 18 maggio 2017 nei 4 oliveti monitorati. [GDD sono stati calcolati su base 7.5 °C (GDD_7.5) e su base 10 °C (GDD_10).

During the monitored period, BBCH_01 occurred between 18th and 31th of March, DOY 77 and 90, respectively for all cultivar (Table 3). Frantoio and Leccino reached BBCH_01 between 18th and 23rd of March (DOY 82), resulting the most precocious cultivars, while Moraiolo from 25th (DOY 84) and 31st of March. For BBCH_01 the results highlighted also a slight difference in GDD between Frantoio and Leccino; the first reached the stage at 27.4 °C (GDD_10) and at 110.9 °C (GDD_7.5), the second at 30.8 °C (GDD_10) and at 118.1 °C (GDD_7.5). Conversely, the vegetative growth appearance of Moraiolo occurred at 47.8 °C (GDD_10) and at 149.1 °C (GDD_75). Our results agree with Mancuso et al. (2002) that, using GDD_10, indicated a requirement of 27.6 °C, 32 °C and 49.9 °C for reaching BBCH_01 in Frantoio, Leccino, and Moraiolo, respectively.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Olive orchard	Frantoio			Leccino			Moraiolo		
	DOY	GDD 10	GDD 7.5	DOY	GGD 10	GDD 7.5	DOY	GDD 10	GDD 7.5
A	77	28,2	122,3	78	31,2	127,8	84	52,4	164,0
B	78	27,2	110,7	79	29,1	115,1	84	46,8	145,3
C	78	28,0	107,4	80	32,7	117,1	86	46,9	143,2
D	80	26,1	103,3	82	30,2	112,4	90	45,1	144,1

Table 3: Date of occurrence of bud development phenological stages (BBCH_01) in the 4 observed olive orchards for Frantoio, Leccino and Moraiolo cultivars.
Tabella 3: Data di raggiungimento della fase di ripresa vegetativa (BBCH_01) nei 4 oliveti osservati per le cultivar Frantoio, Leccino e Moraiolo.

Considering BBCH_55, the observed differences were less evident, occurring between 15^{th} and 18^{th} of May, DOY 135 and 138, respectively in all cultivars and for each site. The amount of GDD_10 and GDD_7.5 was meanly of 257 °C and 476 °C for Leccino and Frantoio and of 274 °C and 497 °C for Moraiolo. The strong decrease in temperatures occurred in April may have stopped the vegetative development of the earlier cultivars (Frantoio e Leccino).
Figure 3 and Figure 4 show the DOY of occurrence of BBCH_01 and BBCH_55 over the last 20 years on the basis of GDD_7.5 and GDD_10 calculated in 2017. Since no differences were observed in the trends obtained with the different "T threshold" we show only the results of GDD_7.5. As expected, as a consequence of global warming, the negative trend indicates a reduction a shortening of the period needed to reach the phenological stages from 1998 to 2017. Nevertheless, these preliminary results show a greater effect of temperature on BBCH_01 rather than on BBCH_55.

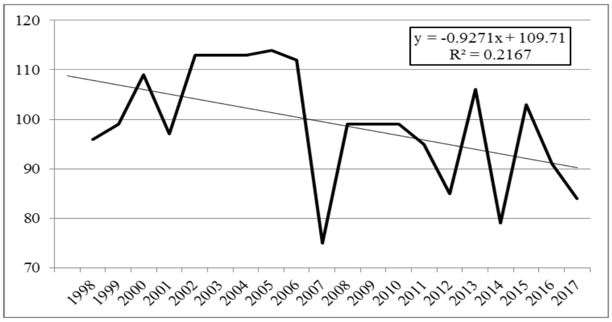


Figure 2: DOY of occurrence of bud development phenological stage (BBCH_01) from 1998 to 2017 according GGD_7.5 calculated on the observed data of 2017.
Figura 2: DOY di raggiungimento della fase fenologica di ripresa vegetative (BBCH_01) dal 1998 al 2017 sulla base dei GDD calcolati nel 2017.

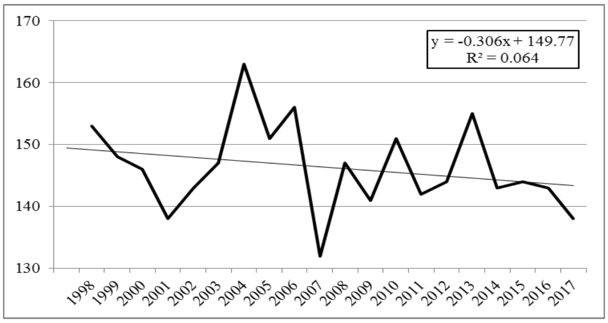


Figure 3: DOY of occurrence of inflorescence emergency phenological stage (BBCH_55) from 1998 to 2017 according GGD_7.5 calculated on the observed data of 2017.
Figura 3: DOY di raggiungimento della fase fenologica di mignola (BBCH_55) dal 1998 al 2017 sulla base dei GDD calcolati nel 2017.

Conclusions
In this research, the effect of the temperature on olive tree phenological dynamics in Val d'Orcia was investigated for the first time. The preliminary results showed that Frantoio and Leccino cultivars are more precocious than Moraiolo in achieving bud development. At the same time, a synchronicity of the three cultivars was observed in the occurrence of inflorescence emergency stage. Moreover, the results seem to show a greater influence of temperature on BBCH_01 than on BBCH_55 phenological stage.
Further analysis will be carried out in the next years in order to assess the effect of temperature on the whole phenological cycle of olive tree in Val d'Orcia. The correlation between observed phenological stages and monitored air temperatures at different quota will be studied with the aim of developing a decision-making tool useful for plan and optimize olive management.

Acknowledgments
Attività in parte svolte nell'ambito del progetto misura 16.2 "APPAGO", PSR 2014/2020 Regione Toscana.

Si ringraziano la Società Cooperativa Oleificio Val d'Orcia Società Agricola, l'Az. Agr. Poggio al Vento di Mascelloni Roberto, l'Az. Agr. La valle del Sole di Erika Formichi, l'Az. Agr. Podere Bernini di Lorenzoni Sergio, l'Az. Agr. Colombaio Martini di Fabio Martini e la Fondazione Cassa di Risparmio di Firenze per il supporto fornito.

References

Bongi G., Berichillo L., Balducci V., Panelli G., 2002. La fioritura dell'olivo come strumento indicatore delle variazioni climatiche. Proc. Intern. Congress of Oliviculture, Spoleto, pp. 183-187.

Bonofiglio T., Orlandi F., Sgromo C., Romano B., Fornaciari M., 2008. Influence of temperature and rainfall on timing of olive (Olea europaea) flowering in southern Italy. New Zealand journal of crop and horticultural science. 36(1), 59-69.

García-Mozo H., Mestre A., Galán C., 2011. Climate change in Spain: phenological trends in southern areas. Climate change socioeconomic effects. InTech. 237-250.

Mancuso S., Pasquali G., Fiorino P., 2002. Phenology modelling and forecasting in olive (*Olea europaea* L.) using artificial neural networks. Advances in Horticultural Science. 16(3-4):,155-164.

Moriondo M., Orlandini S., De Nuntiis P., Mandrioli P., 2001. Effect of agrometeorological parameters on the phenology of pollen emission and production of olive trees (Olea europea L.). Aerobiologia. 17(3), 225-232.

Orlandi F., Ruga L., Romano B., Fornaciari M., 2005. Olive flowering as an indicator of local climatic changes. Theoretical and Applied Climatology. 81(3), 169-176.

Osborne C.P., Chuine I., Viner D., Woodward F.I., 2000. Olive phenology as a sensitive indicator of future climatic warming in the Mediterranean. Plant, Cell & Environment. 23(7), 701-710.

Pérez-López D., Ribas F., Moriana A., Rapoport H.F., De Juan A., 2008. Influence of temperature on the growth and development of olive (Olea europaea L.) trees. The Journal of Horticultural Science and Biotechnology. 83(2), 171-176.

COMPARISON BETWEEN OLD AND MODERN WHEAT VARIETIES IN THE CONTEXT OF CLIMATE CHANGE: PRELIMINARY RESULTS FOR A STUDY IN TUSCANY

CONFRONTO TRA VARIETÀ ANTICHE E MODERNE DI FRUMENTO NEL CONTESTO DEL CAMBIAMENTO CLIMATICO: RISULTATI PRELIMINARI DI UNO STUDIO CONDOTTO IN TOSCANA

Gloria Padovan[1*], Roberto Ferrise[1], Marco Mancini[1], Camilla Dibari[1], Lisetta Ghiselli[1], Marco Bindi[1,2]

[1]Deparment of Agri-food Production and Environmental Sciences (DISPAA), University of Florence, Florence
[2]Research Unit 'Climate chAnge System and Ecosystem' (CLASSE), University of Florence, Florence
*gloria.padovan@unifi.it

Abstract
The prospected climate change in the Mediterranean basin, with an increase in temperatures and an irregular precipitation distribution, may negatively affect wheat development and productivity in the next decades. Despite their lower productivity, old wheat varieties present resistance to biotic and abiotic stresses for which they might be however comparable if not competitive to modern varieties in a context of climate change. The aim of this study is to analyze the effect of climate change in old and modern soft wheat varieties in typical Tuscany wheat producer areas. To this, the process-based model SSM-Wheat was used to simulate wheat development and growth under present and two future periods according to the A1B SRES scenario. Despite precipitation reduction and temperature increased were prospected, the wheat yield seemed to increase significantly in the future because it will mature earlier, escaping of severe heat stress, and because of the CO2 concentration effects. Moreover, old soft wheat varieties seemed to be less sensitive to climate change than the modern one.

Keywords: Soft wheat; SSM-Wheat; Old wheat varieties; Climate change impacts in the Mediterranean
Parole chiave: grano tenero; SSM-Wheat; varietà antiche di grano, impatti del cambiamento climatico nel Mediterraneo

Introduction
Soft wheat (Triticum aestivum L.) is one of the most cultivated crops in Italy, with 554.000 hectares and 29.962 billion of tones in 2015 (ISTAT, 2016). In Tuscany soft wheat represents the second cultivated grain crops, with 14.387 hectares and 48.074 tones (ISTAT, 2011). Soft wheat growth and development are strongly related to weather patterns during the growing season. The future climate projections for the Mediterranean basin suggested an increase in temperatures and an irregular precipitation distribution. Moreover, an increase in drought and in the hot days was forecasted (IPCC, 2013). Soft wheat was very sensitive in heat stress, in particular if it occurred during some phenological phases such as anthesis and grain filling (Porter and Gawith, 1999). During the growing season, wheat could be exposed to heat stress in different growing period, but heat stress during the reproductive phase was more harmful than during the vegetative phase because it had directly effect on grain number and dry weight (Farooq et al., 2011). Plants, as wheat, could adopt different strategies to overcome heat stress: one way was the drought avoidance and another way was the drought tolerance (Semenov et al., 2009). One of the drought avoidance strategies was to accelerate the phenological development to maturing earlier, in this way plants could escape of the most severe drought at the end of growing season.
Crop simulation models were more often used in crop research because they provided the best-known approach for increasing the understanding plant processes particularly the interaction between genotypes, environment and management (Soltani et al., 2013; Semenov et al., 2009). The modern cultivars were selected for the above ground characteristics, so they could be harvest using the modern machineries, and to increasing yield. Selecting for those characteristics, other traits, such as drought tolerance and diseases resistance had been lost. Lots of study suggested that the old wheat varieties could have and important role for the human diet in the future. For instance, because of their biotic and abiotic resistance and their nutritional characteristics (Arzani and Ashraf, 2017), but few study analyzed the behavior of old wheat cultivars under climate change. The agronomic practices used for the production of old wheat varieties contributed to their resistance to stress caused by weather variability. During sowing, a lower seed density favored at first the tillering and then the development of the robust radical apparatus, able to cope with elevate evapotranspiration demand, strictly connected with high air temperature. These characteristics were associated with a low nitrogen fertilization treatment level, so, in that way, the wheat height and lodging were controlled. Surely, a lower nitrogen fertilization level caused a lower wheat yield, but it allowed wheat to better overcame heat stress.

The aim of this study was to simulate the development and growth of three ancient soft wheat cultivars and one modern cultivar under future climate scenarios in different Tuscany wheat productive areas using SSM-Wheat, simplified process-based simulation model created by Soltani et al., (2013).

Materials and Methods

Three soft wheat ancient cultivars, Gentilrosso, Andriolo and Sieve and one modern soft wheat varieties, Bolero, were used for this study. The ancient varieties need more vernalization than the modern one for the promotion of anthesis; instead, Bolero is more sensitive to photoperiod than the others. The process-based model SSM-Wheat (Soltani et al., 2012) was calibrated for all these cultivars using phenological and yield observed data that came from a field experiment carried out in Cesa (Arezzo, Italy) during 2008-2009 and 2011-2012. The cultivars were sown on 13th January 2009 and on 9th November 2011 with an inter row of 0.18 m and a seed density of 450 seeds m^{-2}. The plot size was 5.76 m^2 (4m x1.44 m). Three different fertilization treatments have been tasted: 30, 60, 90 kg N ha^{-1} (40% at sowing and 60 % at tillering). For the calibration phase, daily observed data of temperature, precipitation and radiation were from a weather station close to the field. Measured soil physical and hydraulic properties including texture, saturation, field capacity, wilting point and organic matter content were used to describe the soil in the model.

Once calibrated, the model was applied in four sites considering typical Tuscany soft wheat productive areas: Monteroni D'Arbia (SI), Alberese (GR), San Piero a Grado (PI), Marciano Della Chiana (AR). For this study, the typical Tuscany sowing date and fertilization treatments, both in quantity and distribution timing, were used. The sowing date was selected on 15 December with a plant density of 450 seeds m^{-2}. The first nitrogen fertilization treatment was distributed in pre-sowing with 33 kg N ha^{-1} as $(NH_4)_2SO_4$ (11-25-0), and the other two top-dress treatments during the tillering and the stem elongation with 52 kg N ha^{-1} as NH_4NO_3 (26%). Soil properties and parameters were extracted from the Tuscany Regional Soil Database.

Present and future climate data for feeding the model were produced using the weather generator LARS-WG (Semenov and Barrow, 1997). LARS-WG was first calibrated at each site using a 30-year time-series of observed daily weather data. The weather generator was then applied to create synthetic daily weather time-series referred to present (1981-2010) (1981-2010, PP), medium (2046-2065, MP) and far (2080-2099, FP) future periods. Future weather time-series were created based on HadCM3 general circulation model projections according to the SRES scenario A1B (IPCC, 2001). The CO_2 concentration was 360 ppm under PP, 500 ppm under MP and 640 ppm under FP.

Results and Discussion

Here are presented only Monteroni D'Arbia and Alberese results.

As regard the model calibration, the phenology was very similar for all varieties with a high correlation coefficient, R^2>0.98 and RMSE < 5 days for the emergence, the anthesis and the physiological maturity. The yield calibration was satisfied with RMSE < 0.5 t/ha, too.

Compared to the PP, the weather scenarios showed an increase in mean annual temperature by 2°C in MP and of 3.5C in FP for both locations. Furthermore, the total annual precipitation in Monteroni d'Arbia were reduced by about 10% and 15% respectively in the medium and long period. Instead, in Alberese the reduction of precipitation was lower with 5% and 7% in the medium and far future. The temperature increase and the reduction of yearly total precipitations affected both the duration of wheat phenology and the yield for all cultivars. Compared to the present period, the days from sowing to anthesis were reduced, on average, by 12.5 and of 17.5 in Monteroni D'Arbia and by 20 and 25 average days in Alberese in the medium and long period, respectively (Figure 1). Also, the days from sowing to physiological maturity were reduced: 13.5 and 23.5 average days in the medium and in the long period respectively for Monteroni D'Arbia; 14.5 and 25.5 average days for Alberese (Figure 1). Considering the grain filling phase, for all varieties, the duration for the medium period was similar to the present one. The earlier phenological development was an effect of temperature increasing which anticipated the accumulation of growing degree days. A yield increase of 20% was shown in Alberese for both medium and long periods compared to baseline. Instead, in Monteroni D'Arbia the mean yield increasing was more evident for the long period, with a range between 50 and 100 % (Figure 2).

The results showed that for the present and for the medium periods, the ancient and modern variety yields were comparable. Instead for the far period in Monteroni D'Arbia, the old varieties were more productive than Bolero.

The higher yield, expecially for the far period, was a consequence of the earlier anthesis stage and grain filling phase that happening in more favorable periods with no elevated stress events. The high yield in Monteroni D'Arbia might be caused by the longer crop growing season compared to Alberese, but also because of the CO_2 concentration effect that was able to compensate the detrimental effect of high temperatures. Instead in Alberese, this interaction was less evident, perhaps because the mean annual temperature was higher (+ 2°C) and because of water stress, in fact the annual precipitation was lower (-165 mm) compared to Monteroni. For this, the crop growing season in Alberese was concluded earlier and the yield increase was less evident.

Conclusion

The research results demonstrated that the impact of climate change on soft wheat in Tuscany depend on the spatial and temporal patterns of climate change in addition to the cultivars characteristics. Drier and warmer growing seasons as projected in Tuscany until the end of the century, do not necessarily cause yield reduction because of fertilizing effect of rising CO2 concentration, but also due to a faster phenological development which cause crop to advance the most sensitive phases and escape severe heat and water stress. Furthermore, in this study, the ancient soft wheat cultivars seem to be less sensitive to future climate conditions than the modern one.

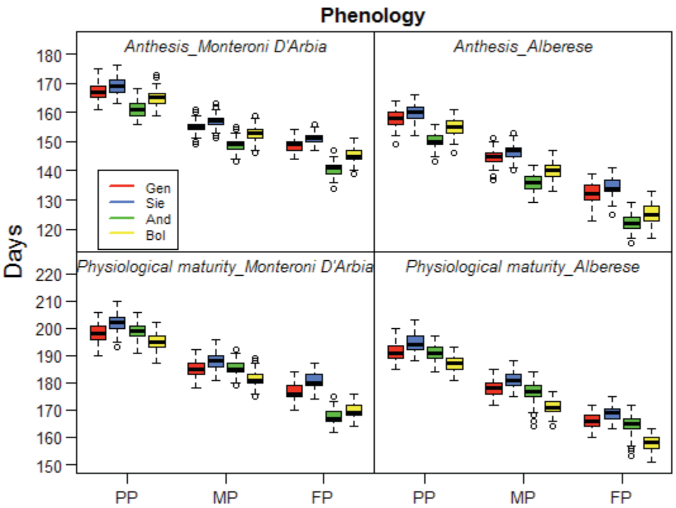


Fig. 1: Days from sowing to anthesis and from sowing to physiological maturity (Days) in Monteroni D'Arbia and Alberese locations during present (PP), medium (MP) and far (FP) periods, for Gentilrosso, Sieve, Andriolo and Bolero soft wheat varieties.
Fig. 1: Duranta in giorni dalla semina alla antesi e dalla semina alla maturità fisiologica (Days) a Monteroni D'Arbia e Alberese durante la fase climatica attuale (PP) e due scenari a medio (MP) e lungo (FP) termine, con riferimento alle varietà di grano tenero Gentilrosso, Sieve, Andriolo e Bolero.

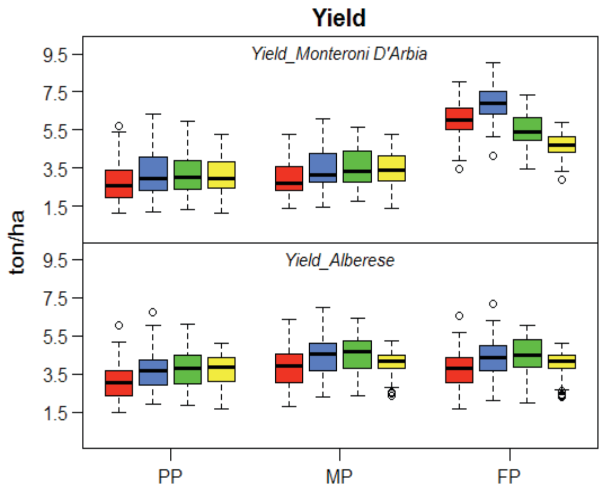


Fig. 2: Yield (t/ha) in Monteroni D'Arbia and Alberese locations during present (PP), medium (MP) and far (FP) periods for Gentilrosso, Sieve, Andriolo and Bolero varieties.
Fig. 2: Rese (t/ha) presso Monteroni D'Arbia e Alberese durante la fase climatica attuale (PP) e due scenari a medio (MP) e lungo (FP) termine, con riferimento alle varietà di grano tenero Gentilrosso, Sieve, Andriolo e Bolero.

Acknowledgments
Attività in parte svolte nell'ambito del progetto misura 16.2 "GRANT", PSR 2014/2020 Regione Toscana. Si ringrazia il Consorzio Agrario di Siena e Terre Regionali Toscane Tenuta di Cesa per il supporto fornito.

References

Arzani, A. and Ashraf M., 2017. Cultivated Ancient Wheats (Triticum spp.): A Potential Source of Health-Beneficial Food Products. Comprehensive Reviews in Food Science and Food Safety, Volume 16, Issue 3

Farooq, M., Bramley, H., Palta, J.A., 2011. Heat stress in whet during Reproductive and Grain-Filling Phases. Plant Sciences, 30: 491-507.

IPCC 2013, Climate Change 2013: The Physical Science Basis, 2013.

IPCC 2011. Climate change 2001: the scientific basis. Contribution of Working Group I. Edited by J.T. Houghton and others. Cambridge University Press, Cambridge.

ISTAT, 2016. Annuario statistico Italiano 2016. Cap.13, Agricoltura.

ISTAT,2011.
http://www.istat.it/it/toscana/dati?qt=gettable&dataset=DCSP_COLTIVAZ&dim=63,4,9,0,0&lang=2&tr=0&te=0
http://www.istat.it/it/toscana/dati?qt=gettable&dataset=DCSP_COLTIVAZ&dim=63,1,9,0,0&lang=2&tr=0&te=0

Porter, J.R. and Gawith, M., 1999. Temperatures and the growth and development of wheat: a review. European Journal of Agronomy, 10:23-36.

Semenov, M.A., Martre, P., Jamieson, P.D., 2009. Quantifying effects of simple wheat traits on yield in water-limited environments using a modelling approach. Agricultural and Forest Meteorology, 149:1095-1104.

Soltani, A., Maddah, V., Sincalir, T.R., 2013. SSM-Wheat: a simulation model for wheat development, growth and yield. International Journal of Plant Production 7:711-740.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

POTENTIAL DISTRIBUTION OF XYLELLA FASTIDIOSA IN MARCHE REGION

DISTRIBUZIONE POTENZIALE DELLA XYLELLA FASTIDIOSA NELLE MARCHE

Leonesi Stefano[1], Nardi Sandro[1], Danilo Tognetti[1*].

[1] ASSAM Regione Marche – Servizio Agrometeorologico Regionale, via dell'Industria 1, 60027, Osimo (AN)
*tognetti_danilo@assam.marche.it

Abstract
Our aim was to investigate the risk of spreading *Xylella fastidiosa* in the Marche region by highlighting the potentially most vulnerable areas. We analyzed the temperature and precipitation data from 1962 to 2016 for the three most important eco-geographical variables in the development of the bacterium: precipitation of the driest month and that of the wettest month, winter mean temperature. The results showed how in the Marche region there seem to be no particularly critical conditions for the development of *X. fastidiosa*. However, the winter temperature (colder quarter) is the most environmentally discriminating factor for the growth of the bacterium and the central and northern coastal areas the most vulnerable to the future, considering the warming that is investing in the Marche region too.

Keywords: *Xylella fastidiosa,* Marche, rain, precipitation, temperature, climate change, global warming.
Parole chiave: *Xylella fastidiosa,* Marche, pioggia, precipitazione, temperature, cambiamenti climatici

Introduction
The species distribution models can provide realistic elements and scenarios to predict future spatializations of organisms, taking into account also the possible bio-climatic changes that may occur. The *Xylella fastidiosa* (Wells et al., 1987 [2]) is a non-sporoginal Gram-negative bacterium belonging to the Xanthomonadaceae family, which is the cause of several major diseases of the plants.
In this paper, we intend to deepen the spreading risk of *X. fastidiosa*. in the Marche Region, by identifying the potentially most vulnerable areas.

Materials and methods
The work starts from the results obtained in [1] through a max entropy distribution model elaborated by *Maxent ver. 3.3.3k*. The model includes 21 eco-geographical variables (*EGVs*). According to model predictions, *X. fastidiosa* has a probability $p > 0.8$ to manifest

- at low altitudes (0-150 m a.s.l.),
- in areas with low rainfall in the driest month (< 10 mm) and in hottest quarter (< 60 mm), average precipitation (80-110 mm) in the wettest month,
- at high average temperature $T_m \geq 8$°C in the coldest quarter,
- and in particularly agricultural areas with high density of crops.

The daily temperature and precipitation data used to calculate the three most influential *EGVs* (precipitation of the driest and wettest months, winter mean temperature) on the Marche region are those recorded by 65 agrometeorological stations of the ASSAM in 1999-2016. In order to identify the periods of the year for these three *EGVs*, longer historical series have been used since 1961 to have a sufficiently long period of time to characterize the climate in the Marche [3].

Results and discussion
The analysis of the monthly historical series since 1961 allowed us to find that, for the Marche, the wettest month of the year is November, the coldest quarter is the winter (December to February), and the driest month is July. Further investigations were carried out for these three periods, considering them from 1999 to 2016.
With *favorable case* we will intend the case where, given a station point, an environmental variable falls within the favorable developmental range of *X. fastidiosa*, in the order: November precipitation of year *N*-1 between 80mm and 110mm; winter temperature of year *N* greater than 8°C; July precipitation of year *N* less than 10mm.
In the 1999-2016 period, the favorable cases occurred in the 20 stations which are at an altitude of no more than 150 m. a.s.l. were 57 for the precipitation of November, 39 for the winter temperature, 76 for the July precipitation. Thus, it would appear that the most discriminating factor for the development of *X.fastidiosa* on our regional territory is the temperature of the winter quarter not warm enough. Moreover, statistically significant trends for the series of favorable cases for each of the three variables during the 1999-2016 period are not observed.

During the period considered, only on two occasions, the three variables dropped *simultaneously* in the favorable range of the development of thr *X.fastidiosa*: Senigallia station, year 2001; Morro d'Alba station, year 2015. The two stations are located in the northern coast of the Marche region (*Fig. 1*).

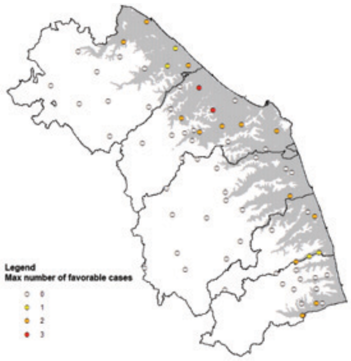


Figure 1. Map of the maximum number of favorable cases for the three environmental variables that occurred simultaneously for each station in the 1999-2016 period. It is noticed that the only two stations which have observed favorable years to the development of X. fastidiosa are located on the northern flat-coastal area and that in that portion of the territory is concentrated the largest number of stations that have recorded years in which two of the three EGVs fell in favorable range.
Figura 1. Mappa del numero massimo di casi favorevoli, per le tre variabili ambientali in esame, che si sono verificati contemporaneamente per ogni punto stazione nel periodo 1999-2016. Si osserva come non solo le uniche due stazioni che hanno incamerato anni favorevoli allo sviluppo della X. fastidiosa siano posizionate sull'area pianeggiante-costiera settentrionale, ma che, in tale porzione di territorio, sia concentrato il maggior numero di stazioni che hanno registrato anni in cui due delle tre EGV sono ricadute negli intervalli favorevoli alla X. fastidiosa.

The next step was to increase the magnitude of the intervals of the three environmental variables (*Table 1*) in order to evaluate a possible increase in favorable cases, both in the number of years and in the territorial distribution, even in the case of a reduction in the percentage of the reliability of the three *EGV* forecasts. These variations have been made in order to consider a gradual warming of the winter season and a predicted reduction in summer precipitation as illustrated in multiple studies, for example in [5].

EGV	Initial Interval	Interval step 1	Interval step 2
November precipitation	80 mm - 110 mm	75 mm - 115 mm	70 mm - 120 mm
Winter temperature	≥ 8°C	≥ 7,5°C	≥ 7°C
July precipitation	< 10 mm	< 15 mm	< 20 mm

Table 1. Variation intervals of the three most influential EGVs for X.fastidiosa.
Tabella 1. Variazione intervalli delle tre EGV di maggior peso previsionale per la X. fastidiosa

In the case of precipitation of wettest month, the most large jump is that in *step 1* with an increase of + 40%. Even in the case of July precipitation, there is bigger increase of favorable cases respect to *step 1* of + 36%. But the relative higher increase was for the average winter temperature: + 60% in *step 1*, + 38% in *step 2*. For what concern the territorial distribution, increasing ranges, also increase the number of favorable cases on the flat-hilly strip for all three environmental variables, also over larger portions of the southern provinces in the case of November precipitation and temperature.
As noted above, the winter temperature (the coldest quarter) seems to be the largest environmental discriminant for the development of *X.fastidiosa* on the regional territory of the Marche. This hypothesis is confirmed by the fact that the number of stations the three *EGVs* fall in the same year (the previous year for November precipitation), in the hypothesized range increases considerably, from 2 to 6, when passing from 8°C to 7,5°C as a minimum limit for winter mean temperature; a further increase in favorable cases, from 6 to 9, occurs also going from 7.5°C to 7°C. On the other hand, no significant variation has changed the other two variables.
Therefore, the difference of -0.5°C more than triples the number of favorable cases for the three variables considered simultaneously. Moreover, this result may have some weight on the *X. fastidiosa*'s potential adaptation in the Marche region in the near future, even because, on the basis of the historical average temperature range since 1961, it is statistically significant at 95% that winter temperature is increasing by about 0.2°C per decade in the Marche.

Conclusions
The study showed that in the Marche there are now no particularly critical conditions for the development of *X. fastidiosa*, at least according to the model discussed in [1]. However, winter temperatures (the coldest quarter) appear to be the most environmentally discriminating for the development of the bacterium and the central and northern coastal areas the most vulnerable to the future, given the warming that is also affecting the Marche.

Acknowledgments
We thank L. Bosso for the clarifications provided on the article [1].

Bibliography

[1] *BOSSO L., D. RUSSO, M. DI FEBBRARO, G. CRISTINZIO, A. ZOINA, Potential distribution of Xylella fastidiosa* in Italy: a maximum entropy model, Phytopathologia Mediterranea (2016) 55, 1, 62–72.

[2] WELLS J.M., B.C. RAJU, H.Y. HUNG, W.G. WEISBURG, L. MANDELCO-PAUL AND D.J. BRENNER, Xylella fastidiosa gen. nov., sp. nov.: gram-negative, xylem-limited, fastidious plant bacteria related to Xanthomonas spp. International Journal of Systematic Bacteriolology (1987) 37, 136–143.

[3] 1981-2010 periodo di clima normale (Cli.No., Climatic Normals) scelto secondo le indicazioni del World Meteorological Organization (WMO, 1989: "Calculation of Monthly and Annual 30-Year Standard Normals", WCPD-n.10, WMO-TD/N.341, Geneva, CH)

[4] Climate Data Homogenization http://etccdi.pacificclimate.org/homogenization.shtml

[5] ISPRA. Clima futuro in Italia: analisi delle proiezioni dei modelli regionali. http://www.isprambiente.gov.it/it/pubblicazioni/stato-dellambiente/il-clima-futuro-in-italia-analisi-delle-proiezioni-dei-modelli-regionali

PHENOLOGICAL MODELLING OF SHRUBS FOR SUPPORTING THE HYDROLOGICAL ASSESSMENT WITHIN THE RAINBO PROJECT

MODELLISTICA FENOLOGICA DEGLI ARBUSTI A SUPPORTO DEGLI STUDI IDROLOGICI ALL'INTERNO DEL PROGETTO RAINBO

Antonio Volta[1*], Giulia Villani[2], Vittorio Marletto[3], Lucio Botarelli[3], Federico Magnani[1]

[1] Dipartimento di Scienze Agrarie, Università di Bologna, Viale Fanin 44, 40127, Bologna
[2] Dipartimento di Scienze e Tecnologie Agro-Alimentari, Università di Bologna, Viale Fanin 50, 40127, Bologna
[3] ARPAE SIMC, viale Silvani 6, 40122, Bologna
*avolta@arpae.it

Abstract

Water runoff strongly depends on surface roughness and rainfall reaching the surface. Despite these evidences hydrological modelling tends to simplify the aspects related to vegetation. In the framework of the EU Life project RainBO we want to give a detailed description of the risk in case of intense rainfall events. This is aimed at setting up an early warning system for the city of Bologna (Italy).

In this work we focus on shrubs autochthonous species who colonised the abandoned areas of the Ravone catchment. Phenology is the first step for a more complex modelingl chain which will include canopy cover and litterfall assessment. The phenological description is given by simple heat thermal sums for the four most present species in the Ravone catchment, i.e. Crataegus monogyna, Sambucus nigra, Prunus spinosa, and Cornus sanguinea.

Keywords: phenology, phenological modelling, shrubs, bud burst.
Parole chiave: fenologia, modellistica fenologica, arbusti, schiusura gemme.

Introduction

The Italian land surface devoted to agriculture was drastically reduced along the last decades. In plain this phenomenon is mostly due to urbanization of new areas, whereas in mountain and hill regions this phenomenon is due to depopulation. Within this frame many areas deal with an uncontrolled growth of the autochthonous species who easily colonize the abandoned catchments. About the above cited vegetation is great known from the botanical and landscape point of view. But due to its negligible economical value, little has been done in scientific literature in order to understand and to simulate its behaviour through agrometeorological modelling.

Arpae is now involved in the EU Life project RainBO. The RainBO project is a follow-up of BLUEAP (Bologna Local Urban Environment Adaptation Plan for a Resilient City) LIFE project, which showed extreme-rain phenomena as a critical consequence of climate changes for urban areas. RainBO will target climate changes related to rainfall phenomena and demonstrate its impact with applications to Bologna municipality. The incoming water comes in Bologna from several creeks characterized by small lengths and unstable flows that during intense events can present several management criticalities (Dottori et al., 2014).

To carefully simulate the impacts of heavy rainfall, it is compulsory to thoroughly describe the type of vegetation covering the nearby valleys in order to get a reliable vision of roughness and water interception due to these natural hurdles. A pilot test is being conducted in the valley of the Ravone creek.

In this project we are developing and implementing plant models necessary to compute the water interception from canopy and litterfall. These depend also on phenology and leaf development. In this work we show a detailed description of the species present in the Ravone valley. In addition we propose simple calculations to describe the phenological development of shrub plants present in the catchment.

Materials and Methods

The Ravone catchment is located in the south-western part of the Bologna municipality (see Fig. 1). Its extension is around 7km^2. The main creek has several short tributaries on both sides. Although the catchment is very close to the town, a big area was gradually abandoned by crop producers since the second world war. This phenomenon brought to spontaneous colonization at different steps. Close to the town pioneering species are present, in particular weeds and shrubs. By rising the hills, shrubs are substituted by small trees and then by forests. In addition spots of the past agriculture are readable as bamboo and giant reed stands close to old dwellings.

If we compare the soil use of the Ravone catchment rural area from 1976 to 2008 we see that crop land passed from 737 ha to 423 ha, whereas forests passed from 130 ha to 240 ha and shrubs from 35 ha to 98 ha. The former had the highest increase, so that it started to have also great relevance in land management.

Inspections were performed within the valley in order to take note of the most present species in the area. For this species

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

we tried to determine simple phenological models based on thermal sums computed assuming different base temperatures from 0°C up to 10°C. It is known that for perennial species chilling temperatures are also very important to determine phenological stages (Chuine, 2000) but this requires a higher number of parameters, difficult to bear for very mixed and spontaneous vegetation. However the main driver of bud burst is the heat temperature sum.
Calibration of the species was performed thanks to the observed data coming from the IPG (International Phenological Garden) of San Pietro Capofiume (BO). Observed data were taken from 2012 to 2017.

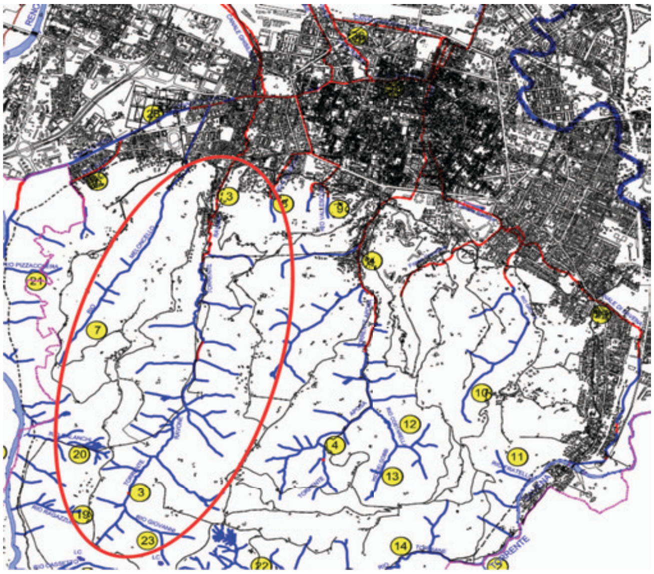


Fig.1: location of the Ravone catchment (red elips) with respect to the town.
Fig. 1: ubicazione del bacino del Ravone (ellisse rossa) rispetto alla città.

Results and Discussion

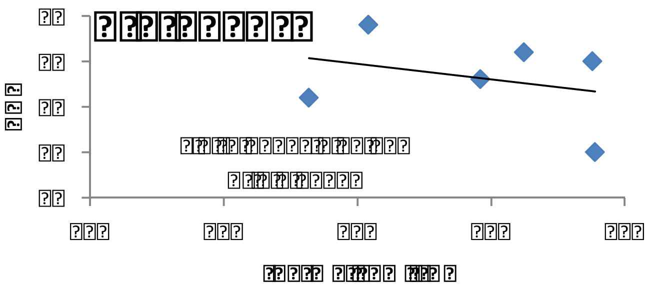


Fig. 2: thermal sum (Tbase = 0 °C) vs day of bud break observed at San Pietro Capofiume for Crategus monogyna.
Fig. 2: somma termica (Tbase = 0 °C) confrontato con il giorno di osservazione della schiusura gemme per Crataegus monogyna.

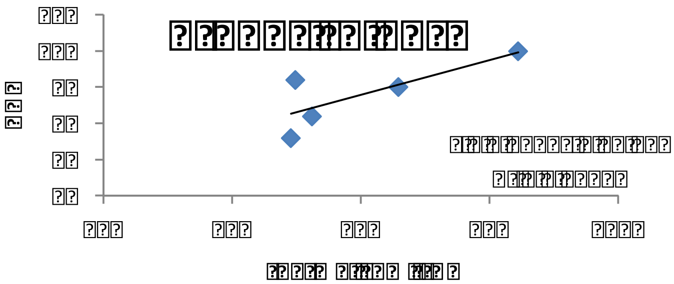


Fig. 3: thermal sum (Tbase = 0 °C) vs day of bud break observed at San Pietro Capofiume for Prunus spinosa.
Fig. 3: somma termica (Tbase = 0 °C) confrontato con il giorno di osservazione della schiusura gemme per Prunus spinosa.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

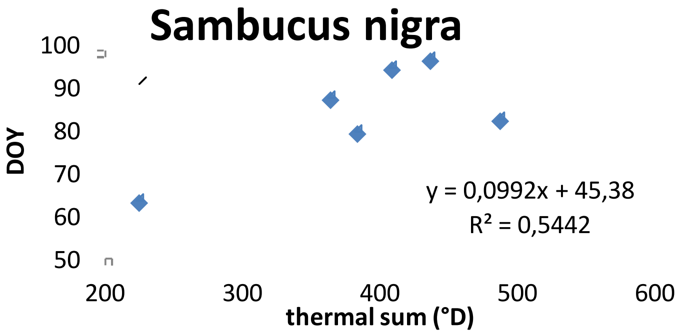


Fig. 4: thermal sum (Tbase = 0 °C) vs day of bud break observed at San Pietro Capofiume for Sambucus nigra.
Fig. 4: somma termica (Tbase = 0 °C) confrontato con il giorno di osservazione della schiusura gemme per Sambucus nigra.

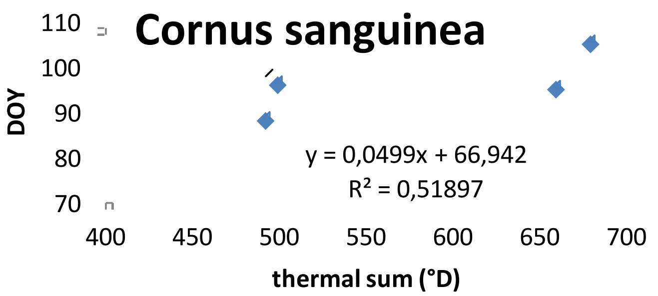


Fig. 5: thermal sum (Tbase = 0 °C) vs day of bud break observed at San Pietro Capofiume for Cornus sanguinea.
Fig. 5: somma termica (Tbase = 0 °C) confrontato con il giorno di osservazione della schiusura gemme per Cornus sanguinea.

The most present shrub species observed during the inspections were *Rosa canina, Prunus spinosa, Crataegus monogyna, Sambucus nigra, and Cornus sanguinea*. Except for *Rosa canina* we found observations from the San Pietro Capofiume IPG for the cited species. We found for all species that the best thermal threshold to describe the behaviour of these species was Tbase= 0 °C. In the figures 2, 3, 4 and 5 we plotted the observations of the bud break stage in terms of DOY (Day Of Year) compared to thermal sum starting at January 1st. *Crataegus monogyna* does not present any clear correlation. For the other species the day of bud break results much more dependent on temperatures, reaching the higher correlation for *Prunus spinosa* (R^2 = 0.62). The bud break date of *Crataegus monogyna* are always included in the range between DOY= 80 and DOY= 94 so that we can consider a fixed date of bud break for modelling the phenomenon.

Conclusions

In this work we presented a very simple attempt to forecast the bud break day of some shrub species. We know that this approach is coarse for perennial species. However, this is at the same time very pragmatic and with sufficient accuracy to be an improvement of the standard hydrological models which do not consider in detail the vegetation characteristics.

References

Chuine I., 2000. A Unifed Model for Budburst of Trees. J. theor. Biol. 207: 337-347

Dottori F., Grazzini F., Di Lorenzo M., Spisni A., Tomei F., 2014. Analysis of flash flood scenarios in an urbanized catchment using a two-dimensional hydraulic model. Proceedings of ICWRS2014, Bologna, Italy, June 2014 (IAHS Publ. 364, 2014).

DOI 10.6092/unibo/amsacta/5692

STILNOVO: SUSTAINABILITY AND INNOVATION TECHNOLOGY FOR DAIRY SHEEP PRODUCTION, AN INNOVATION TRANSFER PROJECT IN TUSCANY

STILNOVO: SOSTENIBILITÀ E TECNOLOGIE INNOVATIVE PER LA FILIERA DEL LATTE OVINO, UN PROGETTO DI TRASFERIMENTO DELL'INNOVAZIONE IN TOSCANA

Alberto Mantino[*1], Iride Volpi[1], Simona Bosco[1], Giorgio Ragaglini[1], Enrico Bonari[1], Alice Cappucci[2], Eleonora Bulleri[2] Arianna Buccioni[3], Carlo Viti[3], Fabiola Giannerini[4], Fabio Villani[4], Carlo Santarelli[4], Marcello Mele[2]

[1] Institute of Life Sciences, Scuola Superiore Sant'Anna, Piazza Martiri della Libertà 33, Pisa, PI Italy
[2] Centro di Ricerche agro-ambientali Enrico Avanzi, San Piero a Grado, Pisa, PI Italy
[3] Dipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente, Università di Firenze, Piazzale delle Cascine 18, Firenze FI, Italy
[4] Caseificio Sociale di Manciano, Società Agricola Cooperativa, Loc. Piano di Cirignano, Manciano GR, Italy
*alberto.mantino@santannapisa.it

Abstract

In Tuscany, the ewes farming for dairy production is facing low incomes and scarce competitiveness of farms, mainly due to a poor level of innovation concerning the management of both the cropping and animal systems. Consequently, in the recent years, the milk quality decreased preventing the production of high-quality dairy products. Moreover, in the Mediterranean, climate change is leading to an increase frequency of extreme rainfall events, raising the risk of soil loss by water. Thus, novel cropping systems have to be more resilient to these new conditions to guarantee the conservation of farm profitability and natural resources.

Within this framework, the STILNOVO project (sustainability and innovation technology for dairy sheep production) is aiming at: (i) improving milk quality at competitive costs, (ii) increasing the efficiency of the grassland-based production by rational management, (iii) optimizing the ewes feeding, (iv) decreasing the risk of contamination by *clostridia* bacteria and (v) optimizing the use of bio-active compounds for cheese aging.

Keywords: milk quality, legume, soil erosion, extension services, resilience.
Parole chiave: qualità del latte, leguminose; erosione del suolo; servizi per l'agricoltura, resilienza.

Introduction

The dairy sheep chain in Tuscany (Italy) is experiencing a particularly unfavourable economic situation, both regarding milk production and processing.

Indeed, dairies have been pointing out since a while a worsening of the milk quality and they are trying to cope with this phenomenon through supplementary premiums given for high quality milk, determined according to specific protein and fat contents. Furthermore, diaries need to introduce innovations in milk processing to reach new consumers and expand marketing opportunities.

On the other hand, the low profitability of the livestock farms prevent farmers to invest in high quality milk production. Another problem concerns the environment risks related to the annual-based forage cropping system in the inner hills of Tuscany. In fact, climate change, and in particular the variation of rainfall amount and distribution, is increasing the risk of soil erosion, that may be mitigated by an adjustment of the cropping systems (Vallebona et al., 2015). Thus, fostering the introduction of perennial crops may reduce the risk of soil erosion due to rainfalls (Vallebona et al., 2016). Moreover, an higher presence of legumes, both annual and perennial, can reduce the supply of nitrogen fertilizers and the relative nitrogen losses in soil, water and atmosphere (Luscher et al., 2014). In the Mediterranean, in order to improve milk quality, the inclusion in the dairy ewes diet of appropriately formulated concentrates is essential to integrate green and dry fodders in several periods of the year (Mele, 2009).

Within the Rural Development Programme (2007-2013) of Tuscany Region, the innovation transfer project "Innovative forage cropping and feeding for the production of Pecorino Toscano cheese with nutraceutical properties" (FORMA NOVA) has been funded (by Measure 124), with the dairy of Manciano (GR, Italy) "Caseificio Sociale di Manciano" as coordinator. FORMA NOVA was aimed at improving the ewes milk quality for the production of "Pecorino Toscano DOP" (Pecorino cheese of Tuscany region), focusing on nutraceutical properties, on the sustainability of forage cropping and on the precision animal feeding.

The key results of the project were:

(i) the increase in productivity of dairy ewes and the increase in self-sufficiency of the involved farms;
(ii) the development of a new product named "Amico del Cuore", a Pecorino DOP cheese naturally enriched with functional fatty acids.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Exploiting the experiences gained during the project FORMA NOVA, the new innovation transfer project (Measure 16.2 – PSR 2014-2020) "Sustainability and innovative technologies for sheep milk production" (STILNOVO) aimed at:

(i) improving the milk quality at suitable costs for farmers;
(ii) improving the productivity of ewes through rational grazing;
(iii) improving the efficiency of concentrate supply;
(iv) reducing the risk of milk contamination with clostridia;
(v) optimize the use of bioactive compounds for Pecorino DOP cheese conservation during seasoning.

The aim of this article is to present the STILONOVO activities that concern the innovation transfer relative to the production of sheep milk for "Pecorino Toscano DOP".

Materials and methods

STILNOVO involves 9 farmers associated to the dairy of Manciano (GR, Italy), "Caseificio Sociale di Manciano" (CSM), which is the coordinator of the project. The associated beneficiaries of the project are: the Centre for agro-environmental research "Enrico Avanzi" (CiRAA) of the University of Pisa, the Institute of Life Sciences of Scuola Superiore Sant'Anna (Pisa) (SSSA) and the Department of Agrifood Production and Environmental Sciences (DISPAA) of the University of Florence.

Concerning agronomic activities, the actions of the project are aimed at innovating the cropping systems in the involved farms: replacing annual forage crops, mainly oat (*Avena sativa* L.) and berseem clover (*Trifolium alexandrinum* L.), with perennial crops, favouring the inclusion of legumes such as sulla, (*Hedysarum coronarium* L.) and common sainfoin (*Onobrychis viciifolia* Scop.), and warm-season species such as sorghum (*Sorghum bicolor* spp. *Sudanense* L.) and pearl millet (*Pennisetum glaucum* L.) (Action 2.1). Moreover, the innovation in livestock management will be focused on optimizing the use of fodders, increasing the intra-annual distribution of grazing period, promoting best practices for livestock grazing management and improving the techniques for haymaking and fodder conservation (Actions 2.1 and 2.2).

Within the project, the use of specific software for the correct formulation of animal diets, will be favoured. In each farm, fodders and concentrate will be sampled and analysed to create the databases that will be used in the diet formulation software (Action 2.2). Furthermore, samples of milk from individual farm will be collected and analysed weekly to evaluate the coagulation properties, casein and fatty acids contents.

The results will be integrated with data collected from the diary of Manciano "Caseificio Sociale di Manciano" to evaluate the effects of the precision feeding techniques on the milk quality and quantity (Actions 2.2 and 2.4).

The risk of *clostridia* contamination of milk will be evaluated and the innovations to reduce that risk will be transfer in Action 2.3. In Action 2.4 techniques for the bactofugation, to reduce the risk of *clostridia* contamination without reducing the cheese yield, will be tested and transferred.

Moreover, the environmental impacts of the business as usual systems will be compared with the systems after the introduction of the innovations proposed in Actions 2.1 and 2.2 through the Life Cycle Assessment (LCA), to evaluate the potential mitigation of the environmental impacts obtained by the project (Action 2.5).

Expected results

The innovative agricultural practices proposed by STILNOVO, applied in other regions, have been increased the resilience of cropping systems to climate change and they have contributed to guarantee the sustainable intensification of agriculture productions (Wezel et al., 2014; Altieri et al., 2015). The increased intra-annual distribution of grazing periods and the increased availability of summer pastures, will contribute to the deseasonalization of milk production, that will guarantee a higher profitability of the farm.

Furthermore, the diaries strongly require deseasonalization to achieve a greater homogeneity of milk collected and processed during the year.

The integration of the diets of dairy ewes with concentrates, mainly self-produced in the farm or produced by local farmers, will guarantee an increment of ewes productivity and, at the same time, an improvement of quality and sanitary characteristics of milk.

Furthermore, the improvement of milk quality will lead to an increase of farm profitability due to the supplementary premiums given by the dairy for high quality milk.

The disseminations activities within the STILNOVO project will lead to a large involvement of the farms present in the region and of all the stakeholders of the dairy sheep chain for the production of Pecorino Toscano cheese DOP.

DOI 10.6092/unibo/amsacta/5692

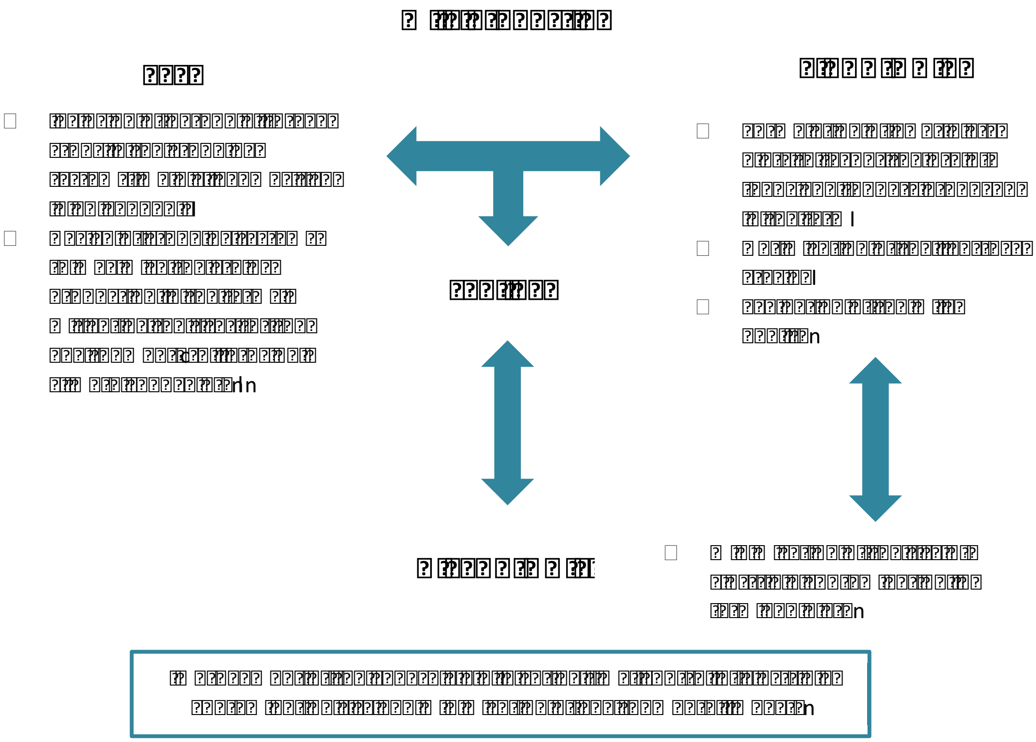


Fig. 1 Scheme of the actions of each partner involved in the STILNOVO project.
Fig. 1 Schema delle azioni condotte dai singoli partner coinvolti nel progetto STILNOVO.

Bibliography

Altieri M., Nicholls C.I., Henao A., Lana M., 2015. Agroecology and the design of climate change-resilient farming systems. Agron Sustain Dev 869–890.

Bonaudo T., Bendahan A.B., Sabatier R., et al., 2014. Agroecological principles for the redesign of integrated crop-livestock systems. Eur J Agron 57:43–51.

Lüscher A., Mueller-Harvey I., Soussana J.F., et al., 2014. Potential of legume-based grassland-livestock systems in Europe: A review. Grass Forage Sci 69:206–228.

Mele M, 2009. Designing milk fat to improve healthfulness and functional properties of dairy products: From feeding strategies to a genetic approach. Ital J Anim Sci 8:365–373.

Vallebona C., Mantino A., Bonari E., 2016. Exploring the potential of perennial crops in reducing soil erosion: A GIS-based scenario analysis in southern Tuscany, Italy. Appl Geogr.

Vallebona C., Pellegrino E., Frumento P., Bonari E., 2014. Temporal trends in extreme rainfall intensity and erosivity in the Mediterranean region: a case study in southern Tuscany, Italy. Clim Change 128:139–151.

Funding

STILNOVO is co-financed by the Rural Development Programme (2014-2020) of Tuscany Region, through the measure 16.2 (2015).

SHORT-TERM EFFECT OF COVER-CROPS ON SOIL BIOPHYSICAL PROPERTIES IN A FIG ORCHARD

EFFETTO A BREVE TERMINE DELLE COLTURE DI COPERTURA SULLE PROPRIETÀ BIOFISICHE DEL SUOLO IN UN FICHETO

Roberta Rossi[1], Francesco Cardone[2], Giuseppe Landi[2], Mariana Amato[2*]

[1] Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Centro di Ricerca Zootecnia e Acquacoltura (CREA-ZA), sede di Bella (PZ) , Italy
[2] Scuola di Scienze Agrarie, Forestali, Alimentari e Ambientali (SAFE) , Università degli Studi della Basilicata (UNIBAS), viale dell'Ateneo Lucano, PZ, Italy
*mariana.amato@unibas.it

Abstract

The use of cover-crops floors in vineyards, olive and fruit orchards represents an environmental-friendly agronomic strategy to control erosion, soil fertility, but also land workability, diseases and pests. Cover-crops display effects at both farm and ecosystem level. In this work we measured in a fig orchard the effects two cover-crops floors a spontaneous grass cover versus subterranean clover cover, on some soil biophysical parameters. We found that under grasses aggregate stability was significantly higher (p-value < 0.05) with 62% of aggregates > 1mm than the 42% measured under clover. Root mass density was also higher for grass cover, pooled root density was linearly related to aggregate stability (R^2=0.75). Organic carbon was slightly higher under grasses but did not differ between treatments. Total N did not differ except when measured on root-soil samples indicating that substantial N was stored in clover roots at the time of sampling. Subterranean clover contributes to soil fertility and is less competitive for water than grasses. Natural grass cover enhanced soil aggregate stability and through the higher root density contributes more than clover to soil reinforcement.

Keywords: root mass density aggregate stability, cover-crops, orchard floor; soil root reinforcement
Parole chiave: densità radicale; stabilità degli aggregati; colture di copertura; inerbimento arboreti , rinforzo radicale del suolo.

Introduction

Cover crops (CC) are by definition crops specifically grown to cover the soil protecting it from sediments and nutrient losses (Reeves, 1994). Depending on the species CC play a role in a number of processes such as erosion control, disease/pest break, weeds suppression, fertility boost, displaying effects at both farm and ecosystem level (Dabney et al., 2001). For farmers the choice of the cover crops depends on the objective (i.e. enhance soil protection/ fertility), on the spatiotemporal window that the CC occupies within a given cropping system and is always a trade-off between direct, indirect and opportunity costs (Snapp et al., 2005).While in annual cropping systems CC are essentially short-term rotations grown during the cash-crop off-time, in perennial woody cropping systems CC are generally long-term rotations intercropped in the cash-crop. In Mediterranean olive, almond and other fruit trees CC provide an environmental-friendly alternative to conventional tillage for floor management (Lopez-Vicente et al., 2016) . In these systems, due to the presence of steep slopes and shallow soils, and the prevalence of rain-fed management CC water use and erosion control capacity are key features (Gomez at al. , 2009). Both traits are influenced by CC roots characteristics. Root length density is correlated to mobile nutrients acquisition capacity while root mass density can be considered a synthetic indicator of soil biophysical quality. Studies on cereals and grasses with different plant densities demonstrated that a root mass density increase reduces exponentially concentrated flow erosion (Gyssels and Poesen, 2003), while other researches showed that roots are at least as important as above-ground cover for controlling rill and ephemeral gully erosion (Gyssels et al., 2005). Root mass density is positively correlated to microbial biomass, labile organic matter fractions and to aggregate stability (Haynes et al., 1997). In this work we compared two types of Fig (Ficus carica L.) orchard CC floors (spontaneous grass cover vs subterranean clover crop) by measuring root mass and length density, CC effects on soil aggregate stability, soil water content and soil C and total N. Results are discussed in terms of management decisions.

Materials and Methods

A field experiment was established in a 10 years (Ficus carica L.) orchard (cv "Fico bianco Dottato"), with a density of of 400 plants/ha spaced 5m x 5m. The farm was located in southern Italy, Agropoli (SA) (lat 40° 20' 08" N long 15° 00' 36" E). The climate is Mediterranean with an average annual precipitation of 698 mm concentrated in fall and winter, and an average annual air temperature of 17°C. The soil was clay (27.3% sand, 20.0% silt, 52.7% clay) with an average organic carbon content of 8.4 g kg^{-1}. Two contiguous plots were established between from October 2015 to November 2016. Two CC floors were compared: a spontaneous grass cover (grass) and subterranean clover cover crop (clover). The

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

subterranean clover (*Trifolium subterraneum* L. cv Rosabrook) was sown in November 2015 at 40 kg ha-after conventional tillage and cut in march 2016, before flowering, and in November 1016. Grass composition varied according to plants phenology but was dominated by graminoids (mean value 70 plants per square meter). Root density was measured at clover flowering stage augering the soil at 0.15 m depth and quantified following the methodology of Amato and Pardo (1994). Root mass data were converted in root mass density (g root cm^{-3}) by multiplying for bulk density(1.2 g cm^{-3}). Root length density was estimated using the specific root length values reported by Gould et al. (2016). Root reinforcement to soil strength was estimated by multiplying root mass density for a specific root reinforcement coefficient reported by Gould et al. (2016). Soil water content was measured weekly during July 2016 for grasses and clovers. Soil aggregate stability was measured following the methodology of Traorè et al. (2000). Soil organic C, total N and total N in soil-root samples were measured in July 2016 (by Springer-Klee and Kjeldhal methods respectively). CC effects were analysed by two-sample t-test.

Results and Discussion

Clover yield ranged from an average value of 2.35 Mg/ha obtained from the first cut to the 1.10 Mg ha^{-1} of the second cut. Root mass density and especially root length density were significantly higher under G-CC (Fig. 1 top) and consistent with values reported for clover and grasses swards (Gould et al., 2016). CC type significantly affected aggregate distribution (Fig 2), a higher percentage of aggregates >1 mm was found under grasses (Fig 1 and 2). Soil organic C was slightly higher under G-CC (Fig. 1 bottom) but the difference was not significant presumably due to the short duration of the experiment. Soil total N did not differ between treatments unless albeit significant differences were found in soil-root samples (Fig. 1 bottom). This indicates that substantial N was still stored in clover roots at the time of sampling. Roots C:N ratio tends to be lower in legumes crops than in non-legumes (Gan et al., 2011), since N mineralization potential is linearly related to C:N clover roots will contribute more and faster than grasses roots to soil fertility. In most works the contribute of legume crops to N balance is based on above-ground biomass, neglecting the important role of roots structures leads to severe biases (van Kessel and Hartley, 2000). Legumes contribute to soil N during the growing season when N fixation is high but also when fixation ceases and belowground N is released through roots and nodules decomposition (Gan et al., 2010).

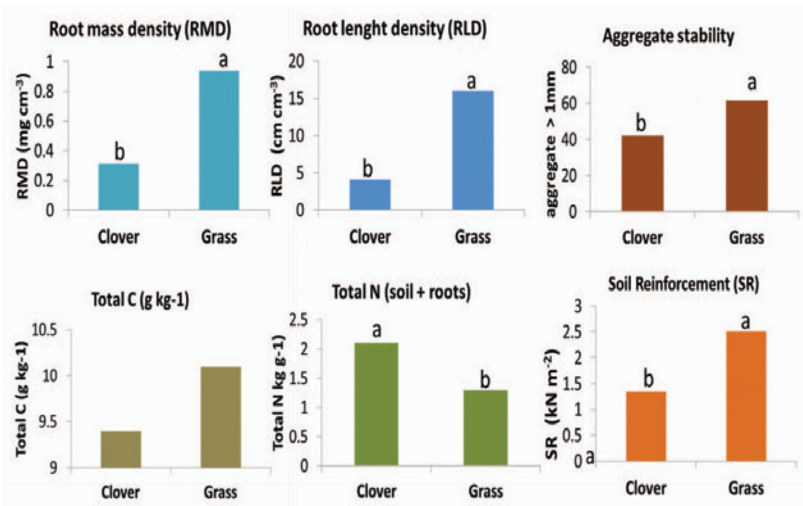


Fig 1: Bar-plots of mean values of soil biophysical parameters. Different letters indicate significant differences at the t-test (P-value < 0.05). From top to bottom, from left to right: root mass density (RMD) (mg roots cm^{-3} soil) ; root length density (RLD) (cm roots cm^{-3} soil); organic carbon (C) (g kg^{-1} soil); total nitrogen (N)(g kg^{-1} soil); aggregate stability (percentage dry weight of soil aggregates >1mm retained on sieves after wet-sieving; soil root reinforcement (SR) (kN m^{-2}).

Fig. 1: Grafico a barre del valor medio dei parametri biofisici del suolo. Lettere differenti indicano differenze significative al test di T (P-value < 0.05). Dall'alto al basso da sinistra verso destra: densità radicale in massa (RMD) (mg radice/ cm^{-3} suolo) ; densità radicale in lunghezza (RLD) (cm radice/ cm^{-3} suolo); carbonio organico (C)(g kg^{-1} suolo); azoto totale (N) (g kg^{-1} soil); indice di stabilità degli aggregati (percentuale in peso di aggregati con diametro > 1mm ritenuti nel setaccio dopo setacciatura umida; rinforzo radicale del suolo (SR) (kN m^{-2}) .

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Root mass density was linearly related to aggregate stability (Fig. 2). Grasses contribute more than clover to soil reinforcement due to both the higher specific reinforcement coefficient and the greater root density .

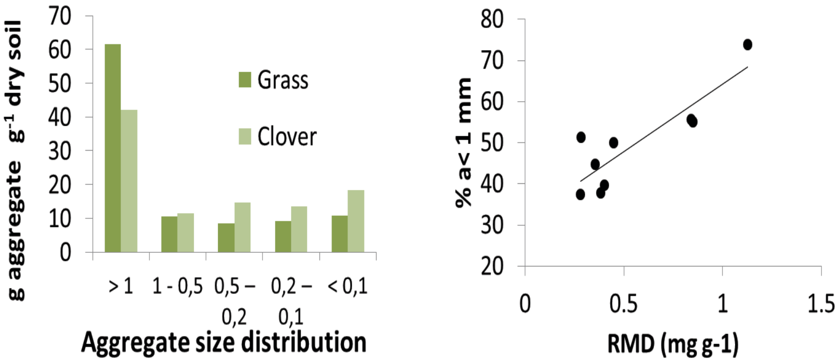


Fig 2: From left to right aggregate size distribution under Grasses (dark grey bars) and Clover (light green bars); Bottom: scatterplot of percentage of aggregates > 1mm (a) (y-axis) versus root mass density (RMD) (x-axis), the solid black line depicts the linear regression ($a_{>1mm}$ =32.8RMD + 31.438, R^2= 0.75)
Fig 2 Da sinistra verso destra: grafico della distribuzione diametrica degli aggregate nell'inerbimento spontaneo (colonne verde scuro) e trifoglio (colonne verde chiaro); grafico di dispersione: sull'asse y la % di aggregati di dimensione > 1mm, sull'asse x la densità radicale in massa (RMD). La linea solida rappresenta la retta di regressione lineare ($a_{>1mm}$ =32.8RMD + 31.438, R^2= 0.75)

Soil water content within the 0-0.3 m was slightly higher under C-CC in July (cloverθ_g = 6% vs grassθ_g = 5%), it was negatively correlated to RMD in the 0.15 m soil strata ($\theta_{g(03/07/2016)}$ = -990.62 RMD + 7.183 ; R^2=0.82) suggesting that clover, by producing a lower root density, could be less competitive for water use compared to grasses . There is a proportionality between root length density and mobile nutrients competing ability (Evans, 1977), in grasses the ratio between root length and weight is greater than in clovers, this is advantageous in terms of mobile nutrients uptake . Water and nitrogen availability are key factors affecting yield in rain-fed low-input cropping systems however in fruit tree crops a moderate water/nutrient stress can be used as a modulator of quality. Muscas et al. (2017) found that in vineyard the CC influenced must quality: while grass mixture floor increased the content of sugar, anthocyanins and polyphenols, the legume mixture CC and the natural covering reduced total polyphenols and anthocyanin content, respectively.

Conclusions
The choice of the cover-crop depends on farmer priorities, subterranean clover is certainly interesting for its contribute to soil fertility and the low competition for water. The high self-reseeding ability makes it more attractable than other legumes in terms of financial investment. The natural grass cover is definitely a low-cost floor with superior ability of contrasting soil degradation.
Root density influences CC performances in several ways by contributing to soil reinforcement and to aggregate stability. Therefore it is important to characterize CC below-ground traits especially for estimating the potential provision of ecosystem services.

References

Amato, M., & Pardo, A. (1994). Root length and biomass losses during sample preparation with different screen mesh sizes. Plant and Soil, 161(2), 299-303.
Dabney, S. M., Delgado, J. A., & Reeves, D. W. (2001). Using winter cover crops to improve soil and water quality. Communications in Soil Science and Plant Analysis, 32(7-8), 1221-1250.
Evans, P. S. (1977). Comparative root morphology of some pasture grasses and clovers. New Zealand journal of agricultural research, 20(3), 331-335.
Gan, Y. T., Liang, B. C., Liu, L. P., Wang, X. Y., & McDonald, C. L. (2011). C: N ratios and carbon distribution profile across rooting zones in oilseed and pulse crops. Crop and Pasture Science, 62(6), 496-503.
Gan, Y., Campbell, C. A., Janzen, H. H., Lemke, R. L., Basnyat, P., & McDonald, C. L. (2010). Nitrogen accumulation in plant tissues and roots and N mineralization under oilseeds, pulses, and spring wheat. Plant and Soil, 332(1-2), 451-461.

DOI 10.6092/unibo/amsacta/5692

Gómez, J. A., Llewellyn, C., Basch, G., Sutton, P. B., Dyson, J. S., & Jones, C. A. (2011). The effects of cover crops and conventional tillage on soil and runoff loss in vineyards and olive groves in several Mediterranean countries. Soil Use and Management, 27(4), 502-514.

Gould, I. J., Quinton, J. N., Weigelt, A., De Deyn, G. B., & Bardgett, R. D. (2016). Plant diversity and root traits benefit physical properties key to soil function in grasslands. Ecology letters, 19(9), 1140-1149.

Gyssels, G., & Poesen, J. (2003). The importance of plant root characteristics in controlling concentrated flow erosion rates. Earth surface processes and Landforms, 28(4), 371-384.

Gyssels, G., Poesen, J., Bochet, E., & Li, Y. (2005). Impact of plant roots on the resistance of soils to erosion by water: a review. Progress in physical geography, 29(2), 189-217.

Haynes, R. J., & Beare, M. H. (1997). Influence of six crop species on aggregate stability and some labile organic matter fractions. Soil Biology and Biochemistry, 29(11-12), 1647-1653.

López-Vicente, M., García-Ruiz, R., Guzmán, G., Vicente-Vicente, J. L., Van Wesemael, B., & Gómez, J. A. (2016). Temporal stability and patterns of runoff and runon with different cover crops in an olive orchard (SW Andalusia, Spain). Catena, 147, 125-137.

Reeves, D. W. (1994). Cover crops and rotations. Advances in Soil Science: Crops Residue Management, 125-172.

Snapp, S. S., Swinton, S. M., Labarta, R., Mutch, D., Black, J. R., Leep, R., ... & O'Neil, K. (2005). Evaluating cover crops for benefits, costs and performance within cropping system niches. Agronomy Journal, 97(1), 322-332.

Traoré, O., Groleau-Renaud, V., Plantureux, S., Tubeileh, A., & Boeuf-Tremblay, V. (2000). Effect of root mucilage and modelled root exudates on soil structure. European Journal of Soil Science, 51(4), 575-581.

Van Kessel, C., & Hartley, C. (2000). Agricultural management of grain legumes: has it led to an increase in nitrogen fixation?. Field Crops Research, 65(2), 165-181.

EVALUATION OF CHIA (SALVIA HISPANICA L.) AS A FORAGE CROP: EFFECTS OF SOWING DENSITY ON BIOMASS YIELD AND QUALITY AND RELATIONSHIPS BETWEEN QUALITY AND CROP BIOMETRY

VALUTAZIONE DELLA CHIA (SALVIA HISPANICA L.) COME COLTURA FORAGGERA: INFLUENZA DELLA DENSITA' DI SEMINA S8LLA RESA E LA QUALITA' DELLA BIOMASSA E RALAZIONI FRA PARAMETRI QUALITATIVI E BIOMETRICI

Roberta Rossi[1*], Rocco Bochicchio[2], Rosanna Labella[2], Mariana Amato[2]

[1] Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria- Centro di Ricerca Zootecnia e Acquacoltura (CREA-ZA) - sede di Bella, via Appia, Bella (PZ) , Italy
[2] Scuola di Scienze Agrarie, Forestali, Alimentari e Ambientali (SAFE) , Università degli Studi della Basilicata (UNIBAS), viale dell'Ateneo Lucano, PZ, Italy
*mariana.amato@unibas.it

Abstract
Chia seeds are considered one of the richest source of omega-3 but recently the interest has shifted to the whole plant. Chia leaves are rich in beneficial long-chain fatty acids and flavonoids and have themselves a market potential as a functional food or feed ingredient. Little is known on crop response to agronomic management and much less is available on herbage yield and quality . These preliminary data indicate that forage quality is affected by plant density, is high at early vegetative stages and decreases during the growing season and is higher at low plant density. Protein content drops from 18% at early vegetative stage to the 9% of early flowering while fiber content (ADF) increases from 25% to 37% on average from sowing to flowering. Proteins and lipids are significantly affected by sowing density at late vegetative and early flowering stages (P-value < 0.05). Chia forage shows a low proportion of palmitic and stearic acids and a high proportion of alpha-linoleic acid especially at early vegetative stage (max value 623 g fatty acid kg^{-1} Total Fatty acid), and a favorable omega-3 to omega-6 FA ratio that during the growing season ranges from 6 to 4. Leaf-to-stem ratio declines exponentially with yield (R^2= 0.87, P-value< 0.05) and it increases with N content following a power relationship (R^2=0.64, P-value< 0.05). Crop height is inversely related to polyunsaturated:total fatty acid ratio and is positively and linearly related to fiber content. These linear relationships differ for the two plant densities being steeper at high plant density. Crop height, LAI and leaf-to-stem ratio are useful indicators of forage quality variation during the growing season and can be used to individuate optimal cutting windows

Keywords: Chia (*Salvia hispanica* L.); forage quality, omega-3; functional feed; allometric relationships
Parole chiave: Chia (*Salvia hispanica* L.); qualità del foraggio; foraggi funzionali; relazioni allometriche

Introduction
In recent years a special attention has been given by dairy industries in altering milk fatty acid (FA) composition by maximizing the content of long-chain polyunsaturated fatty acids (PUFA) such as omega-3 and omega-7 FA (Dewhurst et al., 2003). These bioactive compounds play a key role in reducing cardiovascular risk and increase milk anti-carcinogenic properties (Williams, 2000). Ruminants cannot synthesise long-chain FA endogenously so their content in milk depends on their proportion in ingested feed and is mediated by rumen bio-hydrogenation processes (Witkowska et al., 2008). The use of farm-grown forages represents as a low-cost sustainable approach for modifying milk lipids and at the same time reducing the purchase of expensive formulates (Dewhurst et al., 2006). Chia (*Salvia hispanica* L.) seeds are considered the richest botanical source of omega-3 (Ayerza, 2009). Chia seeds have been used as feed supplements to improve the fatty acid composition of meat (Ayerza et al., 2002), eggs (Ayerza and Coates, 1998) and milk (Ayerza and Coates, 2006) with no adverse effects on sensory attributes. Despite the fact that much work has been undertaken on seeds, Chia vegetative parts are also of great interest. Chia leaf essential oils show potential for their flavoring and fragrance value (Ahmed et al., 1994). Peiretti and Gai (2009) reported for the first time Chia whole plant fatty acid profile and forage gross properties under uniform agronomic management. Chia forage showed potential for large scale ensiling (Peiretti, 2010). The interest in Chia whole plant is also supported by the high biomass yield. Bochicchio et al. (2015) tested the influence of agronomic management on biomass and seed yield of commercial varieties grown in Mediterranean Europe and reported values up to 8.77 t ha^{-1} of total dry mass at flowering under non-limiting irrigation. These authors suggested the high biomass and leaf production during the growing season can be exploited for forage uses, in fact since commercially available varieties are short-day flowering when cultivated at Mediterranean Europe latitude require relatively long growth cycles for flowering which allow the plant to achieve a remarkable size. Chia leaves are also an interesting source of flavonoids, such as

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA. Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

quercetin, common in *Salvia* species and of uncommon flavonoids (acetyl vitexin and acetyl orientin) showing potential as a functional ingredient (Amato et al., 2015). From the traditional growing areas of Mexico and Guatemala, Chia cultivation is rapidly spreading oversea and therefore there is a growing need to develop appropriate agronomic management techniques for maximizing yield and quality in different environments and latitudes and for different market objectives. In this work we analysed the effects of plant density and nitrogen fertilization on chia forage quality and FA profile and analysed the relationships between forage quality and biometric parameters. Allometric relationships between quality parameters and fast measurable crop biometric attributes such as LAI, height, leaf- to- stem ratio can be used to refine agronomic management strategies and help individuating optimal cutting windows for obtaining a Chia forage with a high digestibility and reach in health-promoting polyunsaturated fatty acids.

Materials and Methods

The experiment was conducted in 2013 and 2014 at Masserie Saraceno (Atella - PZ, Southern Italy, Lat. N 40° 51' 37.59", Long. E 15° 38' 49.43") on a Luvi-vertic Phaeozem (Iuss working group, 2006). Soil texture and weather parameters were described by Bochicchio et al. (2015). A black chia (*Salvia hispanica* L.) commercial seed available at Eichenhain (Hofgeismar - DE) was sown on 21/06/2013 and grown with non-limiting water supply. Drip irrigation amounted to 711.3 m^3 ha^{-1}. The soil was amended in June 2013 with 25 t ha^{-1} of the solid fraction of biogas digested materials with the following characteristics: dry matter 8.5%; carbon 20.4 kg t^{-1}; nitrogen (N) 2.8 kg t^{-1}; ammonium (N-NH4) 0.6 kg t^{-1}; P_2O_5 1.4 kg t^{-1}; K_2O 2.5 kg t^{-1}.Sowing density (D1=125 plants m^{-2} and 8 plants m^{-2}) and top-dressing nitrogen fertilization (0 and 20 kg ha^{-1} at 49 DAS) were tested within a split-plot design replicated 2 times . Samples were taken in each plot at different stages: EV (early vegetative stage, 44 DAS), LV (late vegetative stage, 77 DAS) and EF (early flowering, 103 DAS) and crop height and LAI were measured manually. For chemical analyses samples were dried and ground to pass through a 1 mm screen and analysed for the following determinations: total N content by Kjeldahl method, ash content by ignition to 550 ◦C, and ether extract by Soxlet method were determined as described in AOAC 963.15 (1990). Acid detergent fibre and neutral detergent fibre were determined as described by Van Soest et al. (1991) expressed exclusive of residual ash. Lignin was determined by solubilization of cellulose with sulphuric acid as described by Robertson and Van Soest (1981). Lipid extraction was performed on freeze-dried samples according to Hara and Radin (1978). Fatty acids were analysed as their methyl esters (FAME). The analysis was carried out by gas chromatography, using a a Varian Star 3400 CX GC (Varian-Agilent, Milan, Italy), equipped with a SLB®-IL111 Capillary GC Column (100 m × 0.25 mm × 0.20 μm) (Sigma-Aldrich, Milan, Italy). The separation was carried out at 90/240 °C with helium as carrier gas and using a flame ionization detector (FID) at 300 °C. FAMEs were identified by comparison of retention times with FAME standard mixture under the same conditions (Supelco 37 Component FAME Mix analytical standard, Sigma-Aldrich, Milan, Italy). Data were subjected to regression analysis and to a mixed effects ANOVA with random effects for both block and nitrogen top-dressing (Pinheiro and Bates, 2000) .

Results and Discussion

Forage quality (reported in table 1) decreases during the growing season but mostly at high plant density that at all crop stages showed a lower protein and lipids content, the opposite occurs with fibre content, data are consistent with literature (Peiretti and Gai, 2009). Protein content was significantly affected by top-dressing fertilization, a significant interaction with density was found at late vegetative stage (LV), where fertilization increased the difference in protein content between D1 and D4. Chia shows a low proportion of saturated fatty acids and it is rich in polyunsaturated fatty acids (PUFA), Alpha-linolenic acid (ALA) was the most abundant FA reaching the maximum concentration of 62 g 100g FA^{-1} at early vegetative stages, and it is followed by linoleic acid whose proportion slightly increased during the growing season (max value 12 g 100 g FA^{-1} at EF) and by the monounsaturated (MUFA) oleic acid. The proportion of ALA remains relatively high during the growing season. Even averaging only values from late vegetative stage to flowering (53 g 100g FA^{-1}), it is higher than in many forbs and legumes (Elgersma et al., 2013). The percentage of the other fatty acids increased during the growing season, but the omega3:omega 6 ratio remains relatively high ranging from 6 (EV) to 4 (EF) and so is the ratio PUFA:MUFA.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Table 1. Chemical composition (g kg^{-1} DM basis) of Chia forage (Top) and Fatty Acid profile (g Fatty acid kg^{-1} Total FA) measured at three growth stages: 44 Days after sowing (DAS) corresponding to early vegetative stage (EV), 77 DAS late vegetative (LV) and 103 DAS early flowering and at two sowing densities (D1 = 125 plants m^{-2} and D4 = 8 plants m^{-2})
Tabella 1. Composizione chimica (g kg^{-1} DM basis) del foraggio di Chia (in alto) e profilo degli acidi grassi (g acidi grassi kg^{-1} Totale acidi grassi) (in basso) misurati in tre stadi di crescita: 44 giorni dopo la semina (DAS) che corrisponde alla fase denominata fase vegetativa precoce (EV); 77 DAS fase vegetativa tardiva (LV) e 103 DAS inizio fioritura (EF) e a due densità di semina (D1 = 125 piante al m^{-2} e D4 = 8 piante al m^{-2})

Gross quality		g kg^{-1} DM											
Density	Stage	lipids		PC		ash		NDF		ADF		Lignin	
D 1	EV	23,35	b	167,60		141,40		414,70	a	253,70		59,09	b
D 4	EV	33,48	a	184,03		148,78		380,85	b	253,10		59,16	a
average		28,41		175,81		145,09		397,78		253,40		59,13	
D 1	LV	19,18	b	107,78	b	98,38		429,53	b	341,33	a	75,09	a
D 4	LV	24,65	a	125,73	a	98,48		468,53	a	282,85	b	62,04	b
average		21,91		116,75		98,43		449,03		312,09		68,56	
D 1	EF	17,13		81,40	b	67,65	b	434,33	B	394,73	a	85,00	
D 4	EF	21,75		99,63	a	69,00	a	472,10	A	337,73	b	74,88	
average		19,44		90,51		68,33		453,21		366,23		79,94	

Fatty acids		g fatty acid kg^{-1} Total Fatty acid							
Density	Stage	C16		C18	c18:1n–9	C18:2n–6		C18:3n–3	
D 1	EV	94,74	b	19,43	17,75	111,84		630,62	
D 4	EV	98,29	a	20,50	19,56	108,24		615,34	
average		96,52		19,96	18,66	110,04		622,98	
D 1	LV	118,45		26,25	28,06	122,52	a	581,73	a
D 4	LV	121,29		28,25	28,28	119,03	b	571,77	b
average		119,87		27,25	28,17	120,78		576,75	
D 1	EF	124,80		41,00	47,25	125,29		478,11	
D 4	EF	123,78		41,12	44,76	124,55		475,82	
average		124,29		41,06	46,00	124,92		476,96	

Allometric relationships are displayed in Figure 1. Leaf-to-stem ration declined exponentially with yield ($y= \exp(3.23-3.71x$; $R^2= 0.87$, all parameters are significant at $P < 0.05$) and is increased with increasing N content following a power low growth curve ($y=9.52\ x^{1.58}$; $R^2=0.64$, all parameters are significant at $P < 0.05$). Crop height was related to many important quality parameters such as N and ADF though the relationship differs for the two densities being steeper at low density. LAI can be used as a predictor of leaf-to-stem ratio that can be considered a synthetic indicator of forage quality . Crop height was linearly and negatively related to PUFA proportion and inversely and non-linearly related to leaf-to-stem ratio.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

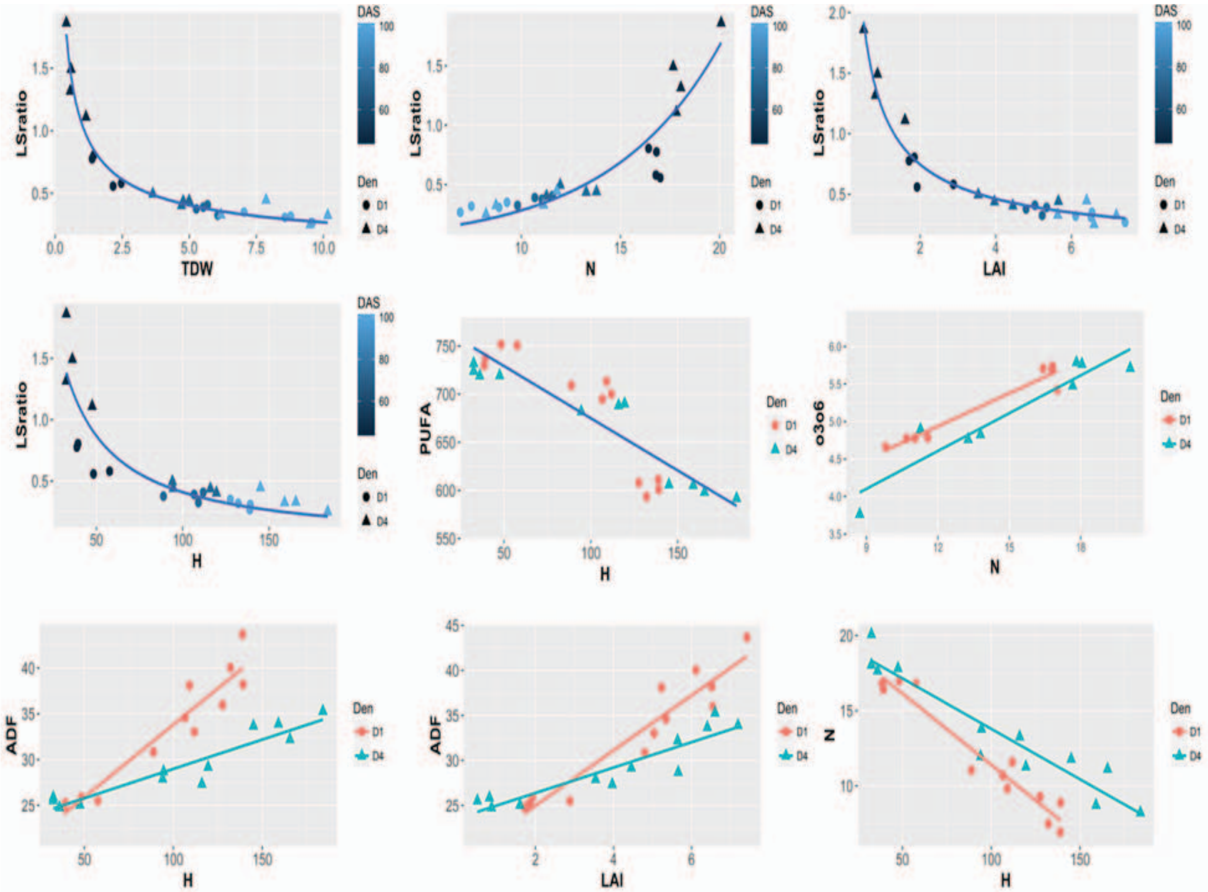


Figure 1 Relationships between Chia forage quality and crop biometry during the growing season and at different plant densities (D1= 125 plants m^{-2} vs D4= 8 plants m^{-2}). Top from left to right: Leaf –to-Stem ratio (LSratio) vs Total Dry weight (TDW) (Mg ha^{-1}) = Total dry weight; LSratio vs Protein content (N) % (DM); LSratio vs Leaf Area Index (LAI). Middle from left to right: LSratio vs crop height (H) (cm); PUFA (g PUFA Kg FA^{-1}) vs H (cm); Omega-3:Omega-6 FA ratio vs protein content (N) (% DM) . Bottom from left to right: Acid Detergent Fiber (ADF) % DM vs H (cm) ; ADF (% DM) vs LAI; Protein content (N) % DM vs H (cm).

Figure 2 Relazione fra i parametri qualitativi del foraggio di Chia e parametri biometrici misurati nel corso del ciclo vegetativo e in corrispondenza di diverse densità di semina (D1= 125 piante al m^{-2} vs D4 = 8 piante al m^{-2}). In alto da sinistra verso destra: il rapporto stelo foglie (LSratio) vs la resa (TDW= biomassa secca totale (Mg ha^{-1}); LSratio vs il contenuto di proteine (N) (% di sostanza secca); LSratio vs indice di area fogliare (LAI). Al centro da sinistra verso destra; LSratio vs altezza piante (H) (cm); PUFA (g PUFA Kg FA^{-1}) vs H (cm); rapporto Omega-3:Omega-6 FA vs contenuto Proteico (N) (% DM) . In basso da sinistra vs destra: Fibra acido detersa (ADF) % DM vs H (cm); ADF (% DM) vs LAI; contenuto proteico (N) % DM vs H (cm).

Maximum forage quality is obtained at very early vegetative stage and tends to be higher at low plant density. At low plant density a cutting window between 44 and 77 DAS which would roughly correspond to a crop height of about 50 cm would allow to harvest about 1.4 tons ha-1 (DM basis) of forage with approximately 17% of protein, an ADF content below 25% and a favourable omega-3:omega-6 ratio. At high planting density protein content and digestibility decline rapidly as crop height increases therefore the optimal cutting window tends to be narrower.

Conclusions

Chia forage shows a high proportion of omega-3 FA and a favourable omega-3 to omega-6 ratio especially at early vegetative stages. Forage quality is influenced by sowing density and declines at flowering. The choice of the optimal plant density is a trade-off between the necessity of weed-control the costs of seeds and machinery requirements, these preliminary data, however, indicate that a better forage quality can be obtained at low plant density especially if harvesting is delayed to late vegetative stages. Protein and fibre content correlate with crops architectural parameters (height, LAI and leaf-to-stem ratio) that can be measured rapidly and at very low cost during the growing season. Validation of these allometric relationships over multiple years and genotypes can help selecting a few fast measuring indicators for crop monitoring that can be used to tune management practices aimed at obtaining a forage with a high digestibility and rich in health-promoting fatty acids.

References

Ahmed, M., Ting, I. P., & Scora, R. W. (1994). Leaf oil composition of Salvia hispanica L. from three geographical areas. Journal of Essential Oil Research, 6(3), 223-228.

Amato, M., Caruso, M. C., Guzzo, F., Galgano, F., Commisso, M., Bochicchio, R., ... & Favati, F. (2015). Nutritional quality of seeds and leaf metabolites of Chia (Salvia hispanica L.) from Southern Italy. European Food Research and Technology, 241(5), 615-625.

Ayerza, R. (2009). The seed's protein and oil content, fatty acid composition, and growing cycle length of a single genotype of chia (Salvia hispanica L.) as affected by environmental factors. Journal of Oleo Science, 58(7), 347-354.

Ayerza, R., & Coates, W. (1999). An ω-3 fatty acid enriched chia diet: influence on egg fatty acid composition, cholesterol and oil content. Canadian Journal of Animal Science, 79(1), 53-58.

Ayerza, R., & Coates, W. (2006). Influence of chia on total fat, cholesterol, and fatty acid profile of Holstein cow's milk.

Ayerza, R., Coates, W., & Lauria, M. (2002). Chia seed (Salvia hispanica L.) as an omega-3 fatty acid source for broilers: influence on fatty acid composition, cholesterol and fat content of white and dark meats, growth performance, and sensory characteristics. Poultry Science, 81(6), 826-837.

Bochicchio, R., Rossi, R., Labella, R., Bitella, G., Perniola, M., & Amato, M. (2015). Effect of sowing density and nitrogen top-dress fertilisation on growth and yield of chia (Salvia hispanica L.) in a Mediterranean environment: first results. Italian Journal of Agronomy, 10(3), 163-166.

Dewhurst, R. J., Scollan, N. D., Lee, M. R. F., Ougham, H. J., & Humphreys, M. O. (2003). Forage breeding and management to increase the beneficial fatty acid content of ruminant products. Proceedings of the Nutrition society, 62(02), 329-336.

Dewhurst, R. J., Shingfield, K. J., Lee, M. A., & Scollan, N. D. (2006). Increasing the concentrations of beneficial polyunsaturated fatty acids in milk produced by dairy cows in high-forage systems. Animal Feed Science and Technology, 131(3), 168-206.

Elgersma, A., Søegaard, K., & Jensen, S. K. (2013). Fatty acids, α-tocopherol, β-carotene, and lutein contents in forage legumes, forbs, and a grass–clover mixture. Journal of agricultural and food chemistry, 61(49), 11913-11920.

Peiretti, P. G. (2010). Ensilability characteristics of chia (Salvia hispanica L.) during its growth cycle and fermentation pattern of its silages affected by wilting degrees. Cub J Agric Sci, 44(1), 33-36.

Peiretti, P. G., & Gai, F. (2009). Fatty acid and nutritive quality of chia (Salvia hispanica L.) seeds and plant during growth. Animal Feed Science and Technology, 148(2), 267-275.

Van Soest, P. V., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of dairy science, 74(10), 3583-3597.

Williams, C. M. (2000, May). Dietary fatty acids and human health. In Annales de Zootechnie (Vol. 49, No. 3, pp. 165-180). EDP Sciences.

Witkowska, I. M., Wever, C., Gort, G., & Elgersma, A. (2008). Effects of nitrogen rate and regrowth interval on perennial ryegrass fatty acid content during the growing season. Agronomy Journal, 100(5), 1371-1379.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

PHOTOSYNTHETIC RESPONSE AT LEAF LEVEL OF BIOMASS SORGHUM TO THE INCREASE OF CO_2 CONCENTRATION
RISPOSTA FOTOSINTETICA A LIVELLO FOGLIARE DEL SORGO DA BIOMASSA ALL'AUMENTO DELLA CONCENTRAZIONE DI CO_2

Michele Rinaldi [1]*, Carmen Maddaluno [1], Pasquale Garofalo [2], Laura D'Andrea [2]

[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA) – Centro di Ricerca Cerealicoltura e Colture Industriali (CI) – S.S. 673, km 25,200 – 71122 Foggia, Italia
[2] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA) – Centro di Ricerca Agricoltura e Ambiente (AA), Via Celso Ulpiani, 5 – 70125 Bari, Italia
* michele.rinaldi@crea.gov.it

Abstract
The aim of this study was to evaluate the effect of CO_2 enrichment at leaf scale on the biomass sorghum cultivated in Southern Italy. An increased concentration from 370 (ambient) to 760 μmol mol^{-1} of CO_2 was set. Leaf photosynthetic rate (A), stomatal conductance (gs) and leaf transpiration rate (E) were measured, and water use efficiency (WUE) was calculated as ratio between A and E. The parameters were measured on fully expanded leaves during three vegetative phases (juvenile phase, full canopy expansion and beginning of senescence) using a Photosynthesis System LCpro+, Portable Infra-Red Gas Analyzer (IRGA). This research showed that as consequence of the increase in carbon dioxide concentration, the biomass sorghum led to an improvement in plant carbon assimilation and processing, by increasing the photosynthesis, reducing the water transpired by the plants and improving the water use efficiency.

Keywords: leaf photosynthetic rate, leaf transpiration rate, stomatal conductance, carbon dioxide, IRGA.
Parole chiave: fotosintesi, traspirazione, conduttanza stomatica, anidride carbonica, IRGA.

Introduction
The atmospheric carbon dioxide concentration [CO_2] has risen by more than 30% since pre-industrial times, from equilibrium levels of about 280 ppm in 1880, to the currently observed levels of 365 ppm, and it will increase to 500-1000 ppm by 2100 (IPCC, 2007). The elevated concentration of CO_2 tends to increase growth and yield of most agricultural crops (Tubiello *et al.*, 2007), with different paths for C_3 and C_4 plants, indeed, the final biomass accumulation is about 40-44% in C_3 plants and 22-33% for C_4 plants (Poorter, 1993; Wand *et al.*, 1999).
Among the C_4 plants, there is the biomass sorghum (*Sorghum bicolor* L.). It is an energy crop, that could represent an alternative renewable resource to fossil fuels, to produce bio-ethanol. Moreover, it is sustainable in Mediterranean environment, because of its low nitrogen and water requirement and its high efficiency in capturing and transforming energy into biomass.
The aim of this study was to evaluate the effect of the CO_2 enrichment at leaf scale on the biomass sorghum cultivated in Southern Italy.

Materials and Methods
The research was carried out in Foggia (lat. 41° 8' 7'' N; long. 15° 83' 5'' E, alt. 90 m a.s.l.) (Southern Italy) in 2010 at the experimental farm of CREA-SCA of Bari. The soil is a vertisol of alluvial origin, Typic Calcixeret, (Soil Taxonomy 10th ed., USDA 2010), silty-clay with available soil water, 202 mm m^{-1}. The local climate is "accentuated thermo-Mediterranean" as classified by FAO-UNESCO Bioclimatic Maps (1962), with daily temperatures below 0 °C in the winter and above 40 °C in the summer. Annual rainfall (average 550 mm) is mostly concentrated during the winter months.
The sowing of biomass sorghum (*Sorghum bicolor* L., hybrid BIOMASS 133) was carried out in the first days of May and the plants were cut early in August at flowering. The crop was cultivated in well watered conditions, supplying the water consumed and was fertilized with 2 q ha^{-1} of diammonium phosphate in pre-sowing.
The parameters were measured on two new fully expanded and sunlight leaves of three plants randomly chosen in the field, using a Photosynthesis System LCpro+, Portable Infra-Red Gas Analyzer (IRGA) (ADC, BioScientific Ltd., Hoddesdon, Herts, UK). The [CO_2] in the leaf chamber (c_{ref}) was increased step by step, starting with 370 (ambient), followed by: 450, 580, 680 and 760 μmol mol^{-1}.
The measurements were carried out in the three phases: 60 days (juvenile phase), 70 days (full canopy expansion) and 90 days (beginning of senescence) after the sowing.
The following parameters were measured: leaf photosynthetic rate (A; μmol m^{-2} s^{-1}), stomatal conductance (gs; mol m^{-2} s^{-1}) and leaf transpiration rate (E; mmol m^{-2} s^{-1}). Water use efficiency (WUE; μmol CO_2 mmol^{-1} H_2O) was calculated as ratio between A and E.

Results and Discussion

The stomatal conductance (gs; mol m^{-2} s^{-1}) and the leaf transpiration rate (E; mmol m^{-2} s^{-1}) remain constant with increasing CO_2, while decreasing during the crop cycle.

The photosynthesis increases with the increase of CO_2, continuously in the phase of senescence beginning, while in the other two phases (juvenile phase and full canopy expansion) the increase is only after the first two increments of CO_2 (450 and 580 µmol mol^{-1}) compared to the environmental one (370 µmol mol^{-1}), then there is the flattening after the other two following increments of CO_2 (680 and 760 µmol mol^{-1}).

The WUE (ratio of photosynthesis and transpiration) increases with the increase in CO_2 concentration and higher values have been found especially during the full expansion phase. The trend is similar to that of photosynthesis.

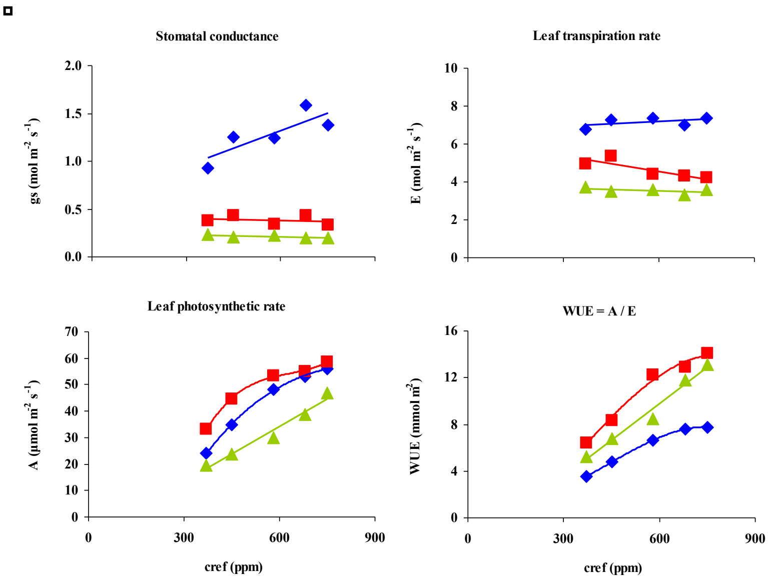


Fig. 1: Photosynthetic components observed on biomass sorghum at 60 days (juvenile phase; blue diamonds), 70 days (full canopy expansion; red squares) and 90 days (beginning of senescence; green triangles) after the sowing.

Fig. 1: Componenti della fotosintesi osservate su sorgo da biomassa a 60 giorni (stadio giovanile; rombi blu), 70 giorni (piena espansione; quadrati rossi) e 90 giorni (inizio di senescenza; triangoli verdi) dopo la semina.

Conclusions

The increase of [CO_2], as predicted by the future climate scenarios, will be accompanied by raise of temperature and rainfall reduction. In these conditions, the C4 plants through the abatement of the stomatal conductance and leaf transpiration, combined with a faster intercellular CO_2 processing, could fit better to the changing environmental conditions than C3 species, enhancing leaf A and growth via increases in Ci improvements of shoot water relations and increases in leaf temperature.

However, the increases in carbon dioxide concentration led to an improvement in plant carbon assimilation and processing, by: (i) increasing the photosynthesis, (ii) reducing the water transpired by the plants and (iii) improving the water use efficiency. These effects indicate that the biomass sorghum (C4 plant) has a better flexibility, in the environmental short term CO_2 enrichment.

Acknowledgement

This work has been supported by the Italian Ministry of Finance and Economy, the Ministry of Education, University and Research, the Ministry of Environment and Territory, the Ministry of Agricultural, Food and Forestry Policies, through the contract no. 285 – 20/02/2006 (CLIMESCO Project, Coordinator: dr. D. Ventrella).

References

IPCC, 2007. Climate Change, 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.), Cambridge University Press, Cambridge, UK, 996 pp.

Poorter H., 1993. Interspecific variation in the growth response of plants to an elevated ambient carbon dioxide. Vegetatio, 104: 77-97.

Tubiello F.N., Amthor J.S., Boote K.J., Donatelli M., Easterling W., Fischer G., Gifford R.M., Howden S.M., Reilly J. and Rosenzweig C., 2007. Crop response to elevated CO_2 and world food supply. A comment on 'Food for Thought ...' by Long et al., Science 312: 1918–1921, 2006. Eur. J. Agronomy 26: 215–233.

Wand S.J.E., Midgley G.F., Jones M.H. and Curtis P.S., 1999. Responses of wild C4 and C3 grass (Poaceae) species to elevated atmospheric CO2 concentration: a meta-analytic test of current theories and perceptions. Global Change Biol.. 5: 723-741.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

PHYSIOLOGICAL RESPONSES OF PROCESSING TOMATO SEEDLINGS INOCULATED WITH ARBUSCULAR MYCORRHIZAL FUNGI DURING DROUGHT STRESS

RISPOSTE FISIOLOGICHE DURANTE STRESS DA SICCITA' ALLO STADIO DI PLANTULA IN POMODORO DA INDUSTRIA INOCULATO CON FUNGHI MICORRIZICI ARBUSCOLARI

Federica Caradonia[1*], Domenico Ronga[1], Leonardo Setti[1], Luca Laviano[1], Enrico Francia[1], Caterina Morcia[2], Roberta Ghizzoni[2], Franz-W. Badeck[2], Fulvia Rizza[2], Valeria Terzi[2]

[1]Department of Life Sciences, University of Modena and Reggio Emilia, Via Amendola, n. 2, 42122 Reggio Emilia (RE), Italy.
[2]Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria - Centro di Ricerca per la Genomica e la Bioinformatica (CREA-GB), Via San Protaso, 302, 29017, Fiorenzuola d'Arda, Italy.
*federica.caradonia@unimore.it

Abstract
Arbuscular mycorrhizal fungi (AMF) are ubiquitous in the natural environment and interact with the roots of most plants providing a range of benefits to the host species. Therefore, the presence of AMF in the soil might improve the tolerance of horticultural crops like tomato to water deficit, and could be an interesting strategy in view of ongoing climate change. In this work, three processing tomato genotypes – Pearson (old), Everton (modern) and H3402 (modern) – were inoculated with two AMF – *Glomus mosseae*, *Rhizophagus intraradices* – to assess their responses to drought stress in a short-term growth chamber experiment evaluating physiological changes at seedlings stage. Data recorded during the stress show that tomato plants growth in presence of AMF – in particular *Rhizophagus intraradices* – have enhanced drought tolerance. The results obtained represent a first step towards the characterization of processing tomato-AMF interaction.

Keywords: drought stress, processing tomato, arbuscular mycorrhizae, sustainable agriculture
Parole chiave: stress da siccità, pomodoro da industria, micorrize arbuscolari, agricoltura sostenibile

Introduction

Tomato (*Solanum lycopersicum* L.), after potato, is the main cultivated horticultural crop in the world, and in 2014 ca. 16.9 M tons were produced in Europe, with Italy being one of the major producers of the region (FAOSTAT, 2017). Many abiotic stresses can threaten the tomato plant causing large production losses and drought stress is considered the most important one (Subramanian et al., 2006). During the growth season processing tomato needs large amounts of water (Patanè et al., 2011) ranging from 400 to 600 mm based on climatic conditions (Rana et al., 2000). Furthermore, the ongoing climate change could raise the frequency of drought stress events; hence, sustainable agronomical strategies aiming at increasing tomato tolerance to drought should be developed. Arbuscular mycorrhizal fungi (AMF) are ubiquitous in natural environment and interact with the roots of most of plants, providing a range of benefits to the hosts. The application of AMF has been reported to improve water and nutrient (P, K, Mg, N and micronutrients) uptake, enhance tolerance to soil-borne pathogens and environmental stresses, reduce sensitivity to heavy metals, and have positive influence on soil structural properties (Baum et al., 2015; Bernardo et al., 2017; Cavagnaro et al., 2012; Gosling et al., 2006; Hart et al., 2014; Subramanian et al., 2006; Zouari et al., 2014). Furthermore, Ruth and colleagues (2011) showed as AMF contributed to the direct and indirect total water uptake of the plants. Therefore, the use AMF could be an interesting solution to reduce yield losses due to growth in water limiting conditions. In this context, the aim of the present study was to assess the physiological responses during drought stress of three different processing tomato genotypes – Pearson (old), Everton (modern) and H3402 (modern) – inoculated with two AMF (*Glomus mosseae* and *Rhizophagus intraradices*) at seedlings stage.

Materials and Methods

The study was conducted in the CREA-GB growth chambers (Fiorenzuola d'Arda, Italy), following a fully randomised experimental design. The experiment was carried out in pots using three genotypes: Person (old), Everton (modern) and H3402 (modern). Seed was provided by ISI Sementi S.p.A. (Fidenza, Italy) and plants were grown in pots containing the same quantity of peat (pH 6, electrical conductivity 0.25 dS m^{-1}, dry apparent density 110 kg m^{-3}). Before transplanting, *G. mosseae* and *R. intraradices* were mixed with peat 50g:500g (w/w) (1g of inoculum contained 10 propagules). AMF inocula were obtained from MycAgro, LabTechnopôle Agro Environnement, Bretenière, France. The experiments had two level of irrigation: full (100%) and partial (65%).

Five tomato seedlings per treatment were cultivated in a growth chamber at 23°C day/17°C night with 14h photoperiod. Three weeks later, seedlings were subjected to drought stress for 3 weeks by withholding watering. Relative soil water

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA. Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

content (RSWC) was controlled gravimetrically weighing the pots every 3 days (Bernardo et al., 2017). Some morphological (height of plant, number of leaves, stem diameter, dry weight of leaves, stems and roots and the total dry weight) and physiological (chlorophyll, flavonoid and nitrogen estimation content, transpiration index) parameters were recorded at 3 timing during the stress: at start, in the middle, and at the end. Chlorophyll (Chl), flavonoids (Flav) and nitrogen content (NBI) were estimated on the youngest fully expanded leaf using Dualex 4 Scientific (Dx4) (FORCE-A, Orsay, France). The different parts of the plant (leaves, stems and root) were weighted and oven-dried at 65°C until constant weight to obtain the dry weight of single organs and the total dry weight.
Analysis of variance (ANOVA) was performed with GenStat 17.0th edition on data recorded at the end of drought stress. Means were compared using Duncan's test at the 5% level. Moreover, all recorded data during the experiment was analyzed by Principal Component Analysis (PCA) model (Jackson, 1991; Wold et al., 1987) to evaluate the relationships between the analyzed objects and the original variables, a biplot graph was used.

Results and Discussion

Irrigation regimes significantly affected all parameters investigated (Table 1). Plant growth was reduced as observed by plant height, number of leaves, steam diameter, and root and total dry weight. Noteworthy, chlorophyll content was apparently higher in seedlings under partial irrigation (+11%), probably because of an increase Chl concentration rather than greater accumulation. Partially irrigated seedlings, when inoculated with AMF, showed a higher value of flavonoids but also an interesting increase of plant height; furthermore, inoculation with *G. mossae* showed a higher stem diameter and plant height/stem diameter. On the other hand, inoculation with *R. intraradices* showed a higher number of leaves, stem diameter, root and total dry weight under stress, but also a lower ratio between water use and leaf fresh weight that might suggest a greater resistance to drought. Our data agree with the findings by Subramanianet al. (2006) who reported that AMF increased tomato shoot dry matter.
No significant differences in water use could be ascribed to AMF inoculation; however, Pearson was the genotype that showed the highest value (+3%) and *R. intraradices* showed the lowest water use/leaf fresh weight ratio.
Principal Component Analysis (PCA) explained 66.79% of the variability, with the first two PCs being 54.01% and 12.78%, respectively (data not shown). In general, seedlings inoculated with AMF, and in particular using *R. intraradices*, increased the growth in term of number of leaves, stems and total dry weights and the content of flavonoids showing similar trend among all genotypes. In addition, AMF improved Chl during the stress period. These results are in agreement with those showed by Ruiz-Lozano et al. (2016), who reported that AMF symbiosis alleviates drought stress by altering plant physiology in the host plant. As expected the highest physiological and morphological values were obtained without drought stress; however, the indications obtained in this first year of experiment show the sustainability of AMF inoculation in alleviating drought stress effects on processing tomato seedlings.

Conclusions

The present study provides some useful information on the application of AMF on processing tomato at seedlings stage during drought stress. The results showed how AMF could improve drought tolerance and enhance plant growth. Hence, a multidisciplinary approach to investigate the interaction between élite genotypes and AMF is being performed to obtain useful information that might promptly converted in agronomic practices to face future climate change.

DOI 10.6092/unibo/amsacta/5692

Tab.1: Morphological and physiological data recorded at the end of drought stress.
Chlorophyll content = Chl; flavonoid content = Flav; nutrient balance index = NBI; water use = WU; leaves dry weight = LDW; steams dry weight = SDW; root dry weight = RDW; total dry weight = TDW; no arbuscular mycorrhizal fungi treatment = M-; G. mosseae treatment = MG+; R. intraradices treatments = MR+; not significant = n.s. Mean values (n=5) within a column followed by different lowercase letters are significantly different at p<.05, according to Duncan's test.
Tab.1: Dati morfologici e fisiologici rilevati alla fine dello stress da siccità.
Contenuto in clorofilla = Chl; contenuto in flavonoidi = Flv; Indice del bilancio dell'azoto = NBI; acqua utilizzata = WU; peso secco delle foglie = LDW; peso secco dei fusti = SDW; peso secco delle radici = RDW; peso secco totale = TDW; nessun trattamento con fungi micorrizici arbucolari = -M; trattamento con G. mosseae = MG+; trattamento con R. intaradices = MR+; non significativo = n.s. I valori medi (n = 5) all'interno di una colonna seguita da diverse lettere minuscole sono significativamente diverse a p <0,05, secondo il test di Duncan.

Treatment	Chl$_3$		Flav$_3$		NBI$_3$		WU$_3$		Leaves$_3$ (no.)		Plant height$_3$ (cm)		Stem diameter$_3$ (cm)		Plant height Stem diamter$^{-1}{}_3$		LDW$_3$ (g)		SDW$_3$ (g)		RDW$_3$ (g)		TDW$_3$ (g)		Root Shoot$^{-1}{}_3$		WU LFW$^{-1}{}_3$	
Genotype																												
Pearson	29.02		1.11	a	29.40		55.12	a	6.23	b	23.70	a	0.53		45.09	a	6.96	a	6.38	a	6.19		19.53		0.42	b	4.12	a
Everton	28.09		0.97	b	31.20		53.15	ab	6.57	a	21.79	c	0.51		42.56	b	6.83	b	6.28	b	6.24		19.35		0.48	a	4.14	a
H3402	28.61		1.02	ab	31.50		52.10	b	5.86	c	18.97	b	0.52		36.78	c	6.93	a	6.28	b	6.19		19.17		0.45	c	3.82	b
Mychorrizae																												
M-	29.41		0.92	b	34.40		53.81		6.15		20.77	b	0.51	b	41.00	ab	6.86	b	6.28	b	6.24	a	19.14		0.47	a	4.10	a
MG+	28.32		1.11	a	29.60		52.75		6.17		21.97	a	0.51	b	43.10	a	6.83	b	6.28	b	6.17	b	19.28		0.44	b	4.14	a
MR+	27.99		1.07	a	28.10		53.81		6.34		21.72	a	0.54	a	40.34	b	7.02	a	6.38	a	6.21	a	19.62		0.44	b	3.85	b
Irrigation																												
100%	26.96	b	1.19	a	24.50	b	73.99	a	6.54	a	24.48	a	0.54	a	45.46	a	7.12	a	6.39	a	6.27	a	19.61	a	0.44	b	5.15	a
65%	30.19	a	0.87	b	36.90	a	32.93	b	5.90	b	18.49	b	0.50	b	37.50	b	6.70	b	6.24	b	6.15	b	19.09	b	0.46	a	2.91	b
G	n.s.		<.05		n.s.		<.05		<.001		<.001		n.s.		<.001		<.01		<.001		n.s		n.s.		<.001		<.001	
M	n.s.		<.001		n.s.		n.s.		n.s.		<.01		<.05		<.05		<.001		<.001		<.01		n.s.		<.001		<.01	
I	<.01		<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.01		<.001	
G*M	n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s		n.s.		n.s.		n.s.	
G*I	n.s.		<.01		n.s.		n.s.		n.s.		<.001		<.01		<.001		<.001		<.05		n.s		n.s.		n.s.		<.05	
M*I	n.s.		n.s.		n.s.		<.01		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s		n.s.		n.s.		n.s.	
G*M*I	n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s		n.s.		n.s.		n.s.	

DOI 10.6092/unibo/amsacta/5692

References

Baum C., El-Tohamy W., Gruda N., 2015. Increasing the productivity and product quality of vegetable crop using arbuscular mycorrhizal fungi: A review. Scientia Horticulturae, 187: 131-141.

Bernardo L., Morcia C., Carletti P., Ghizzoni R., Badeck F.W., Rizza F., Lucini L., Terzi V., 2017. Proteomic insight into the mitigation of wheat root drought stress by arbuscular mycorrhizae. Journal of Proteomics. In press. doi: 10.1016/j.jprot.2017.03.024.

Cavagnaro T.R., Barrios-Masias F.H., & Jackson L.E., 2012. Arbuscular mycorrhizas and their role in plant growth, nitrogen interception and soil gas efflux in an organic production system. Plant and Soil, 353: 181-194. http://link.springer.com/article/10.1007/s11104-011-1021-6#/page-1

FAOSTAT, 2017. http://www.fao.org/faostat/en/.

Gosling P., Hodge A., Goodlass G., Bending G.D., 2006. Arbuscular mycorrhizal fungi and organic farming. Agriculture. Ecosystems and Environment, 113: 17-35. http://www.sciencedirect.com/science/article/pii/S0167880905004457

Hart M., Ehret D.L., Krumbein A., Leung C., Murch S., Turi C., Franken P., 2015. Inoculation with arbuscular mycorrhizal fungi improves the nutritional value of tomatoes. Mycorrhiza, 25(5): 359-376. http://link.springer.com/article/10.1007%2Fs00572-014-0617-0

Jackson J. E., 1991. A Users Guide to Principal Components. Nr. 1. Wiley & Sons Ltd, New York, USA.

Patanè C., Tringali S., Sortino O., 2011. Effects of deficit irrigation on biomass, yield, water productivity and fruit quality of processing tomato under semi-arid Mediterranean climate conditions. Scientia Horticulturae, 129: 590-596.

Rana G., Rinaldi M., Introna M., Ciciretti L., 2000. Determinazione sperimentale dei consumi idrici del pomodoro da industria in Capitanata. Atti Convegno POM B19. Gutenberg, Salerno, 99-106.

Ruiz-Lozano J.M., Aroca R., Zamarreño Á.M., Molina S., Andreo-Jiménez B., Porcel R., Garcìa-Mina J.M., Ruyter-Spira C., & López Ráez J.A., 2016. Arbuscular mycorrhizal symbiosis induces strigolactone biosynthesis under drought and improves drought tolerance in lettuce and tomato. Plant, cell & environment, 39: 441-452.

Ruth B., Khalvati M., Schmidhalter U., 2011. Quantification of mycorrhizal water uptake via high-resolution on-line water content sensors. Plant Soil, 342: 459–468

Subramanian K.S., Santhanakrishnan P. & Balasubramanian P., 2006. Responses of field grown tomato plants to arbuscular mycorrhizal fungal colonization under varying intensities of drought stress. Scientia Horticulturae, 107(3): 245-253. http://www.sciencedirect.com/science/article/pii/S0304423805002578.

Wold, S., Esbensen K., and Geladi P., 1987. Principal component analysis. Chemometrics and Intelligent Laboratory Systems, 2: 37–52.

Zouari I., Salvioli A., Chialva M., Novero M., Miozzi L., Tenore G.C., Bagnaresi P., Bonfante P., 2014. From root to fruit: RNA-Seq analysis shows that arbuscular mycorrhizal symbiosis may affect tomato fruit metabolism. BMC Genomics, 15: 221. http://www.biomedcentral.com/1471-2164/15/221.

AGRONOMIC TRAITS ASSOCIATED TO YIELD IN OLD AND MODERN PROCESSING TOMATO CULTIVARS

CARATTERI AGRONOMICI ASSOCIATI ALLA RESA IN VARIETA' ANTICHE E MODERNE DI POMODORO DA INDUSTRIA

Domenico Ronga*[1], Federica Caradonia[1], Fulvia Rizza[2], Franz-W. Badeck[2], Enrico Francia[1], Marianna Pasquariello[1], Giuseppe Montevecchi[1], Luca Laviano[1], Justyna Milc[1], Nicola Pecchioni[1]

[1]Department of Life Sciences, University of Modena and Reggio Emilia, Via Amendola, n. 2, 42122 Reggio Emilia (RE), Italy.
[2]Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria - Centro di ricerca per la Genomica e la Bioinformatica (CREA-GB), Via San Protaso, 302, 29017, Fiorenzuola d'Arda, Italy.
*domenico.ronga@unimore.it

Abstract

Changes in agronomic traits of processing tomato cultivated in the past decades might give useful information to develop breeding programs in order to face future food security challenges. The present study investigated six different processing tomato genotypes selected among the most widely cultivated over the past 60 years in Southern Europe. The aim was to assess morphological and physiological traits associated to yield improvement, studying the changes that have occurred until nowadays to highlight some of these that could contribute to improve the sustainability of the crop. Several agronomic trait data were collected in open field using currently management. The most modern genotype H3402 resulted as expected more suitable to the mechanized management, and showed distinct assemblies of traits such as higher harvest index and number of fruits vs. the old variety Pearson. However, no significant differences were observed between the two in marketable yield per square meter and solid soluble content.

Keywords: processing tomato, physiology, morphology, biomass, quality, breeding
Parole chiave: pomodoro da industria, fisiologia, morfologia, biomassa, qualità, miglioramento gentico

Introduction

Ranking second after potato among horticultural crops, tomato (*Solanum lycopersicum* L.) yield in Europe has increased by 200% from 1961 until nowadays (FAOSTAT, 2017). This increase might be attributed both to advancements in agricultural practices and to plant breeding (Barrios-Masias and Jackson, 2014; Foolad, 2007; Grandillo et al., 1999; van der Ploeg et al., 2007). The main characters improved by breeders in processing tomato were: tolerance to biotic and abiotic stresses, plant growth habit, fruit firmness and jointless fruits (Foolad, 2007). For fresh market tomato, van der Ploeg et al. (2007) and Higashide and Heuvelink (2009) reported that, under current management, modern genotypes show an important increase of yield in comparison to old cultivars released starting from 1950s, and this increase was due to higher light use efficiency. Barrios-Masias and Jackson (2014) compared eight processing tomato genotypes released in California in the past 80 years reporting that the modern cultivars have accumulated phenological traits (i.e. early flowering and concentrated fruit set) together with morphological ones (e.g. smaller canopy and low vegetative biomass), correlated with gains in nitrogen concentration in biomass and photosynthetic rates. On the other hand, to the author's knowledge, no such studies are available for Southern Europe, another important area of tomato cultivation. Hence, this study investigated six different processing tomato genotypes, released and cultivated over the past 60 years, with the final aim to investigate agronomic, morphological and physiological changes that occurred in tomato genotypes.

Materials and Methods

Six processing tomato genotypes – Pearson released in the 1950s, C33 released in the 1970s, H2274 released in 1975, E6203 released in 1984, Brigade released in 1989 and H3402 released in 2002 – were evaluated in an open field trial at ISI Sementi S.p.A. (Fidenza, Italy), during the spring-summer 2013 using current management techniques. Six-weeks old tomato seedlings were transplanted at the end of April in single row (1.40 m spacing between rows), with a final density of 3.6 plants m^{-2} for all genotypes tested in each year. The experimental design was a randomized complete block design with three replicates. A total of 166 Kg ha^{-1} of N, 84 Kg ha^{-1} of P, 214 Kg ha^{-1} of K were applied; phosphorus and potassium were supplied before transplanting while nitrogen was applied 33% at transplanting and 67% from full flowering to fruit set and seed ripening. Irrigation water, distributed with a drip system, was determined on the base of the total water lost by evapotranspiration calculated according the formula: $ETc = ETo \times Kc$, where ETo is the reference evapotranspiration and Kc was the crop coefficient of tomato (Allen et al., 1998). The 100% ETc was restored when 40% of total available water in the soil was depleted in agreement with the evapotranspiration method of Doorenbos and Pruitt (1977). During the trial

about 4500 m^3 ha^{-1} of irrigation water was applied. Weeds and pests were controlled according to the conventional management rules of Emilia Romagna Region, Italy.
Growth and physiological parameters were assessed every 2 weeks starting from one month after transplant by sampling 2 plants per plot and then converting values per square meter. A total of 21 traits were recorded at four timings: 0 (transplanting), 1 (full flowering), 2 (fruit ripening), 3 (fruit harvest). Number and angle of leaves, number of stems, number of flowers and fruits and heights of plants were recorded for the morphological characterization. Physiological traits were evaluated in term of estimation of chlorophyll content (Chl), flavonoid (Flv) and nitrogen status (NBI). Chlorophyll (a/b) (Chl_{MASS}) was measured also by specific spectrophotometric assay (V-550 UV-VIS, Jasco Inc, Easton, USA). The physiological parameters were measured on the youngest fully expanded leaf using Dualex 4 Scientific (Dx4) (FORCE-A, Orsay, France). At harvest time, leaf area index, marketable yield, total fresh biomass, dry weight of leaves, stems, fruits and harvest index, were recorded along with a series of quality-related parameters: pH, °Brix, total carotenoid and polyphenol content. Leaf area was measured using subsamples of fresh leaves that were run through the leaf area meter LI-3000A (LI-COR Inc., Nebraska, USA).
Analysis of variance (ANOVA) was performed with GenStat 17.0th edition on data recorded at harvest time. Means were compared using Duncan's test at the 5% level. In addition, a Principal Component Analysis (PCA) model (Jackson, 1991; Wold et al., 1987) was used for biplot generation on all data recorded during the cropping season.

Results and Discussion

Fruits were harvested at mature stage at the end of August 2013. As reported in Table 1, H2204 was the cultivar with the highest leaves dry weight and stem dry weight. C33 and E6203 reported the highest marketable yield and harvest index, the latter trait was showed also by the most modern cultivar (H3402). As regard fruit quality, Brigade showed the highest value of solid soluble content (°Brix). These results are partially in agreement with the previous work of Higashide and Heuvelink (2009) on fresh market tomato, which showed an increase of yield *per* year of release, an increase of fruit and total dry weight, and harvest index in modern genotypes. These differences were probably due to the different genotypes investigated. In fact, Higashide and Heuvelink (2009) studied genotypes suitable for greenhouse cultivation, with indeterminate growth habit, while in the present study were assessed genotypes suitable for the cultivation in open field characterized by traits for mechanized harvest.

Tab. 1: Traits recorded at harvest time. LDW = leaves dry weight; SDW = stem dry weight; FDW = fruit dry weight; TDW = total dry weight; LAI = leaf area index; MY = marketable yield; HI = harvest index; ns = not significant. Values within columns followed by different letters are significantly different at P<0.05.
Tab.1: Parametri rilevati alla raccolta. LDW = peso secco delle foglie; SDW = peso secco dei fusti; FDW = peso secco dei frutti; TDW = peso secco totale; LAI = indice di area fogliare; MY = produzione commerciale; HI = indice di raccolta; ns = non significativo. Valori all'interno delle colonne seguiti da lettere differenti sono statisticamente significativi a P<0.05.

	LDW ($g\ m^{-2}$)		SDW ($g\ m^{-2}$)		FDW ($g\ m^{-2}$)		TDW ($g\ m^{-2}$)		LAI ($m\ m^{-2}$)		MY ($g\ m^{-2}$)		HI		°Brix	
Cultivar																
Pearson	418.6	b	425.4	ab	462.7	ns	1776.3	ns	3.0	ns	9435.2	ab	36.1	abc	6.0	ab
C33	528.2	ab	302.5	ab	605.2	ns	1435.8	ns	4.2	ns	13398.6	a	42.6	a	5.2	b
H2274	887.6	a	712.3	a	423.2	ns	2023.1	ns	3.7	ns	9681.7	ab	22.8	b	5.1	b
E6203	621.6	ab	338.6	ab	653.5	ns	1613.7	ns	3.7	ns	13043.7	a	42.2	a	5.4	b
Brigade	389.9	b	75.3	b	438.2	ns	903.4	ns	3.1	ns	7877.5	b	36.3	abc	6.9	a
H3402	414.1	b	208.3	ab	638.8	ns	1261.1	ns	3.0	ns	11525.4	ab	50.3	a	5.8	ab
Average	543.3		343.7		536.9		1502.2		3.5		10827.0		38.4		5.8	

All measured traits were also analyzed using Principal Component Analysis (PCA) to determine putative associations between the investigated traits and the six genotypes cultivated over the past decades (Figure 1). The relative contribution of the various physiological traits might give some useful information that might be used in future breeding programs to design new élite genotypes. The contributions of the first two PCs were 42.12% and 23.84% and their sum explained 65.96% of the variation. The negative side of PC1, included E6203 (rel. 1984) and H3402 (rel. 2002), two genotypes with higher values of Chl_{MASS} and leaf, stem and total dry weight at transplant, high number of leaves at full flowering time, high number of fruits recorded at each timing and high value of fruit dry weight at harvest time.
The positive side of PC1 included Pearson (rel. 1950s) and H2274 (rel. 1975) with high value of Chl_{DX} and height at each timing; high values of flower number, Flv_{DX} and number of leaves at fruit ripening; while at harvest time reported the high value of leaves, stem and total dry weight, number of stem, Flv_{DX}, pH and carotenoids content in fruits. Finally, C33 and

Brigade showed intermediate values ranging among the other investigated genotypes. Our result regarding phenological and morphological traits highlighted higher harvest index and number of fruit, smaller canopies and lower total dry weight, in the most modern genotype (H3402) respect to the oldest one (Pearson) confirming results reported by Barrios-Masias and Jackson (2014) who studied processing tomato genotypes released over the past 80 years and suitable for Californian environments.

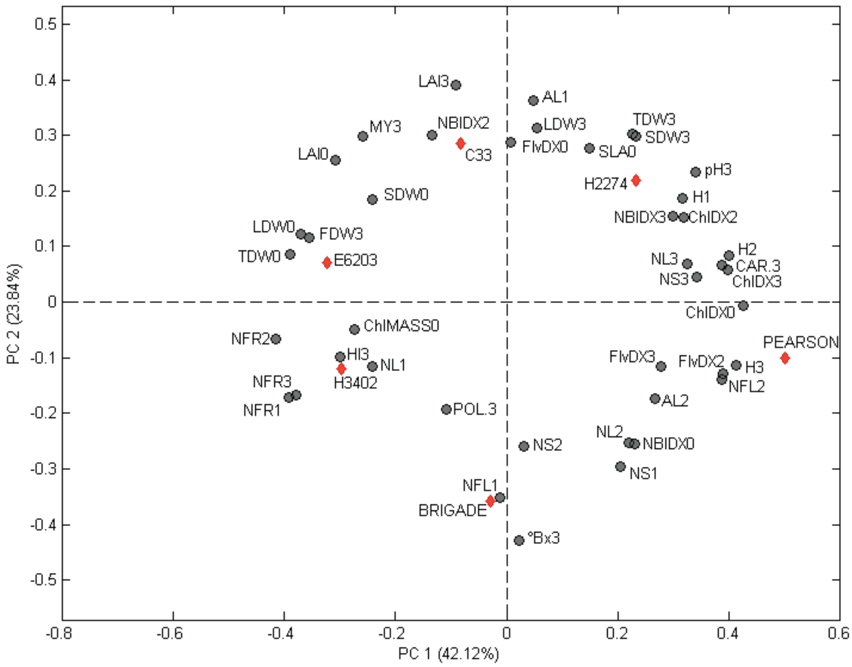


Fig. 1: Biplots of PCA results. Physiological and morphological traits are in relation with the tested genotypes.
0, 1, 2 and 3 = measures recorded at transplanting, full flowering, fruit ripening and fruit maturity.
Red diamonds = cultivars studied; grey circles = traits investigated
NL = number of leaves; AL = angle of leaves; NS = number of stems; NFL = number of flowers; NFR = number of fruits; ChlDX = chlorophyll content; FlvDX = flavonoid content; NBIDX = nitrogen balance index; ChlMASS = chlorophyll a/b; LDW = leaves dry weight; SDW = stem dry weight; FDW = fruit dray weight; TDW = total dry weight; MY = marketable yield; LAI = leaf area index; HI = harvest index; Bx = °Brix; CAR = total carotenoids; POL = total polyphenols; BTH = Brix t ha^{-1}; H = plant height; SLA= specific leaf area.
Fig. 1: Biplot dei risultatti della PCA. I parametri fisiologici e morfologici sono in relazione con i genotipi testati.
0, 1, 2 e 3 = misure rilevate al trapianto, alla piena fioritura, adll'ingrossamento delle bacche e alla maturazione dei frutti.
Rombi rossi= cultivar studiate; cerchi grigi = parametri investigati.
NL = numero delle foglie; AL = angolo delle foglie; NS = numero dei fusti; NFL = numero dei fiori; NFR = numero dei fiori; ChlDX = contenuto in clorofilla; FlvDX = contenuto in flavonoidi; NBIDX = indice di bilancio del'azoto; ChlMASS = clorofilla a/b; LDW = peso secco foglie; SDW = peso secco fusti; FDW = peso secco frutti; TDW = peso secco totale; MY = produzione commerciale; LAI =leaf area index; HI = harvest index; Bx = °Brix; CAR = carotenoidi totali; POL = polifenoli totali; BTH= Brix t ha^{-1};H= altezza piante; SLA= specific leaf area.

Conclusions

In view of the global climate change, providing sufficient amounts of food and quality is impellent. Therefore, the knowledge of traits that might lead to an increase in tomato production and quality is useful to design the plant ideotype for future breeding programs. This work focused on changes that occurred in tomato putatively influencing the production in the last 60 years in Southern Europe. The change from indeterminate to determinate growth habit and other traits are highlighted in the most modern genotype such as smaller canopies, lower leaf biomass and higher harvest index. In the near future, more attention might be considered on angle of leaves, and °Brix, which are important traits to improve the production but also the quality of fruit. These results might provide information to examine new suites of traits that might drive future breeding and crop improvement reflecting the demands of future scenarios.

Acknowledgements

We wish to thanks Dr. P. Passeri, Dr. Massimiliano Beretta and ISI Sementi Spa (Fidenza, PR, Italy) for providing the seeds of cultivars and the experimental field used in this study.

References

Allen R.G., Pereira L.S., Raes D., Smith M., 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. Irrigation and Drainage, 56. FAO, Rome, Italy.

Barrios-Masias F.H., Jackson L.E., 2014. California processing tomatoes: Morphological, physiological and phenological traits associated with crop improvement during the last 80 years. European Journal of Agronomy, 53: 45-55.

Doorenbos, J., Pruitt W.O., 1977. Guidelines for prediction of crop water requirements. Irrigation and Drainage, 24, FAO, Rome, Italy, 144.

FAOSTAT, 2017. http://www.fao.org/faostat/en/#home

Foolad M.R., 2007. Genome Mapping and Molecular Breeding of Tomato. International Journal of Plant Genomics. doi:10.1155/2007/64358.

Grandillo S., Zamir D., Tanksley S.D., 1999. Genetic improvement of processing tomatoes: A 20 years perspective. Euphytica, 110: 85-97.

Higashide T., Heuvelink E., 2009. Physiological and Morphological Changes Over the Past 50 Years in Yield Components in Tomato. The Journal of the American Society for Horticultural Science, 134(4): 460-465.

Jackson J. E., 1991. A Users Guide to Principal Components. Nr. 1. Wiley & Sons Ltd, New York, USA.

van der Ploeg A., van der Meer M., Heuvelink E., 2007. Breeding for more energy efficient greenhouse tomato: Past and future perspectives. Euphytica, 158:129-138.

Wold S., Esbensen K., Geladi P., 1987: Principal component analysis. Chemometrics and Intelligent Laboratory Systems, 2: 37–52.

MYCOTOXINS MONITORING IN MAIZE AGRONOMIC TRIALS – VARIETALS NETWORK.
MONITORAGGIO DI MICOTOSSINE NELLA RETE DI CONFRONTO VARIETALE MAIS.

Chiara Lanzanova[1*], Francesca Fumagalli[1], Stefania Mascheroni[1], Fabrizio Facchinetti[1], Sabrina Locatelli[1]

[1] Consiglio per la sperimentazione in agricoltura e l'analisi dell'economia. Centro Cerealicoltura e Colture Industriali (CREA-CI), Via Stezzano, 24, 24126 Bergamo
*chiara.lanzanova@crea.gov.it

Abstract
Maize varietal network of agronomic trials began in the mid-1950s with the introduction of the first hybrids from the USA, and was born in order to evaluate these materials that gradually replaced the old local varieties.
CREA Bergamo has been called to coordinate this public network that provided every year objective information about yield potential, adaptability, susceptibility to disease and destination use of different hybrids tested in order to supply hybrids the most suitable for cultivation in different environments and climatic conditions.
Over the past decade, with the spread of mycotoxins in Italy, safety of maize production has become increasingly important. During 2015 seven hybrids selected from maize varietal network were cultivated under different environmental and agronomic factors and analyzed by ELISA tests for a characterization in fumonisins, aflatoxin B_1, deoxynivalenol and zearalenone accumulation in the grain.

Keywords: maize, varietal network, micotoxins, safety
Parole chiave: mais, confronto varietale, micotossine, sicurezza alimentare

Introduction
The varietal network of Maize agronomic trials began in the mid-1950s with the introduction of the first hybrids from the USA, and was born in order to evaluate these materials that gradually replaced the old local varieties. The existence of a public network that provided objective information about yield potential, adaptability to different crop environments, susceptibility to disease and destination use of different hybrids became therefore significant and CREA Bergamo was called to coordinate this activity. The agronomic trials – varietals network is based on the collaboration of various public and private subjects. Currently, about 70-80 maize hybrids belonging to 300-700 FAO maturity classes, are tested in 18-20 principal cultivation areas in Northern Italy (Piemonte, Lombardia, Veneto, Friuli Venezia Giulia, Emilia Romagna).
Until the mid-1990s tests were essentially focused on general evaluation of productive potential and agronomic adaptability of hybrids, both grain and forage. Subsequently, agronomic factors such as sowing time, density, nitrogen fertilization, irrigation and insecticide treatments were introduced to evaluate a possible interaction with hybrids in order to identify materials that could better adapt to reduced agronomic inputs.
This network has also been a useful technical support for several national research projects concerning alerts such as the presence of insects (IDIAM), mycotoxin contamination (MICOCER, AFLARID, MICOPRINCEM) and the ban of use on use of neonicotinoid (APENET).
Over the past decade, with the spread of mycotoxins in Italian maize trade, safety of maize production has become increasingly important. In order to provide information on safety of Italian maize materials, within the RQC-Mais Project (Cereal Quality Network – Maize, Project 2014-2017), during the 2015, 7 of 40 hybrids selected from maize varietal network were cultivated under different environmental and agronomic factors and analyzed by ELISA tests for a characterization in the main mycotoxins: fumonisins (FBs), aflatoxin B_1 (AFB1), deoxynivalenol (DON) and zearalenone (ZEA) accumulation in the grain.

Materials and Methods
Maize samples. In 2015, seven hybrids representative of the main FAO classes (500–600–700) were grown in nine locations of distinct geographic area in the Northern of Italy (Figure 1). At harvest, samples were collected.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Locations 2015
Chivasso (TO)
Noventa Vicentina (VI)
Camino al Tagliamento (UD)
Beano (UD)
Palazzolo dello stella (UD)
Gariga di Podenzano PC)
Caleppio di Settala (MI)
Trigolo (CR)

Fig. 1: Distribution of trial fields during 2015
Fig. 1: Distribuzione delle località in prova durante il 2015

Agronomical factor input. For each hybrid, 32 samples were collected.
Weather conditions. 2015 season was characterized by an extremely hot and droughty summer. Thermal performance above the average in May caused cold and adequate rains. Averaged extremely high temperatures, especially in July and moderately low precipitation have been observed during June, July and August.
Chemical analyses. The grain samples were milled with Retsch - ZM 200 mill with 0.5 mm sieve. Mycotoxin concentration levels were determined by the Enzyme-Linked Immunoassorbent Assay (ELISA). The Ridascreen® R-Biopharm kit tests were performed using the Chemwell Automatic Awareness Engineer (inc.).

Results and Discussion
Total yield average of all seven hybrids cultivated in all locations and agronomic environments during 2015 was about 123 q/ha (15.5% moisture).
Preliminary results obtained point up, on average, a critical situation in 2015 both for FBs and AFB1, considering the level for these mycotoxin as raw material for direct human food consumption. In particular results indicated that agronomic environments with suitable fertilization, irrigation and sanitary protection provided both higher yields quality as indicated in the MIPAAF guidelines (Reyneri et al., 2015).
Fumonisins: during 2015 a total average value of 5234,38 µg/kg, with a minimum of 3918,69 µg/kg and a maximum of 7792,09 µg/kg of all cultivated hybrids was recorded. Overall, the average contaminant values of each hybrid have been placed above the EU level fixed for direct human food use (4000 µg /kg). All the analyzed samples were found to be suitable in comparison with the standards for feed raw materials (Table 2). No statistical significance was found in fumonisins accumulation.
Aflatoxin B_1: preliminary data showed that total level of contamination of all hybrids selected and cultivated in the different agronomic environments was 2,41 µg/kg, with a minimum of 0,82 µg/kg and a maximum of 4,87 µg/kg. Two hybrids reported values of AFB1 below 2,00 µg/kg fixed as maximum limit for direct human-use grain (European Commission, 2011). On the other hand, all hybrids showed an adequate hygienic health profile as feed material with a level of AFB1 contamination below 20 µg/kg (Table 2). No statistical significance was found in AFB1 accumulation.
Zearalenone – deoxynivalenol: considering the climatic condition during 2015, level of DON and ZEA have been found adequate to EU legislation limit. It has been noted that under stress conditions DON and ZEA levels are higher but within

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

the fixed limit (Table 2). With regard to the accumulation of DON and ZEA a statistical significance was found. There are ongoing analyzes of the distribution of different mycotoxins in the trial fields under study.

	Yield (q/ha 15,5% u.m.)	FBs (µg/Kg)	ns	AFB1 (µg/Kg)	ns	DON (µg/Kg)	*	ZEA (µg/Kg)	*
H1	123,28	4720,50		2,16		49,01	b	2,25	b
H2	130,50	7792,09		3,65		40,08	b	1,72	b
H3	124,81	5017,44		4,87		203,13	a	17,02	a
H4	121,41	5399,34		1,21		20,67	b	0,95	b
H5	124,57	5657,66		2,00		45,41	b	0,94	b
H6	119,34	3946,16		0,82		19,29	b	0,84	b
H7	117,27	3918,69		2,14		108,41	ab	3,08	b

Tab.2: Yield (q/ha 15,5% u.m.) and accumulation of different mycotoxins (µg/Kg) in 7selected hybrids
Tab.2: Resa (q/ha 15,5% u.m.) e quantificazione delle diverse micotossine (µg/Kg) in 7 ibridi selezionati

Conclusions

The maize agronomic trials-varietals network was born until the mid-1990s in order to assess the potentiality and adaptability of different hybrids, both grain and forage.

To stakeholders it is a useful tool for the selection of maize the most suitable for cultivation in different environments. It provides: i) objective information on the performance of tested hybrids (production potential, adaptability to different crop environments, susceptibility to disease); ii) update data on varietal characterization; iii) reliable data due to the number of tested hybrids.

Over the past decade, with the spread of mycotoxins in Italian maize trade, safety of maize production has become increasingly important. Therefore, the determination of different mycotoxins in maize grain aims to assess the effect of the combination of the different agronomic techniques, in order to establish strategies to prevent their development.

Preliminary data showed that there are no significant differences regarding the accumulation of fumonisins and aflatoxin B1. Regarding DON and ZEA statistical significance has been observed in the distribution of seven hybrids.

Acknowledgments

The research was carried out within the RQC-Mais research project, funded by the Ministry of Food and Forestry Policies (MiPAAF, DD 88666 of 03/12/2014).

Special thanks to Gianfranco Mazzinelli, Maize agronomic trials varietal network coordinator.

References

European Commission, 2006. Commission Recommendation (EC) on the presence of deoxynivalenol, zearalenone, ochratoxin A, T-2 and HT-2 and fumonisins in products intended for animal feeding. Official Journal of European Union 229:7-9.

European Commission, 2007. Commission Regulation (EC) No 1126/2007 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards Fusarium toxins in maize and maize products. Official Journal of European Union 255:14–17.

European Commission, 2011. Commission Regulation (EC) No 574/2011 amending Annex I to Directive 2002/32/EC. Official Journal of European Union 159:7-24.

Mazzinelli G. et al. 2016. Prove agronomiche di ibridi di mais FAO 500, 600, 700. L'informatore Agrario n°3 5-21

Berardo N., C. Lanzanova, S. Locatelli, P. Laganà, A. Verderio and M. Motto, 2011. Levels of total fumonisins in maize samples from Italy during 2006–2008. Food Additives and Contaminants: Part B. 4, 116–124.

Reyneri A., Bruno G., D'Egidio M.G., Balconi C. (a cura di), 2015. Linee guida per il controllo delle micotossine nella granella di mais e frumento. Linee guida per il controllo delle micotossine nella granella di mais e frumento. Ministero delle politiche agricole, alimentari e forestali - Dip.to delle politiche competitive, della qualità agroalimentare, ippiche e della pesca - Piano cerealicolo nazionale, 2010.
https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/9703

OCCURRENCE OF MYCOTOXINS IN ITALIAN MAIZE DURING 2014-2016.
INCIDENZA DI MICOTOSSINE IN MAIS ITALIANO NEL PERIODO 2014-2016.

Sabrina Locatelli[1*], Francesca Fumagalli[1], Stefania Mascheroni[1], Fabrizio Facchinetti[1], Chiara Lanzanova[1]

[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria. Cerealicoltura e colture industriali. (CREA-CI). Via Stezzano, 24, 24126, Bergamo (BG).
*sabrina.locatelli@crea.gov.it

Abstract
Maize is subjected to infection by a variety of toxigenic fungi. This study is focused in Northern Italy, the main area of maize production (Piemonte, Lombardia, Veneto, Friuli Venezia Giulia, Emilia Romagna), to monitor the occurrence and accumulation of principal mycotoxins in the early stages of storage. A total of 1076 grain samples from about 50 storage centers distributed in the principal maize cultivation areas, were collected over a 3-year period (2014-2016). Fumonisins (FBs) were present in all samples and the percentage with a FBs content over 4000 µg/kg ranged from a minimum of 27% in 2015 to a maximum of 54% in 2014. Climatic conditions strongly affect growth of different fungal species. In 2015, the growing season of maize was characterized by prolonged high temperatures and low rainfall. These conditions have greatly promoted the development of *Aspergillus flavus*: 18% of maize samples were found over 20 µg/kg of aflatoxin B_1 (AFB1). In 2014 spring was extremely rainy. This delayed sowing, development and harvest and favoured the growth of *Fusarium graminearum*; in fact, in 2014, 49% of the samples had a content of deoxynivalenol (DON) exceeding 1750 µg/kg and 40% exceeded 350 µg/kg for zearalenone (ZEA). In 2016 climate conditions (temperatures and precipitation) were favourable to maize until the third week of August; subsequently, an abrupt rise in temperatures caused a fall in yields, placing them between 2014 and 2015. Therefore, analysis carried out in 2016 showed that 12% of maize samples showed AFB1 content greater than 20 µg/kg.

Keywords: maize; mycotoxins; fumonisins; aflatoxin B_1; deoxynivalenol; zearalenone; storage.
Parole chiave: mais; micotossine; fumonisine; aflatossina B_1; deossinivalenolo; zearalenone; stoccaggio.

Introduction
Maize is a major crop in Italy, where it plays an important role in animal feed, for direct human consumption and as source of many commercial products. A number of studies have documented that maize is subjected to infection by a variety of toxigenicity fungi. In Italy mainly *Fusarium verticillioides, F. graminearum,* and *Aspergillus flavus* are responsible for the presence of the most common toxins fumonisins (FBs), deoxynivalenol (DON), zearalenone (ZEA), and aflatoxins (AFB) respectively. The presence of different fungi and their mycotoxins is influenced by environments and years. Indeed, the development of maize fungi and the consequent accumulation of mycotoxins are strongly influenced by: i) climatic factors (temperature, humidity), ii) biotic factors (insect attacks), iii) abiotic factors (hail, mechanical damage), iv) field stress conditions in the field (drought).
Available data for the incidence of mycotoxins on maize production in Italy are limited and irregular; additionally, no national database for collecting information to predict annual risk exposure is active (Berardo et al., 2011). Therefore, a systematic effort to monitor the levels of mycotoxin contaminants in maize grain production is needed. Since 1999, CREA coordinates a network of about 50 storage centers (Figure 1), stable in the years of investigation, distributed in Northern Italy, the main area of maize production (Piemonte, Lombardia, Veneto, Friuli Venezia Giulia, Emilia Romagna), to monitor the occurrence and levels of the main mycotoxins in the early stages of storage and preservation.

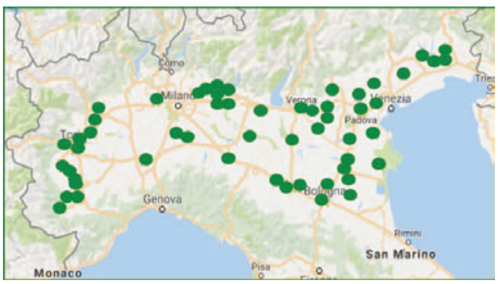


Figure 1: Italian Mycotoxin Maize Monitoring Network
Figura 1: Rete di monitoraggio delle micotossine in mais in Italia.

Maize grain samples were collected over a 3-year period (2014–2016). This study shows the results of a survey on mycotoxin occurrence in Italian maize produced from in this period.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Materials and Methods

Maize samples. A total of 1076 representative grain samples were collected, after dry processing, over a 3-year period (2014–2016) from about 50 storage centers. From each storage center, 5–10 samples were collected each year. A dynamic grain sampling strategy (Munkvold 2003) was performed on the product in motion to obtain a representative sample (Council for Agricultural Science and Technology (CAST) 2003). Accordingly, we took a pre-sample of 15–20 kg from all production components (whole and broken grains and small parts). From these pre-samples, by applying standard procedures, sorter samples of 1–1.5 kg each were obtained for laboratory analyses. These samples were placed in sealed bags and stored in a cool room for 1 day until milling, according to European recommendations (Commission Regulation 2006).

Chemical analyses. The grain samples were milled with Retsch - ZM 200 mill with 0.5 mm sieve. Mycotoxin concentration levels were determined by the Enzyme-Linked Immunoassorbent Assay (ELISA). The Ridascreen® R-Biopharm kit tests were performed using the Chemwell Automatic Awareness Engineer (inc.).

Results and Discussion

An overview of mycotoxin contamination found in maize in the three years is presented in Table 1.

Table 1: Mycotoxins detected from 2014 to 2016 and percentage of maize samples resulted positive for contamination; fumonisins (FBs), aflatoxin B1 (AFB1), deoxynivalenol (DON), zearalenone (ZEA).

Tabella 1: Micotossine rilevate dal 2014 al 2016 e percentuale di campioni di mais risultati positive alla contaminazione; fumonisine (FBs), aflatossina B1 (AFB1), deossinivalenolo (DON), zearalenone (ZEA).

Years	N° of samples	% of samples with FBs > 4000 µg/kg	% of samples with AFB1 > 20 µg/kg	% of samples with DON > 1750 µg/kg	% of samples with ZEA > 350 µg/kg
2014	356	54%	0%	49%	40%
2015	400	27%	18%	1%	0%
2016	320	39%	12%	11%	0%

Fumonisins (FBs) are the most common mycotoxins found in the Italian maize area and the distribution of their concentration classes frequency is, in the different years, the most homogeneous and constant within all mycotoxins considered (Locatelli et al., 2016a). Fumonisins are produced by *Fusarium verticillioides* which, *as Aspergillus flavus* is ubiquitous, but is not able to tolerate drought and high temperatures. It prefers a milder humid weather conditions (optimum temperature between 22 and 27 °C), especially in post flowering. During 2016 (Locatelli et al., 2017), 39% of maize samples from storage centers showed FBs content above 4000 µg/kg, the limit value for food use (EC Regulation, 2007). This percentage ranged from 27% in 2015 (Locatelli et al., 2016b) to a 54%, in 2014 (Locatelli et al., 2015), as shown in Table 1.

Aflatoxin B1 (AFB1) is produced by *Aspergillus flavus*, whose growth is favored by high temperatures (optimum 32 °C - 36 °C, T min 12 °C, T max 42 °C) and low moisture content. The physiological phases in which maize cultivation is more susceptible to fungal attack are flowering and ripening; in particular, when silks are senescent (yellow-brown) and the grain moisture drops below 28%. An irregular evolution for maize cultivation was observed during 2016. The weather data provided by meteorological station of CREA Bergamo indicate that after a relatively cool and rainy period from June to August, during the period between August 20 and September 20, there was an exceptionally warm temperature with average temperatures higher than 3 °C over the reference period. This anomalous trend, observed in different regions affected: an anticipation of phenotypes of senescence and physiological maturation, a shortening of the accumulation period with consequent decrement production compared to forecasts until the beginning of August and finally allowed favorable conditions to the accumulation of aflatoxins (Mazzinelli et al., 2017). Therefore, analysis carried out in 2016 showed that 12% of maize samples showed AFB1 content greater than 20 µg/kg (Table 1), the reference value for maize destined for feed materials (EC Regulation, 2011). This result observed is lower than 18% obtained in 2015, year during which a hot and droughty summer, with average temperatures lower than in 2016 in the second half of August and September, involved the entire maize cycle. The maize field during 2014, characterized by mild and rainy summer, had not reported the presence of aflatoxins in the analysed samples.

Fusarium graminearum prefers a rainy climate condition and low temperatures from flowering to harvest. Better temperature for its growth is between 24 and 26 °C. As for moisture, a greater need for *Fusarium verticillioides* was observed. During 2014: 49% of samples analysed showed deoxynivalenol (DON) values above 1750 µg/Kg (1% in 2015, 11% in 2016) and 40% of maize samples showed zearalenone (ZEA) above 350 µg/Kg, reference value for maize intended for human consumption (EC Regulation, 2007). In 2015 and 2016, none of the samples tested showed zearalenone (ZEA) content above 350 µg / Kg.

DOI 10.6092/unibo/amsacta/5692

Conclusions

This study provides data on incidence and distribution of mycotoxin contamination of maize by sampling a large fraction of Italian maize grain production. The findings allow an assessment of the status of Italian production affected by mycotoxin contamination. The number of samples tested encompassed a large number of storage centers. Although variations in toxin levels is highly dependent on weather and growing conditions, the number of samples was sufficiently large to give a picture of the level of contamination in Italian maize grain production.

Fusarium verticillioides is endemically present in Italy, because of specific adaptation to the environmental and climatic conditions. Particular climatic anomalies favour the presence of *Aspergillus flavus* or *Fusarium graminearum*. The problem related to mycotoxin contamination has reached levels of attention that cannot longer be considered less important e in relation to its use in human food and livestock. Monitoring activities conducted through a network of sampling stable over the years, is an essential tool for the management of domestic stocks and to highlight new mycotoxin alerts.

Acknowledgments

The research was carried out within the RQC-Mais research project, funded by the Ministry of Food and Forestry Policies (MiPAAF, DD 88666 of 03/12/2014).

Special thanks to storage centers belonging to the Mycotoxin Maize Monitoring Network.

References

Berardo N., Lanzanova C., Locatelli S., Laganà P., Verderio A. and Motto M., 2011. Levels of total fumonisins in maize samples from Italy during 2006–2008. Food Additives and Contaminants: Part B. 4, 116–124.

CAST. 2003. Mycotoxins: Risks in plant, animal, and human systems. Ames (IA): Council for Agricultural Science and Technology. Task Force Report 139.

European Commission, 2006. Commission Regulation (EC) N 401/2006 of 23 February 2006. Laying down the methods of sampling and analysis for the official control of the levels of mycotoxins in foodstuffs. Off J Eur Union L70:12–34.

European Commission, 2007. Commission Regulation (EC) No 1126/2007 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards Fusarium toxins in maize and maize products. Official Journal of European Union 255:14–17.

European Commission, 2011. Commission Regulation (EC) No 574/2011 amending Annex I to Directive 2002/32/EC. Official Journal of European Union 159:7-24.

Locatelli S., Balconi C. 2015. Micotossine in mais: campagna 2014. Mangimi & Alimenti, 3:32-33.

Locatelli S., Lanzanova C., Facchinetti F., Mascheroni S., Mazzinelli G., Balconi C. 2016 (a). Mais: monitoraggio micotossine in Italia dal 2006 al 2014. Atti V Congresso Nazionale: le micotossine nella filiera Agro-Alimentare, Rapporti ISTISAN 16/28: 82-86.

Locatelli S., Facchinetti F., Mascheroni S., Balconi C. 2016 (b). Micotossine nel mais 2015: risultati del monitoraggio. Supplemento a L'Informatore Agrario 11/2016, pag. 8 – 10.

Locatelli S., Fumagalli F., Mascheroni S., Facchinetti F., Lanzanova C., Balconi C. 2017. Micotossine su mais: risultati del monitoraggio 2016. L'Informatore Agrario, 11: 51-53.

Mazzinelli et al. 2017. Prove agronomiche di ibridi di mais Fao 500, 600 e 700. L'Informatore Agrario, n. 3/2017, pag. 39-50.

Munkvold GP. 2003. Mycotoxins in corn-occurrence, impact, and management. In: White PJ, Johnson LA, editors. Corn: Chemistry and Technology. 2nd ed. St. Paul (MN): AAC. p. 811–881.

BIOREGIONE: HOW TO PROMOTE SUSTAINABLE LOCAL DEVELOPMENT BY THE TERRITORIAL ORGANIZATION OF FOOD SUPPLY AND DEMAND

BIOREGIONE: COME PROMUOVERE UNO SVILUPPO LOCALE SOSTENIBILE PER MEZZO DELL'ORGANIZZAZIONE TERRITORIALE DELL'OFFERTA E DELLA DOMANDA DI CIBO

Bocchi, Stefano[1]; Spigarolo, Roberto[1*]

[1] Dipartimento di Scienze e Politiche Ambientali, Università di Milano, via Celoria 2, 20133, Milano
*roberto.spigarolo@guest.unimi.it

Abstract

An important challenge for agrifood products trade and for increasing income and opportunities for farmers is to improve the activities related to direct sales, such as the direct sale to the consumer often called "farm to fork". Furthermore, another important activity regards direct sale to the catering system: this sector represents a great share of the demand of foodstuff and also homogenous characteristics and seasonal menus that make it particularly interesting to a direct relationship with local productions. The development of local and sustainable agri-food systems should be fostered, by coordinating supply with demand. To increase the percentage of local food in the providing of mass catering it is necessary to know very well both the demand of mass catering system and the supply chain of local products

The aim of this research is to analyze both demand and supply in public procurement of the mass catering in Lombardy, in order to promote a change in agricultural production and its sustainability over time, improving the sustainability of agrifood cycles in Lombardy, enabling the conditions for a virtuous encounter between an organized demand for quality food and different types of local sustainable production.

Keywords: Local Agrifood Systems; supply, demand; local products; sustainable agriculture.

Parole chiave: Sistemi Agroalimentari Locali; offerta, domanda; prodotti locali; agricoltura sostenibile.

Introduction

The activities related to direct sales are those to the consumer, a distribution channel often called "farm to fork". They encompass different types of activities, such as farmers' markets, community supported agriculture (CSAs), direct sales in farms, solidarity based purchasing groups (in IT GAS) (in Lombardy there are 25% of all IT groups), "pick your own" operations. Furthermore, another important activity regards direct sale to the catering system - this distribution channel includes the sale to restaurants, local retailers and public procurement organizations for institutions such as schools, day-care centers for elderly people and hospitals.

The distribution channel that is considered most interesting and which will then be better investigated in the case study of the Lombardy Region and the research project "BioRegione", is the direct relationship between local production and mass catering. This sector represents a great share of the demand of foodstuff and also homogenous characteristics and seasonal menus that make it particularly interesting to a direct relationship with local productions.

Fipe, the Federation of Italian public exercises, has calculated that in the last thirty years the average expenditure for food consumption outside home has increased by 78.7% to EUR 2,118 per family (Fipe, 2008). In 2008, 32.1% (national average) of the meals were eaten outside the home (38% in northern Italy). If the trend detected by the latest opinion polls continue in this direction, in 2020 every Italian will spend at least 50% of its food out of home.

The main aim of the research is to analyze both demand and supply in public procurement of the mass catering in Lombardy. The public procurement of the mass catering involves a potential demand, highly concentrated and of considerable size.

Through a direct survey in schools, hospitals and other facilities we have tried to quantify the magnitude of this demand, focusing on the demand for organic and local products. On the other hand we have analyzed the actual amount of the main products that compose the menu.

The research analyses the Local Agrifood Systems and in particular the role of the public catering as an innovative driver for the local development and an important opportunity for the farms.

The results are the first step of the research project Bioregione which has the aim of developing approaches and tools, to design a regional food system, capable of economic self-sustainability and to generate systemic positive effects.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Similar processes are undergoing in different areas of the world with the so-called experiences of Local Food Systems (LFS) (Feagan, 2007), according to the US definition, or Local Agrifood Systems (LAS), which instead is the French definition (CIRAD-SAR, 1996) [in French SyAL].
The **general objectives** of the research is to promote a change in agricultural production and its sustainability over time, improving the sustainability of agrifood cycles in Lombardy, enabling the conditions for a virtuous encounter between an organized demand for quality food and different types of local sustainable production.
The main scientific references of this research are i) ecological agriculture, ii) the territorialist approach, iii) the analysis of the territorial metabolism and food chains (Bocchi et al., 2001).

Methodology

The research was based, with regard to the school catering, on a questionnaire sent to all the Municipalities of Lombardy. In Italy, the municipalities are responsible for providing canteen service in primary schools.
The questionnaire allowed to collect a huge quantity of data, such as the number of meals provided per year, the frequency distribution of 47 food products and their origin (conventional, sustainable or organic agriculture). The data sample collected represents 72 % of the total public school systems.
With regard to the other types of mass catering, in hospitals, kindergartens and day-care institutions for elderly people, 100% of data on the number of meals provided per year were collected.
The supply analysis was carried out by comparing the data of the national census of agriculture (ISTAT, 2011) with those of the SIARL (Agriculture Information System of the Lombardy Region). These data, collected at municipality level, allowed to know which crops are grown and how many hectares are allocated to each crop as well as which and how many animals are bred.
By using the data of the average yields, available at the provincial level, it was possible to calculate the production of crops and livestock for each municipality of the Lombardy Region. Data collected through direct survey, relating to the demand for food by the mass catering, were compared with the agricultural land use. In particular, the research has focused on organic consumption and production. Several thematic maps that show the distribution of cultivated areas have been produced using GIS (Geografical Information System) software.

Table 1. Geographical distribution of meals in mass catering in Lombardy by type of structure
Tabella 1. Distribuzione geografica della tipologia di pasti forniti dai servizi di catering in Lombardia in relazione al tipo di struttura.

District.	School (n. of meals per year)	Hospital (n. of meals per year)	Centers for minors (n. of meals per year)	Centers for elderly (n. of meals per year)	Centers for disabled people (n. of meals per year)	Total Mass catering (n. of meals per year)
BG	6,519,819	4,863,649	5,308,664	4,940,411	658,344	22,290,887
BS	6,831,889	6,663,654	3,956,426	6,730,050	701,928	24,883,947
CO	3,858,990	2,486,295	1,215,078	4,026,318	388,901	11,975,582
CR	2,766,201	1,909,428	888,822	3,939,889	718,041	10,222,381
LC	2,595,052	1,634,554	596,166	1,852,514	258,044	6,936,329
LO	2,052,994	1,006,314	864,112	1,128,306	105,826	5,157,552
MB	7,830,588	5,410,807	1,666,037	2,827,190	342,751	18,077,374
MI	28,850,685	16,302,682	10,072,118	15,404,335	1,459,359	72,089,179
MN	2,150,601	1,977,854	1,048,315	2,917,232	227,720	8,321,722
PV	4,008,025	4,152,545	1,354,721	4,893,544	367,632	14,776,467
SO	1,378,011	1,185,732	212,436	1,156,218	108,728	4,041,125
VA	6,416,812	2,346,052	1,620,095	4,986,535	486,248	15,855,742
Tot.	75,259,669	49,939,566	28,802,990	54,802,542	5,823,521	214,628,289

Results

The fundamental result of the data collection is the quantification of the importance of the mass catering in Lombardy. As shown in Table 1, every year more than 210 million meals are served in mass catering. These are allocated as follows:

- 35% (more than 75 million) of those are served in schools
- 23% (about 50 million) in hospitals

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

- 13% (more than 28 million) in Centers for minors
- 25% (about 55 million) in Centers for elderly people
- 3% (about 6 million) in Centers for disabled people

Actually, in some environments, such as hospitals or centers for elderly, the computing unit is normally the “food day” (from breakfast to dinner) and not the single meal, but in order to standardize the calculation, the food days have been transformed into number of meals.

Conclusions

The demand for local products continued to increase in recent years. It is expressed in different forms: short chain products, zero-km products, local products; terms which are often used one for the other. To prepare the about 214 million meals served annually by the mass catering in Lombardy a considerable quantity of food products are today purchased on the global market.

In parallel, the agri-food production is nowadays devoted mainly to large retailers. The possibility that a part of these products can be retrieved on the regional market, and most importantly, on local markets can be a driving force for the development of LAS and especially a tool for rural development.

The continuous improvement of the quality of procurement and of mass catering service can be realized by operating several choices which altogether can ensure the achievement of this goal. First of all the development of local and sustainable agri-food systems should be fostered, by coordinating supply with demand. To increase the percentage of local food in the providing of mass catering it is necessary to know very well both the demand of mass catering system and the supply chain of local products.

Furthermore, the catering service is very easily suitable to build up win-win strategies on a territorial basis, pursuing different forms of integration, such as horizontal integration: small-medium sized municipalities may share call for tender documents, with the goal of making a single tender, as well as share facilities such as cooking centers, that are often underutilized; vertical integration: is it possible to realize different forms of integration in the same area, between the various sectors of the mass catering: schools, hospitals, day-care institutions for elder people in order to reduce costs and streamline the service.

The development of the integration of services allows streamlining the environmental and economic costs, even by checking the optimal market conditions and sharing facilities and human resources. The rationalization of the supply chains of mass catering, their qualification and improving the sustainability of the system are a significant challenge for public institutions.

The first important result to be achieved is to make possible a new ongoing relationship between the demand of the mass catering, which requires constant supplies and relevant quantities, and the local food production system. The difficulties in satisfying the current demand can be overcome with a higher/better knowledge of territory, production (quantity, quality, spatial distribution, seasonal availability), required quality standards (food safety, etc…) with an aggregation of offer based on local and multi-product platforms and a more efficient organization of supply chains.

References

Bocchi S., Bellingeri D., Galli A. 2001. Classification and land evolution in the South Milan Agricultural Park. Proc. Int. Symp. Multitemp. Trieste, 14 – 16 Sept.2001.

CIRAD/SAR, 1996. Systèmes agroalimentaires localisés (organisations, innovations et développement local), proposition d’animation scientifique du laboratoire STSC. Nov., n° 134/96

Feagan R., 2007. The place of food: mapping out the 'local' in local food systems . Prog Hum Geogr 2007 31: 23.

Fipe, 2008. I consumi alimentari fuori casa. Last access January 31, 2013 available at: http://www.fipe.it/files/ricerche/2008/06-08consumi-alimentari-fuoricasa06-08.pdf

DOI 10.6092/unibo/amsacta/5692

DIGITAL EARTH: A USE CASE IN URBAN AGRICULTURE GEOSPATIAL DATASET CREATION

DIGITAL EARTH: UN CASO D'USO DI CREAZIONE DI DATASET GEOSPAZIALI SULL'AGRICOLTURA URBANA

Flavio Lupia[1*], Giuseppe Pulighe[1], Francesca Giarè[1]

[1] CREA Centro di ricerca Politiche e Bio-economia, Via Po, 14, 00198 Roma
*flavio.lupia@crea.gov.it

Abstract
Urban agriculture is being recognized as spreading activity in many metropolitan areas with positive impacts on the socio-economic sphere, favouring forms of sustainable urban environments. A stepping stone for analysing potential benefits, sustainability aspects and to define planning strategies is the availability of high resolution land use datasets. Often, metropolitan areas have limited geospatial datasets and, if available, they lack of details especially when very small cultivated parcels are considered. In this work, Digital Earth tools (i.e. Google Earth) are exploited for a mapping exercise carried out for the city of Milan by using web-based freely available very high resolution imagery. We built a geodatabase of cultivated polygons in 2014 through photointerpretation by performing a classification based on different typologies of urban agriculture. A first assessment of the phenomenon is done by reporting statistics and a spatial representation.

Keywords: urban agriculture; Google Earth, Milano, food garden, land use.
Parole chiave: agricoltura urbana; Google Earth, orti urbani, uso del suolo.

Introduction
Several studies during the last decades have highlighted the growing interest on urban agriculture (UA) and its aspects in many metropolitan areas with different facets in Global North and Global South.
Sustaining the food production within cities can contribute to urban resilience (Barthel and Isendahl 2013) and to facilitate the relationships between agriculture, urban water and recycled nutrients to address future climate changes (Lovell 2010; Moglia 2014). As urbanization and population trends keep growing, UA contributes to reduce environmental degradation and enhance biodiversity, ecosystem services, quality of life, human health and wellbeing of citizens (Lin et al. 2015).
UA responds also to different economic, social and environmental needs and is characterized by a high number of relationships with different actors. UA shows a high capacity to maintain and/or create social services and ecosystem services (García-Llorente et al. 2016) and contributes to create inclusive communities (Giarè, 2012).
The basis of many UA experiences - also in the case of farms - is the multifunctional approach to agriculture and a model of agricultural development not based on the productive intensification and industrial modernization of the primary sector, but on the recognition of new and different functions. Although UA farms are not able to feed the whole population of a city, their activity provides a broad range of products and services that enhance the ecological, social, and even economic sustainability of metropolitan areas (Henke et al. 2015).
Understanding the role of UA within the urban environment requires data on the spatial distribution and characteristics of cultivated sites. This information is a stepping stone for any research question and for defining strategies for the management of urban spaces and resources.
However, many metropolitan areas, like in Italy, lack of detailed and updated land use map that can enable to explore the existing UA geographies as well as to trace temporal changes. Detailed mapping is imperative for capturing some of UA sites, such as hobby farming usually characterize by very small parcels.
Several mapping approaches have been carried out in various metropolitan areas worldwide. For example, in the city of Philadelphia (USA) Kremer and DeLiberty (2011) used a pixel-based classification techniques in conjunction with a Geographic Information System (GIS) to estimate the available land for food production. Similarly, in the city of Dunedin (New Zealand) Mathieu et al. (2007) identified private gardens through object-oriented classification of very high-resolution images. Pulighe and Lupia (2016), successfully implemented a detailed inventory of UA in Rome (Italy) through photointerpretation of Google Earth imagery. Similarly, manual photointerpretation of Google Earth imagery was conducted by Drechsel and Dongus (2010) in Dar er Saalam (Tanzania) to detect areas with crop production larger than 1000 m^2. In addition, municipalities, non-governmental organizations and research institutes promote and realize UA geospatial inventories, sometimes with the support and partnerships of city gardeners, citizens, associations and students (Lupia, 2015).
Today, in the era of Geospatial Big Data, vast amounts of data are generated and collected from several sources that can be mined to extract knowledge about several phenomena, particularly within urban spaces. Freely available maps and imagery

DOI 10.6092/unibo/amsacta/5692

data, distributed by web mapping tools and virtual globes (i.e. Google Earth, NASA World Wind, Microsoft Bing Maps), (Goodchild et al. 2012) are opening new routes in the geospatial data production determining a paradigm shift from knowledge-driven to data-driven science (Kitchin, 2014).
In this study we present the results of mapping exercise carried out to detect and inventory cultivated polygons located within the administrative area of Milan. We exploited the very high resolution imagery (year 2014) provided by Google Earth to build a comprehensive dataset on UA where cultivated parcels are recognized and classified into five distinct typologies by integrating additional information derived from other sources. We provide statistics on the UA sites and observation about their spatial distribution within the city. We argue that UA geospatial dataset is a starting point for strategic planning and further researches on the role of UA to creating a more sustainable food system and urban land use.
The city of Milan has a long history of agricultural activities dating back to the inception of the industrial period when food gardens were the main economic subsidy for the new working class. Nowadays, UA is growing rapidly with different forms led by citizens initiatives and thanks to the support of the Municipality. The public support to UA has taken place with projects, assignments of vacant lands to citizens and regulations. These initiatives encourage alternative and sustainable urban land uses to counterbalance urbanization and soil sealing in a city where artificial areas cover more than 76% of the total surface (ISPRA, 2012).

Materials and Methods

The spatial inventory of UA in Milan was based on a photointerpretation approach centred on the use of the very high resolution imagery provided by Google Earth followed by an integration procedure with additional datasets and a final validation step. The total time spent for the entire process was about 200 hours.
Photointerpretation was carried out on 2014 images. Nevertheless, Google Earth provides archived imagery (2001-2017 for the Milan area), with adequate spatial resolution and accuracy (Pulighe et al. 2016) to identify cultivated parcels enabling for temporal updated of the datasets and change detection analysis.
The approach was based on the following phases:

1. identification of cultivated parcels through photointerpretation of Google Earth 2014 very high resolution imagery;
2. identification of the parcel within imagery of other web mapping services (i.e. Google Maps, Microsoft Bing Maps and Google Street View) in order to confirm the recognition thanks to different visual perspective (i.e. panoramic and street-level view);
3. acquisition of data and documents to be used as support for the parcel identification and attribute assignment (e.g. reports, scientific publications, cartographic datasets, etc.);
4. digitization of polygons representing the cultivated parcels with Google Earth tools;
5. assignment of attributes to each polygon (i.e. typology of UA site and agricultural land use);
6. dataset validation with in-field visits and street-level imagery from Google Street View;
7. GIS dataset post-processing and geodatabase creation.

Five types of UA sites were identified in the city (Tab. 1): residential gardens, community gardens, urban farms, institutional garden and “illegal” gardens. Each type was also classified according to the dominant agricultural land use with the following classes: horticulture, fruit trees, mixed crops, vineyards and olive trees. Fig. 1 depict an example of the five types of sites detected with the street-level view provided by Google Street View used to support both sites detection and validation phases.

Type	Description
Residential garden	Small-size parcel located nearby houses (e.g. backyard), villas, buildings, industrial and commercial activities.
Community garden	Large-size area subdivided into multiple plots managed individually (i.e. allotment) or collectively by citizens (i.e. community garden).
Urban farm	Group of parcels managed by professional farmers with an intensive and an advanced cropping system.
Institutional garden	Areas with variable size managed by institutions or organizations (e.g. schools, religious center, prisons and non-profit organizations, etc.).
“Illegal” garden	Small-size isolated parcel or larger areas subdivided in small plots, cultivated probably without authorization in public or private spaces.

Tab. 1: The five types of urban agriculture sites identified through photointerpretation.
Tab. 2: Le cinque tipologie di siti di agricoltura urbana identificati attraverso la fotointerpretazione.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

In the following we focus on polygons belonging to non-professional farming (residential, community, institutional and "illegal" gardens). The inventory of the urban farms actually underestimate the total farmed area since several uncropped areas (e.g. set-aside) cannot be distinguished from other natural areas only through photointerpretation.

Fig. 1: Street-level recognition trough Google Street View for each urban agriculture type.
Fig. 1: Riconoscimento mediante la visualizzazione a livello stradale di Google Street View per ogni tipologia di agricoltura urbana.

Results and Discussion

The mapping approach allowed to build a comprehensive inventory of non-professional agricultural activities located in the administrative area of Milan that extends for more than 18000 hectares.

As far as spatial distribution is concerned UA sited are distributed outside the city centre with a concentration in the southern and eastern borders where artificial areas have a sparse pattern (Fig. 2). This concentration is connected to the wide area of the Parco Agricolo Sud Milano that forms a half-circle around Milan. Fewer sites, mainly residential and community gardens, are found in the north side.

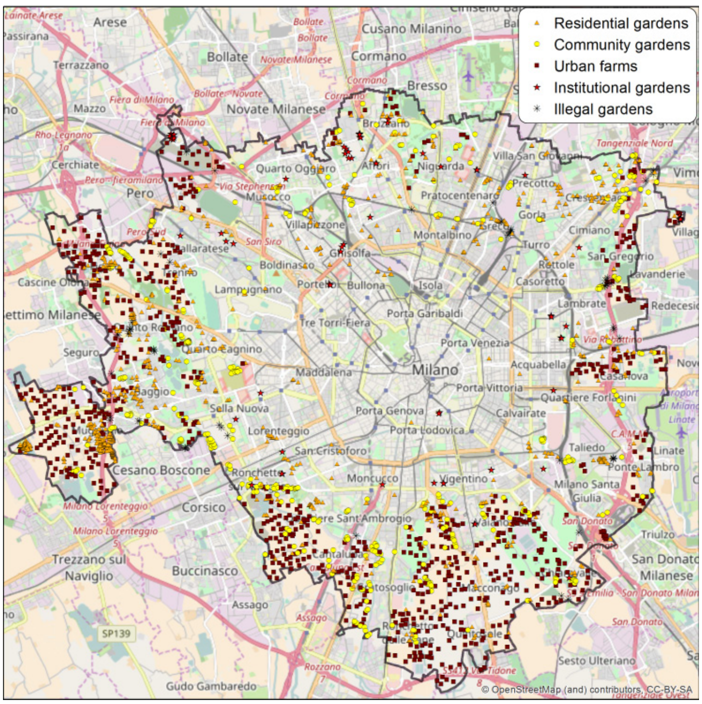


Fig. 2: Spatial distribution of urban agriculture sites classified into the five typologies inside the administrative boundary of Milan. Points represent the centroid of the polygons identified on 2014 Google Earth imagery. A single urban farm is generally made up of a set of cultivated polygons.
Fig. 2: Distribuzione spaziale dei siti di agricoltura urbana classificati nelle cinque tipologie all'interno dell'area amministrativa di Milano. Ogni punto rappresenta il centroide del poligono identificato sulle immagini Google Earth del 2014. Una singola azienda Agricola urbana è generalmente costituita da un insieme di poligoni coltivati.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

A total of 945 sites are located in the city with a total farmed area of 80 hectares. Despite the number of sites highlights an important diffusion of non-professional farming, in terms of farmed area the latter constitutes a small percentage compared to the area covered by urban farms (80 over 2730 ha, 3.4% ca.).
In terms of number of polygons, residential gardens prevail over all categories (595; 63%), followed by community gardens (272; 29 %), institutional gardens (61; 6%) and "illegal" gardens (17; 2%).
When cultivated area is considered, community gardens have the largest extension (about 57 ha ; 71%), followed by residential gardens (about 18 ha ; 23%), institutional gardens (about 4 ha.; 5%) and "illegal" gardens (0.7 ha; 1%).

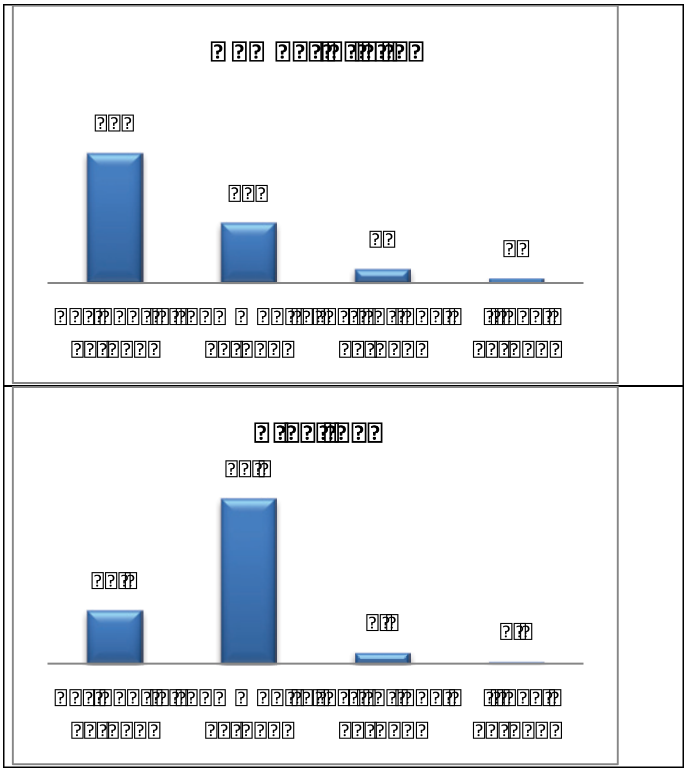


Fig. 3: Number and area covered by urban agriculture sites for each non-professional category.
Fig. 3: Numero e superficie coperta dei siti di agricoltura urbana per le categorie non professionali.

Conclusions

The growing interest around urban food production by the so-called "citizen farmers" opens new questions about sustainable urban land use and resources that can be addressed if detailed and updated geospatial datasets are available. We demonstrated that the exploitation of the rising amount of very high resolution imagery provided through web mapping services and virtual globes (e.g. Google Earth) is a viable option for building geospatial datasets on cultivated sites in urban areas. Building geospatial datasets on UA is the first step toward the definition of planning strategies. Furthermore, these datasets would allow to explore several related issues on the sustainable use of urban resources (i.e. water and soil), the interaction with peri-urban areas and the expanding artificial surfaces, the ecosystem services provided and the socio-economic impacts.

References

Barthel, S. & Isendahl, C., 2013. Urban gardens, Agriculture, And water management: Sources of resilience for long-term food security in cities. *Ecological Economics*, 86, pp.224–234. Available at: http://dx.doi.org/10.1016/j.ecolecon.2012.06.018.

Drechsel, P. & Dongus, S., 2010. Dynamics and sustainability of urban agriculture: Examples from sub-Saharan Africa. *Sustainability Science*, 5(1), pp.69–78.

García-Llorente, M. et al., 2016. Social Farming in the Promotion of Social-Ecological Sustainability in Rural and Periurban Areas. *Sustainability*, 8(12), p.1238. Available at: http://www.mdpi.com/2071-1050/8/12/1238.

Giarè F., Henke R., Vanni F., 2015. Agriculture in urban poles: an empirical analysis of farm strategies in Italy, *2nd International Conference on Agriculture in an Urbanizing Society*, Rome, 14-17 September 2015

Giarè, F., 2012. Forme e modi dell'agricoltura, *Agriregionieuropa.* Available at: https://agriregionieuropa.univpm.it/it/content/article/31/30/forme-e-modi-dellagricoltura

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

ISPRA. SINAnet – Rete del Sistema Informativo Nazionale Ambientale. Corine Land Cover 2012 IV livello. In: http://www.sinanet.isprambiente.it/it/sia-ispra/download-mais/corine-land-cover (Accessed October 5, 2015)

Kitchin, R., 2014. Big Data, new epistemologies and paradigm shifts. *Big Data & Society*, 1(1), p.205395171452848. Available at: http://journals.sagepub.com/doi/10.1177/2053951714528481 (Accessed June 1, 2017).

Kremer, P. & DeLiberty, T.L., 2011. Local food practices and growing potential: Mapping the case of Philadelphia. *Applied Geography*, 31(4), pp.1252–1261. Available at: http://www.sciencedirect.com/science/article/pii/S0143622811000087.

Goodchild, M. F., H. Guo, A. Annoni, L. Bian, K. de Bie, F. Campbell, M. Craglia, et al. 2012. Next-generation Digital Earth. *Proceedings of the National Academy of Sciences*, 109: 11088 –11094. doi:10.1073/pnas.120238310.

Lin, B.B., Philpott, S.M. & Jha, S., 2015. The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. *Basic and Applied Ecology*, 16(3), pp.189–201. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1439179115000067.

Lovell, S.T.S.T., 2010. Multifunctional Urban Agriculture for Sustainable Land Use Planning in the United States. *Sustainability*, 2(8), pp.2499–2522. Available at: http://www.mdpi.com/2071-1050/2/8/2499.

Lupia, F., 2015. *Mappatura spaziale dell'agricoltura urbana: analisi di alcune esperienze realizzate con strumenti di web-mapping*, Rome: INEA. Available at: http://dspace.crea.gov.it/bitstream/inea/1140/1/Mappatura_spaziale_Lupia.pdf.

Mathieu, R., Freeman, C. & Aryal, J., 2007. Mapping private gardens in urban areas using object-oriented techniques and very high-resolution satellite imagery. *Landscape and Urban Planning*, 81(3), pp.179–192.

Moglia, M., 2014. Urban agriculture and related water supply: Explorations and discussion. *Habitat International*, 42, pp.273–280. Available at: http://dx.doi.org/10.1016/j.habitatint.2014.01.008.

Pulighe, G., Baiocchi, V. & Lupia, F., 2016. Horizontal accuracy assessment of very high resolution Google Earth images in the city of Rome, Italy. *International Journal of Digital Earth*, 9(4), pp.342–362. Available at: https://www.tandfonline.com/doi/full/10.1080/17538947.2015.1031716.

EFFECT OF CLIMATE AND OF AGRICULTURAL PRACTICE ON THE VEGETO-PRODUCTIVE RESPONSE OF ANCIENT WHEAT VARIETIES: PRELIMINARY RESULTS

EFFETTO DEL CLIMA E DELLA TECNICA AGRONOMICA SULLA RISPOSTA VEGETO-PRODUTTIVA DI VARIETÀ ANTICHE DI FRUMENTO: RISULTATI PRELIMINARI

Marco Napoli*[1], Marco Mancini[2], Giada Brandani[1], Martina Petralli[1], Leonardo Verdi[1], Simone Orlandini[1], Anna Dalla Marta[1]

[1] Dipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente, Università di Firenze, Piazzale delle Cascine 18, 50144, Firenze
[2] Fondazione per il Clima e la Sostenibilità, Via Caproni 8, 50144, Firenze
*marco.napoli@unifi.it

Abstract
This research aims to assess the effect of climate and of the agronomic management, in particular sowing density and fertilization, on the growth and development of three ancient genotypes of winter wheat (Verna, Sieve and Andriolo) compared to the modern cultivar Bologna. Results showed that the ancient genotypes reached the flowering stage between 5 and 10 days after the modern cultivar, and required additional GDD_0 between 80 and 184. Nitrogen affected the vegetative as well as reproductive growth of all the four cultivars, resulting in more days and GDD_0 to flowering as nitrogen increased. Concerning the accumulated biomass, Verna showed a positive relation with the three nitrogen levels; Andriolo was not affected by the highest nitrogen rate, on the contrary of Bologna and Sieve. The obtained results allowed to obtain quantitative information about the vegeto-productive responses of the ancient wheat varieties so far unavailable and useful for their cultivation with modern agronomic management.

Keywords: growing degree days; sowing density; fertilization; phenology; dry biomass.
Parole chiave: sommatorie termiche; densità di semina; concimazione; fenologia; biomassa secca.

Introduction

Tuscany has a great tradition of durum and ordinary wheat cultivation but in recent years, economic constraints and negative impacts of climate change are increasingly putting at risk such agricultural productions that is not more ensuring a sufficient and stable income for the farmer. This also involves a progressive abandonment of marginal areas that are very expensive to cultivate, both because of low obtainable yields and for technical difficulties of cultivation. In this context, the reintroduction of ancient varieties of wheat adapted to the environment and the development of new cereal supply chains represent therefore a valuable opportunity for farmers. Recent studies demonstrated that some ancient varieties, such as Verna, Gentil Rosso, Frassineto, and Andriolo, have high nutraceutical value due to the presence of polyphenolic compounds in grains. Beside the cultivar itself, also the environment and the crop management strongly affect wheat productivity and the phytochemical profile of the grain (Heimler, 2010). In particular, the quantity and the quality of the final production are affected by the pedo-climatic conditions of the cultivation area and by the agronomic technique, with particular reference to the last phases of the productive cycle, related to the grain filling and ripening. Therefore, the evaluation of the productive potential of these ancient varieties cannot ignore the study of genotype-environment interactions and the identification of an agronomic technique capable of enhancing its yield and its quality. The aim of this research is to assess the effect of climate and of the agronomic technique, in particular sowing density and fertilization, on biomass accumulation and phenological dynamics of three ancient varieties of winter wheat: Verna, Sieve and Andriolo.

Materials and Methods

The field experiments were established in October 2016 under rainfed conditions at the "Giuseppe Chiarion" farm, which is located in Monteroni d'Arbia, about 20 km south-east of Siena, Tuscany, Italy (43.2007 N, 11.4182 E, 160 m asl). Egyptian clover (*Trifolium alexandrinum* L.) was the previous crop. The soil is a silty clay loam, and the 0–30-cm layer contains 11.4 g kg^{-1} total organic carbon, 1620 mg kg^{-1} total nitrogen (N), 14.2 mg kg^{-1} available phospourus (P), and 273 mg kg^{-1} potassium (K). A meteorological station was placed near experimental field and data on temperature and humidity are recorded. Four Italian varieties of common wheat (*Triticum aestivum* L.) are involved in the present study, including three "old" genotypes (Andriolo, Sieve and Verna), and one dwarf registered cultivar (Bologna). The experiment includes 24 treatments, which are the combinations of four varieties of common wheat, three N fertilization levels, i.e. 35, 85 and 135 kg N ha^{-1} (N1, N2 and N3), and two seeding rates, i.e. 90 and 180 kg ha^{-1} of seed (D1 and D2). The experimental arrangement is a split-strip-plot design, where wheat cultivars are arranged in vertical strips (main plots), N fertilization levels are allocated in the horizontal

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA. Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

ones (subplots) and seeding density is applied vertically to sub-subplots. Seeds were sown on December 19. No noticeable crop damage was observed during the growing season due to weeds, insects, or diseases.
The phenological development for each variety was recorded (BBCH scale – Biologische Bundesanstalt, Bundessortenamt and CHemical Industry) and elaborated on the basis of the growing degree days with a cutoff of 0 °C (GDD_0). At the flowering three samples of 0.25 m^2 were randomly chosen from each sub-subplot to measure plant height (PH; cm), plant and spike weight per square meter (PDW and SDW; kg m^{-2}).
Statistical comparisons of measured parameters were made with ANOVA. Thereafter, pairwise comparisons were performed using the post hoc Tukey's HSD (honest significant difference) test.

Results and Discussion
During the initial phenological stages (BBCH 9–30) no differences were detected among genotypes, that developed almost simultaneously during the tillering period. The cultivar Bologna and Andriolo were shown to be the earliest and the latest, respectively, in reaching booting (BBCH 40) and middle of the heading (BBCH 55) phases. As regards the flowering stage (BBCH 69) (Table 1) and the extent of the flowering period differences were observed among genotypes. In particular, Andriolo, Verna and Sieve showed a longer growing season than Bologna of 10, 7 and 5 d, respectively, and corresponding to about 184, 122 and 80 additional GGD_0, respectively. Moreover, all the old varieties showed an extended spike flowering period (7.7 ± 1.5 d, 8.3 ± 0.6 d and 9.3 ± 0.7 d for Verna, Andriolo and Sieve, respectively), while Bologna in 5.7 ± 0.6 d passed to the maturity stages (BBCH 71). This trend may be related to an increase of maturity rate of Bologna, due to warm and dry environmental conditions during the last part of the crop cycle which had favoured the typical earliness of the modern cultivar. Nitrogen affected the vegetative as well as reproductive growth, which resulted in more days and GDD_0 to flowering as nitrogen increased. Nitrogen treatments increased the sum of GGD_0 to reach the flowering stage by about 34 GDD_0 for Bologna and Sieve, 56 GDD_0 for Andriolo and 73 GDD_0 for Verna.

	Bologna			Andriolo			Sieve			Verna		
	N1	N2	N3	N1	N2	N3	N1	N2	N3	N1	N2	N3
GDD_0	1245	1261	1279	1421	1440	1477	1330	1330	1365	1347	1383	1421
DOY	129	131	132	140	141	143	135	135	137	136	138	140

Tab. 1: Annual dates of the flowering (expressed in days of the year, DOY) and growing degree-days with a cut-off of 0 °C (GDD_0) required to reach the full flowering for the four cultivars of common wheat and the three nitrogen levels (N1: 35 kg N ha^{-1}*, N2: 85* kg N ha^{-1} *and N3: 185* kg N ha^{-1}*).*
Tab. 1: Data di fioritura (espressa in giorno dell'anno, DOY) e gradi giorno cumulate con una soglia di 0 °C (GDD_0) necessario per raggiungere la piena fioritura per le quattro cultivar di frumento tenero e per i tre livelli di azoto adottati (N1: 35 kg N ha^{-1}*, N2: 85* kg N ha^{-1} *and N3: 185* kg N ha^{-1}*).*

Significant ($p < 0.05$) positive relationship were determined between sowing density and both PDW and SDW for Bologna (Table 2). On the contrary, PDW and SDW significantly reduced ($p < 0.05$) with the increasing plant density for the three tall varieties. PH significantly increased ($p < 0.05$) with the increasing plant density for the old varieties, while PH was not affected for Bologna. Nitrogen effect on PH was not significant on Andriolo and Bologna, while significantly ($p < 0.05$) affected Sieve and Verna. Verna showed a positive and significant relationship between N levels and both PDW and SDW. PDW and SDW in Andriolo significantly increased with the increasing N content from N1 to N2, but not furter increases were observed for N3 level. On the contrary, PDW and SDW in Bologna and Sieve were not significantly affected by the increasing N content from N1 to N2, while they significanlty increased for N3 level.

Cultivar	Nitrogen level	Sowing density level	PDW (g m^{-2})	SDW (g m^{-2})	PH (cm)
Bologna	N1	D1	627.56 ab	529.76 b	60.4 f
		D2	765 ab	586.56 ab	62.13 ef
	N2	D1	807.12 ab	659.68 ab	61.27 f
		D2	701.36 ab	519.2 b	60.13 f
	N3	D1	703.8 ab	586.24 ab	64.33 e
		D2	1148.88 a	1009.92 a	64.4 e
Andriolo	N1	D1	973.56 ab	548.96 b	113.07 ab
		D2	753.8 ab	468.48 b	102.8 abc
	N2	D1	1204.32 a	633.92 ab	115.13 a
		D2	1162.24 a	658.4 ab	112.6 ab

	N3	D1	1200.96 a	702.72 ab	117.47 a
		D2	1178.56 a	617.76 ab	110.2 ab
Sieve	N1	D1	900.72 ab	678.08 ab	93.53 abcde
		D2	648.12 ab	488.64 b	77.6 cd
	N2	D1	839.88 ab	641.6 ab	85.2 bcde
		D2	840.4 ab	563.36 b	86.53 bcde
	N3	D1	802.84 ab	638.4 ab	90.07 bcde
		D2	1210.24 a	840.48 a	106.4 ab
Verna	N1	D1	536.52 ab	397.44 b	85.8 bcde
		D2	394.44 b	304.48 b	66.33 de
	N2	D1	661.88 ab	439.2 b	88.93 bcde
		D2	719.12 ab	468.16 b	98.13 abc
	N3	D1	1189.24 a	798.4 a	113.13 a
		D2	947.48 ab	584.16 ab	105.27 ab

Tab. 2: Plant height (PH; cm), plant and spike weight per square meter (PDW and SDW; kg m^{-2}) measured at flowering. in four wheat cultivars, 'Bologna', 'Andriolo', 'Sieve' and 'Verna' grown under two sowing densities (D1: 90 kg ha^{-1} of seed and D2: 180 kg ha^{-1} of seed) and three level of nitrogen (N1: 35 kg N ha^{-1}, N2: 85 kg N ha^{-1} and N3: 185 kg N ha^{-1}). Lowercase letters indicate different means ($p < 0.05$) according to the Tukey post hoc test.

Tab. 2: Altezza della pianta (PH; cm), peso della pianta e delle spighe per metro quadro (PDW and SDW; kg m^{-2}) misurati alla fioritura per quattro cultivar di frumento tenero, 'Bologna', 'Andriolo', 'Sieve' and 'Verna' cresciute in due diverse densità di semina (D1: 90 kg ha^{-1} di seme e D2: 180 kg ha^{-1} di seme) e tre livelli di fertilizzazione azotata (N1: 35 kg N ha^{-1}, N2: 85 kg N ha^{-1} e N3: 185 kg N ha^{-1}). Le lettere minuscole indicano differenze significative ($p < 0.05$) secondo il Tukey post hoc test.

Conclusion

The research shows that among the ancient varieties, Andriolo and Verna, behave significantly different from the cultivar Bologna, while Sieve is more similar to the modern varieties. In particular, the vegetative phase of ancient wheat is about 8 days longer than modern one, which can result in an interruption of the grain filling due to the limiting environmental conditions, especially high temperature and drought typical of Mediterranean summer period.

Also for the sowing density the response of modern and ancient varieties is opposite, as the latter show a higher efficiency in biomass accumulation also with lower sowing rates. Finally, concerning nitrogen fertilization, the response of ancient varieties is very variable and not clearly explained, therefore more information is expected at harvest.

Acknowledgments

Attività in parte svolte nell'ambito del progetto misura 16.2 "GRANT", PSR 2014/2020 Regione Toscana. Si ringraziano il Consorzio Agrario di Siena, le Az. Agr. Chiarion Giuseppe e Francesco e Podere Belvedere Di Del Sere Federica, e la Fondazione Cassa di Risparmio di Firenze per il supporto fornito.

References

R. Bonhomme, 2000. Bases and limits to using 'degree day' units. Eur. J. Agron. 13: 1-10.

A. Dalla Marta, D. Grifoni, M. Mancini, G. Zipoli, S. Orlandini, 2011. The influence of climate on durum wheat quality in Tuscany, Central Italy. International Journal of Biometeorology, 55, 87-96.

F. Guasconi, A. Dalla Marta, D. Grifoni, M. Mancini, F. Orlando, S. Orlandini, 2011. Influence of climate on durum wheat production and use remote sensing and weather data to predict quality and quantity of harvest. Italian Journal of Agrometeorology – 3/2011, 21-28.

G.S. Mc Master, T.R. Green, R.H .Erskine, D. Edmunds, J.C. Ascough II, 2012. Spatial interrelationships between wheat phenology, thermal time and terrain attributes. Agron. J. 104 (4), 1110-1121.

J. R. Porter, M. Gawith, 1999. Temperatures and the growth and development of wheat: a review. Eur. J. Agron. 10: 23-36.

AGRONOMIC AND ECONOMIC EVALUATION OF TWO AGRICULTURAL SYSTEMS: CONVENTIONAL TILLAGE AND NO-TILLAGE
VALUTAZIONE AGRONOMICA ED ECONOMICA DI DUE SISTEMI AGRICOLI: LAVORAZIONE CONVENZIONALE E NON LAVORAZIONE

Vincenzo Tabaglio[1*], Paolo Caprioli[1], Roberta Boselli[1], Andrea Fiorini[1], Cristina Ganimede[1], Giovanni Lazzari[1], Dora Inés Melo Ortiz[1], Stefano Santelli[1], Romano Demaldè[2]

[1] Dipartimento di Scienze delle Produzioni Vegetali Sostenibili, Università Cattolica del Sacro Cuore di Piacenza, Via E. Parmense 84, 29122, Piacenza
[2] Istituto di Enologia e ingegneria agro-alimentare, Università Cattolica del Sacro Cuore di Piacenza, Via E. Parmense 84, 29122, Piacenza
*vincenzo.tabaglio@unicatt.it

Abstract
A field trial was carried out to compare two agricultural management systems in the Po Valley (Northern Italy): Conventional tillage (CT) vs. No-tillage (NT). The different management of the experimental field had been established since 2011. In 2014 the trial was cropped with maize and CT system was compared with NT system concerning crop yields, soil characteristics and operating costs. Experimental trial was set up as randomized complete block design with four replicates. The soil is a *fine, mixed, mesic, Udertic Haplustalf.* The software C.E.M.A. was used to determine operating costs and fuel consumption of the two agro-ecosystems. In term of net income it was observed a difference of about 100 € per hectare in favor of NT system. Regarding greenhouse gases emissions NT saved about 360 kg per hectare of CO_2.

Keywords: no-tillage, conventional tillage, crop yields, operating costs, farmers' net income, GHG emission, climate change mitigation.
Parole chiave: non lavorazione, lavorazione convenzionale, rese colturali, costi di esercizio, reddito netto aziendale, emissioni di gas serra, mitigazione del cambiamento climatico.

Introduction
Conventional tillage practices based on the plowing have several negative aspects: reduction of soil organic carbon (Schlesinger, 1985), enhancing of soil aeration and metabolic respiration of soil biota (Dungait *et al*., 2012), increasing of soil erosion (Lal, 2003), disruption of soil aggregate stability (Pagliai *et al*., 2004), and soil compaction (Hamza and Anderson, 2005). Conservation Agriculture is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment (FAO, 2012). Conservation agriculture is a sustainable approach that reduces the number of tillage, saving soil moisture, fuel, labor, and machinery costs, as well as reducing wind and water erosion (Ribera *et al*., 2004). In particular, n*o-tillage* (NT) rely on direct seeding which is performed by special seed drills, that open a narrow slot with minimal disturbance of the surface crop residue. Moreover, NT does not require additional tillage for seedbed preparation and the agronomic practices in field are limited to fertilizers and pesticides treatments and, if necessary, interventions for weeds control (Hanna, 1995). This approach is based on four basic pillars: (1) *crop rotation,* (2) *minimization of soil tillage*, (3) *permanent soil cover by crop residues (4) cover cropping* (FAO, 2012; Lal, 2015). This conservation strategy improves yield stability, enhances inputs use efficiency, increase soil quality and improves agro-ecosystems services.
The aim of this study was to evaluate crop yields, management costs, soil fertility parameters and the impact on the farm's income in a NT compared to a CT system for maize cropping.

Materials and Methods
The trial was carried out at CERZOO, the experimental farm of the Università Cattolica, near Piacenza (Northern Italy, lat. 45.006108 N; long. 9.707523 E) during 2014. The soil was a *fine, mixed, mesic, Udertic Haplustalf* (USDA, 2014). Since 2011 the experimental field has been established to compare two different tillage systems: CT and NT. The experiment was designed as a Randomized Complete Block with four replicates. Each plot has a surface of 1430 m^2. In 2014 maize was the planned crop in rotation, following wheat and a cover crop. CT plots were ploughed at 30 cm depth and then harrowed twice with a rotating harrow to provide a suitable seedbed. NT plots were direct-planted through the crop residues. Before maize planting all plots were treated with Glyphosate, at the rate of 3 L ha^{-1} to terminate the cover crop. The maize hybrid was SNH 9609, FAO 600.
CT plots were sown with a 4-row precision planter (Kuhn mod. Maxima 2) and NT plots with a no-till 4-row precision planter (Semeato mod. SPE 06). Fertilizer was top dressed twice as urea (46% N): 125 kg N ha^{-1} immediately before planting, and 85 kg N ha^{-1} at V6-V8 stage. The software C.E.M.A. (developed by the Department for Sustainable Food Process – DiSTAS of Università Cattolica del Sacro Cuore di Piacenza) was used to calculate the operating costs of agricultural practices on the basis of the used machinery. The main outputs of this software are: operating costs per hectare

and fuel consumption per hour; then, from these parameters it is possible to calculate operating costs of CT and NT systems and to calculate the net income of farmers.

Results and Discussion

OPERATING COSTS

Operating costs (€ ha^{-1})		
Operation	**CT**	**NT**
Residue chopping	39	-
Plowing (30 cm depth)	123	-
Harrowing (No. 2)	83	-
Pre-sowing weeding	36	36
Pre-sowing fertilization	25	25
Sowing	46	108
Post-emergence weeding	36	36
Irrigation (No. 2)	240	240
Fertilization + Cultivation (only CT)	42	25
Pest treatment (insecticide)	42	42
Harvesting	138	138
Total	**850**	**650**
Balance		**-200**

Tab. 1: Operating costs referred to agronomic operations, calculated by adding tractors and tools hourly operating costs (€ per hectare).
Tab. 1: Costi di esercizio delle diverse operazioni colturali, calcolati sommando il costo orario di esercizio della specifica trattrice e dell'attrezzo ad essa associato (€ ad ettaro).

Regarding the operating costs, NT system showed an economic advantage of 200 € ha^{-1} compared with CT system (Table 1), that is 23.5% cost reduction. The main reason was due to the elimination of tillage operations for the seedbed preparation. The total in Table 1 includes all operating costs excluding the agronomic inputs (seeds, fertilizers, agrochemicals), the last one being presented in Table 2. In this case, NT system was more expensive than CT (+30 € ha^{-1}). The higher costs in NT system were imputable to the treatment against slugs, which can represent one of the major pests in humid years and that could create a failure of maize emergence in NT systems (Hammond *et al*., 1999).

Agronomic inputs (€ ha^{-1})		
	CT	**NT**
Fertilizers (urea)	85	85
Pre-sowing herbicides	12	12
Seed	210	210
Bait against slugs	-	30
Post-emergence herbicides	78	78
Insecticides	70	70
Total	**455**	**485**
Balance		**+30**

Tab. 2: Costs of agronomic inputs (fertilizers, herbicides, insecticides, seeds).
Tab. 2: Costo degli input agronomici (concimi, diserbanti, insetticidi, sementi).

The reduction of operating costs in NT systems can reach up to 70% after stabilization of the biotic no-till regimen and the requirement for chemical inputs, especially herbicides, can decrease due to crop rotations and to allelopathic cover crops (Tabaglio *et al.*, 2013).

CROP YIELDS

Maize yields are shown in Table 3 both for grain and total biomass, on dry matter basis (Mg ha^{-1}). CT grain yield was only 3% higher than NT, without statistical differences. These yields are comparable with the maize average performances observed in the Po Valley environment, this is a positive aspect considering that the field in 2014 was at the third year of transition to NT system (Soane *et al.,* 2012).

Crop yields (Mg ha^{-1})		
	CT	**NT**
Grain dry yield	13.1	12.7
Total dry yield	25.2	25.0

Tab.3: Maize yields (on dry matter basis).
Tab.3: Rese colturali del mais sulla sostanza secca.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

NET INCOME

Gross saleable production, obtained multiplying yield by average market price (2014), was used to calculate net income by deducing costs. Net income generated by NT system was 100 € higher than CT one (Table 4).

Cropping system	Yield (Mg ha^{-1})	Market price (€ Mg^{-1})	Gross saleable product (€ ha^{-1})	Costs (€ ha^{-1})	Net income (€ ha^{-1})
CT	13.1	175	2,292.50	1,305.00	987.50
NT	12.7	175	2,222.50	1,135.00	1,087.50
Δ_{NT-CT}	-0.4	-	-70,00	- 170.00	**+100.00**

Tab. 4: Determination of gross saleable product and net income.
Tab. 4: Calcolo della produzione lorda vendibile e del reddito netto.

FUEL CONSUMPTION

Considering other environmental benefits, fuel consumption was calculated for each agricultural operation and, as shown in Table 5, NT system saved 136 liters of diesel fuel per hectare, which corresponds about to 360 kg ha^{-1} of CO_2 emissions (EIA, 2016).

Fuel consumption (L ha^{-1})		
Operation	**CT**	**NT**
Residue chopping	23	-
Plowing	55	-
Harrowing (n° 2)	60	-
Pre sowing weeding	13	13
Pre sowing fertilization	15	15
Sowing	13	30
Post emergence weeding	13	13
Irrigation (n° 2)	80	80
Fertilization + Cultivation (only CT)	30	15
Pest treatment (insecticide)	13	13
Harvesting	38	38
Total	**353**	**217**
Balance		**-136**

Tab. 5: Fuel consumption for agronomic intervention.
Tab. 5: Consumo di carburante per ogni operazione colturale.

SOIL FERTILITY

Some soil fertility indicators that were monitored for both tillage systems during the period 2011-2014 are shown in Table 6). A comparison between values observed at the beginning of the conversion to NT system (2011) and at the end of 2014 is presented for soil organic matter (SOM), total nitrogen (N_k), C/N ratio, and water aggregate stability (WAS).

Soil parameters (0-30 cm)			
CT	**2011**	**2014**	**Significance**
SOM (g kg^{-1})	23	21	n. s.
Total N (g kg^{-1})	1.3	1.0	n. s.
C/N	10	11	n. s.
Water aggregate stability (%)	27	36	n. s.
NT	**2011**	**2014**	**Significance**
SOM (g kg^{-1})	23	23	n. s.
Total N (g kg^{-1})	1.1	1.3	n. s.
C/N	11	10	n. s.
Water aggregate stability (%)	24 b	50 a	0.01

Tab. 6: Soil fertility parameters at the beginning of the NT conversion and at the end of the third year.
Tab. 6: Parametri di fertilità del suolo all'inizio della conversione a no-till e alla fine del terzo anno.

After three years of the comparison trial it was observed a little, statistically not significant, decrease in SOM content in CT plots, while no change was observed in NT plots. Soil N was declined in CT plots, and raised in NT ones, again without statistical significance. Furthermore, an opposite dynamic was observed for C/N ratio, but with no statistical relevance. As regarding water aggregate stability, obtained according to the Malquori-Cecconi method, in CT plots was noticed a slight

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

increase, statistically not significant. On the contrary, in NT plots, WAS was significantly doubled, from 24 to 50%, (Tukey test, $\alpha = 0.05$).

Conclusions

The objective of this study was to evaluate positive effect of adopting conservation agriculture principles in conventional agroecosystems, comparing costs and revenues of CT and NT systems on maize, and considering CO_2 emissions and soil fertility effects.

Regarding operating costs, NT system allowed a reduction of 200 € per hectare compared with CT system; while the expense for the purchase of agronomic inputs was 30 € per hectare higher in NT than CT.

Considering maize yield, net income was obtained by deducing costs from gross saleable production; in NT net income was 100 € higher than in CT, without considering the premium payment by the EU Rural Development Policy for NT adoption.

In addition, NT management has spared 360 kg ha^{-1} of CO_2 emissions and has favored the stabilization of organic matter and the improvement of nitrogen and aggregate stability in soil.

References

Dungait J.A.J., Hopkins D.W., Gregory A.S., Whitmore A.P., 2012. Soil organic matter turnover is governed by accessibility not recalcitrance. *Global Change Biology*, 18(6):1781–1796.

EIA, 2016. Carbon Dioxide Emissions Coefficients. https://www.eia.gov/tools/faqs/faq.php?id=307&t=11

FAO, 2012. What is Conservation Agriculture? www.fao.org/ag/ca/1a.html. Accessed 5 May 2017.

Hammond R. B., Beck T., Smith J. A., Amos R., Barker J., Moore R., Siegrist H., Slates D., Ward B., 1999. Slugs in Conservation Tillage corn and soybeans in the Eastern Corn Belt. *Journal of Entomological Science*, 34: 467-478.

Hamza, M.A., Anderson, W.K., 2005. Soil compaction in cropping systems. A review of the nature, causes and possible solutions. *Soil & Tillage Research*, 82:121–145.

Hanna, M. 1995. Conservation tillage and no tillage. Publ. AE-3052. Coop. Ext. Serv., Iowa State Univ., Ames.

Lal R., 2003. Soil erosion and the global carbon budget. *Environment International*, 29:437–450.

Lal R., 2015. Sequestering carbon and increasing productivity by conservation agriculture. *Journal of Soil Water Conservation*, 70(3): 55A-62.

Pagliai M., La Marca M., Lucamante G., Genovese L., 1984. Effects of zero and conventional tillage on the length and irregularity of elongated pores in a clay loam soil under viticulture. *Soil & Tillage Research*, 4:433–444.

Ribera L.A., Hons F.M., Richardson J.W., 2004. Tillage and cropping systems. An Economic Comparison between Conventional and No-Tillage Farming Systems in Burleson County, Texas. *Agronomy Journal*, 96:415-424.

Schlesinger W.H., 1985. Changes in soil carbon storage and associated properties with disturbance and recovery. *In*: Trabalha J.R., Reichle D.E. (Eds.), *The Changing Carbon Cycle. A Global Analysis.* Springer-Verlag, New York, 194-220.

Soane B.D., Ball B.C., Arvidsson J., Basch G., Moreno F., Roger Estrade J., 2012. No-till in northern, western and south-western Europe: A review of problems and opportunities for crop production and the environment. *Soil and Tillage Research*, 118:66-87.

Tabaglio V., Marocco A., Schulz M., 2013. Rye Allelopathic Cover Crop for Integrated Weed Control in Sustainable Agroecosystems. *Italian Journal of Agronomy* 8(1):35-40.

USDA - United States Department of Agriculture, 2014. Keys to Soil Taxonomy, Twelfth edition.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA. Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

N_2O EMISSIONS SAVING BY THE REDUCTION OF N-FERTILIZATION IN DURUM WHEAT IN TUSCANY: A SPATIALLY EXPLICIT ASSESSMENT BASED ON DNDC MODEL

MITIGAZIONE DELLE EMISSIONI DI N_2O ATTRAVERSO LA RIDUZIONE DELLA CONCIMAZIONE AZOTATA IN FRUMENTO DURO IN TOSCANA: VALUTAZIONE A SCALA TERRITORIALE BASATA SUL MODELLO DNDC

Giorgio Ragaglini*, Ricardo Villani, Federico Triana, Iride Volpi, Nicoletta Nassi o Di Nasso, Enrico Bonari, Simona Bosco

Institute of Life Sciences, Scuola Superiore Sant'Anna, Pisa
*Giorgio.ragaglini@santannapisa.it

Abstract
In this study, conducted in Tuscany region (Central Italy), site and regional DNDC models were used for simulating the potential effect on N_2O emissions in durum wheat cultivation caused by the shift from conventional to low nitrogen fertilization rates (from 170 to 110 kg N ha^{-1} $year^{-1}$). In particular, the site model was used for defining the parameter sets for running the model and for crop parameter calibrations, while the regional module allowed to estimate emissions at wider scale, for the portions of the study area under durum wheat cultivation, using a regional climate and soil database.
Since the magnitude of N_2O flux is strongly influenced by the amount and the distribution of rainfall, three climatic scenarios were built based on the level of annual rain considering: a) a dry year, b) a wet year, and c) a year with an average precipitation level. Climate scenarios were selected out of a 25-year continuous time-series database of climatic parameters with daily values available for 98 weather stations of the regional agrometeorological network of Tuscany Region.
In the year with the average precipitation level, the regional average of N_2O emission reduction was -0.62 kg N ha yr^{-1} when shifting from conventional to low nitrogen fertilization. This represents -41% N_2O emission saving, for a total reduction of -70,960 kg N $year^{-1}$. These values vary from -26% to -45% N_2O emission saving as the climatic scenarios vary from dry to wet years.
The results highlighted that spatially explicit modelling of the effects on N_2O emissions of a single mitigation strategy, may provide helpful insights for decision making at district and regional scale to mitigate emissions from agriculture.

Keywords: nitrogen; nitrous oxide; GHG soil fluxes; GIS; geostatistics.
Parole chiave: Azoto; protossido d'azoto; flussi di gas serra dal suolo; GIS; geostatistica.

Introduction
Agricultural soils emit approximately 10.3–12.8 Tg N_2O-N $year^{-1}$ globally, a harmful greenhouse gas (GHG) and ozone depleting gas (Butterbach-Bahl et al., 2013). According to estimates, N_2O emissions from agriculture represent about 70% of total emissions of this gas in Italy: some of this comes from manure (20%), but 80% comes from agricultural soils (ISPRA, 2016).
Agricultural practices have been previously reported to influence N_2O emissions from soil, thus the challenge is to identify management practices for N_2O mitigation (Snyder et al., 2014).
The evaluation of best management practices is necessary in order to contribute to a widespread adoption of mitigation strategies and to provide to policy makers information at territorial scale concerning the effects of possible and reliable alternatives.
In particular, an improved efficiency in the use of N by crops was often reported to be an effective strategy to mitigate N_2O emissions, since increased N fertilizer rates may increase N_2O emissions (Shcherbak et al., 2014) without impacting the yield. However, the mitigation potential of agricultural management practices is difficult to assess due to the huge background variability in time and space of the N_2O flux and its close dependence to meteorological conditions (e.g. air temperature, rainfall amount and distribution) and soil conditions (e.g. soil temperature, soil water content, oxygen availability) (Skiba and Smith, 2000). Combining direct measurements of N_2O emissions from soil with process-based spatially explicit models can allow the analysis of alternative scenarios of crop cultivation and provide helpful insights for decision making at district level. In such manner, a regional simulation can provide further support in the decision of the management practice to be prioritized for a specific crop.
Among existing GHGs simulation models, the DNDC (Denitrification–Decomposition) (Li et al, 1992) process-based model, has been developed for simulating N_2O fluxes from soil under variable conditions. This model can predict C and N

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

biogeochemistry in agroecosystems at site and regional scales. Four major ecological drivers, namely climate, soil physical properties, vegetation, and anthropogenic activities, drive the entire model (Li et al, 1992).
DNDC has been independently tested worldwide in a wide range of researches carried out during the past decades on several different ecosystems and climate (Smith et al., 1997; Cai et al., 2003; Beheydt et al., 2007; Hastings et al., 2010).
This paper reports the results of a study conducted within the LIFE+ “Improved flux Prototypes for N_2O emission reduction from Agriculture” (IPNOA) project in Tuscany region, central Italy. Direct measurements of soil N_2O emissions from durum wheat under two different N fertilizer rates were used to calibrate the model with field data, and then to up-scale results at regional level. The study was focused on durum wheat, being the most spread crop in the study area, covering 21.4% of the total arable land (ISTAT, 2010).
The aim was to contribute to a possible improvement of the regional GHGs inventory in Tuscany to a Tier 3 approach on durum wheat, modelling a business as usual scenario and a mitigation scenario over tree different climate conditions, concerning two N fertilizer rates.

Materials and Methods

Site-specific model calibration

The calibration of DNDC at field scale was required to define the parameters set for running the model and calibrate specific crop parameters. In this study the DNDC model was firstly calibrated at field scale with data on measured N_2O emissions and grain yield, provided in Bosco et al. (2015), and referred to the 2013-2014 growing season of durum wheat cultivated in the tuscan coastal plains, specifically in San Piero a Grado, Pisa (43° 40’ N, 10° 19’ E and 1 m a.s.l.). In this experiment, measurements were carried out on durum wheat under two tillage intensities and three fertilization rates. N_2O fluxes were monitored twice a month, with samplings intensified immediately after nitrogen fertilization events, when measurements were carried out twice a week for two/three consecutive weeks, giving a total of 29 sampling days per year. The monitoring of N_2O emissions was carried out with the closed dynamic chamber (flow-through non-steady state) method, using a portable instrument developed within the LIFE+IPNOA project and described in Laville et al (2015). The standard set of non-site specific parameters in DNDC were left unchanged while site specific parameterization included specifying the field capacity and wilting point, soil texture, bulk density and total soil C content.

Model running at territorial scale

When the DNDC is used for regional estimates, the model needs spatially and temporally differentiated input data stored in geographical information system type database. Therefore, a georeferenced database containing climate (agrometeorological network of Tuscany Region), land use (Corine Land-Cover 2012), soil texture and soil organic matter content data (1:250.000 soil database of Tuscany Region – LaMMA Consortium) was developed by integrating ArcGIS 10.2 and PostgreSQL software.
Outputs from the model simulations are daily variation of soil temperature, moisture and concentrations of total soil organic carbon, nitrate, nitrite, ammonium, ammonia as well as daily fluxes of trace gases (N_2O, CH4 and CO_2). We focused on simulations of N_2O emissions from durum wheat cultivation under two different N fertilization levels, considering spatial variability of climate and soil conditions in Tuscany.
Simulations were performed with a high spatial resolution (100 x100 m) by using regional land use, climate and soil databases on a set of 6 scenarios given by the combination of three annual precipitation patterns per two N fertilization levels: 170 kg N ha^{-1} (SC1) 110 kg N ha^{-1} (SC2). Climate data from a 25-year continuous time-series database (years 1990-2014) containing daily values of climatic parameters were analysed in order to identify representative annual precipitation patterns of: *i)* a DRY year (2007), *ii)* a WET year (2014), and *iii)* a year with an average (AVG) precipitation level (1999). The DNDC model was run for each weather station considering the six scenarios and 23 soil classes derived from the regional soil geodatabase considering clay fraction and soil organic matter content. Overall, 138 simulations were obtained and then elaborated through geostatistical interpolation using the ordinary kriging model. Kriging contour maps were merged according to their spatial match to specific areas covered by the corresponding soil type. In this way for each scenario, maps of grain yield and N_2O annual emissions were obtained taking into account both climate spatial variability and the spatial patterns of the soil properties (Fig. 1).
Finally, obtained maps allowed to estimate the N_2O emission saving potentially derived by shifting from SC1 to SC2 under each of the three precipitation patterns considered.

DOI 10.6092/unibo/amsacta/5692

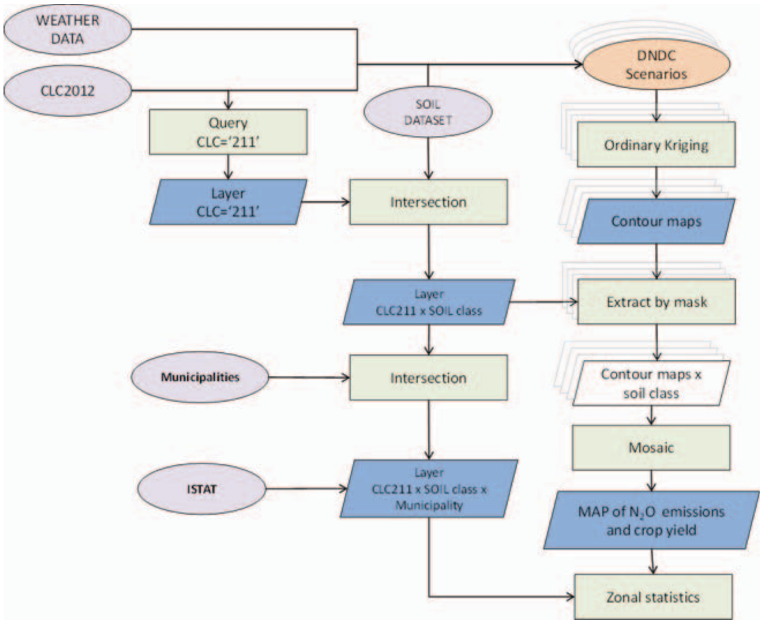


Fig. 1: Scheme of the process based on DNDC model for the spatial simulation of N_2O soil emission.
Fig. 1: Schema del processo basato sul modello DNDC per la simulazione a scala territoriale delle emissioni di N_2O dal suolo.

Results and Discussion

Regional simulations allowed to take into account the complex relationships between soil spatial variability, distribution of rain and annual precipitation volume in arable land suited to durum wheat cultivation in Tuscany. The different climate patterns determined an important effect on N_2O emissions and thus on potential saving, deriving from the reduction of N fertilization. On regional basis, the shifting from SC1 to SC2 showed the highest N_2O emissions saving in the WET year (-111,980 kg N year^{-1}, -45%), while in the DRY year, it showed the lowest mitigation potential (-27,500 kg N year^{-1}, -26%). In the AVG year (Fig. 2) the estimated N_2O emission saving at regional level equaled to -41% (-70,962 kg N year^{-1})

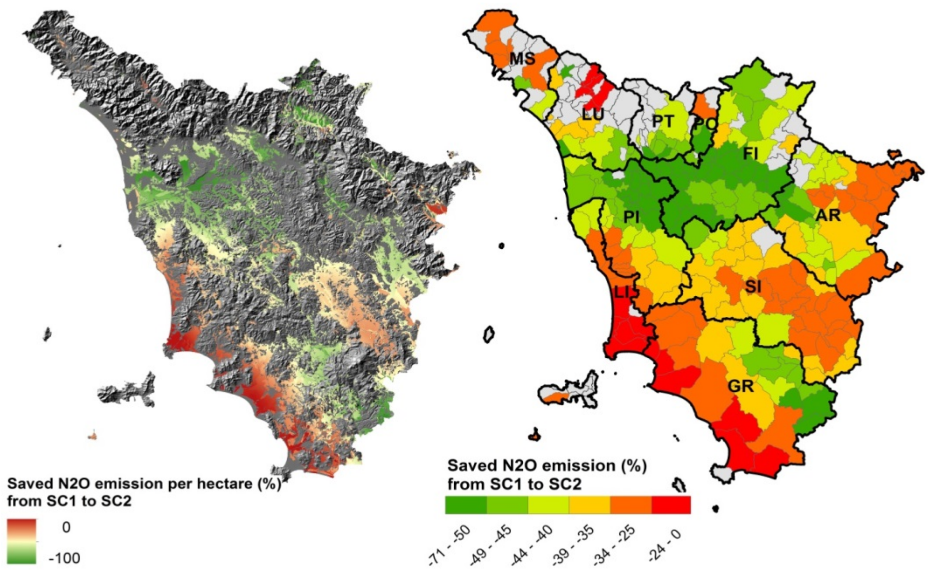


Fig. 2: Maps of annual N_2O emissions saving by reducing N-fertilization rate, from SC1 (170 kg N ha^{-1}) to SC2 (110 kg N ha^{-1}), in durum wheat in the average rainfall scenario (AVG).
Fig. 3: Mappe della diminuzione annuale delle emissioni di N_2O attraverso la riduzione della concimazione azotata, da SC1 (170 kg N ha^{-1}) a SC2 (110 kg N ha^{-1}), in frumento duro nello scenario con piovosità annuale media (AVG).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Fig. 2 allows to observe the spatial variability of N_2O emissions saving per hectare and at municipality level. In the latter case, we estimated variation of the potential emission saving from 0%, mainly southern coastal areas, to -70% in the inland alluvial plains. At regional level the mitigation potential of N_2O soil emissions, which may derive by the reduction of N fertilization levels in durum wheat, ranges between -52,000 t CO_2 eq year^{-1} (WET) and -13,000 t CO_2 eq year^{-1} (DRY). Besides the results, that emphasized the potential impact of mitigation strategies over a large scale, the used methodology could be implemented in order to identify priorities and to define district-specific mitigation strategies.

Acknowledgments

This research was carried out with the contribution of the LIFE financial Instrument of the European Union, within the framework of the project LIFE+ IPNOA "Improved flux Prototypes for N_2O emission from Agriculture" (LIFE/11/ENV/IT/302, www.ipnoa.eu).

References

S. Bosco, I. Volpi, N. Nassi o Di Nasso, F. Triana, N. Roncucci, C. Tozzini, R. Villani, P. Laville, S. Neri, F. Mattei, G. Virgili, S. Nuvoli, L. Fabbrini, E. Bonari, 2015. LIFE+IPNOA mobile prototype for the monitoring of soil N_2O emissions from arable crops: first-year results on durum wheat. Ital J Agron 10:669.

K. Butterbach-Bahl, E.M. Baggs, M. Dannenmann, R. Kiese, S. Zechmeister-Boltenstern, 2013. Nitrous oxide emissions from soils: how well do we understand the processes and their controls? Philos. Trans. R. Soc. Lond. B. Biol. Sci. 368, 20130122.

Consorzio LaMMA (2002), progetto “Carta dei Suoli della Toscana a scala 1:250.000”.

IRSE, 2010. Inventario delle Sorgenti di Emissione della Regione Toscana.

ISPRA, 2016. A., Gonella, E. Taurino, M. Vitullo, 2016. Italian Greenhouse Gas Inventory 1990 - 2014. National Inventory Report 2016, ISPRA – Istituto Superiore per la Protezione e la Ricerca Ambientale, Institute for Environmental Protection and Research.

P. Laville, S. Neri, D. Continanza, L.F. Vero, S. Bosco, G. Virgili, 2015. Cross-Validation of a Mobile N_2O Flux Prototype (IPNOA) Using Micrometeorological and Chamber Methods. Journal of Energy and Power Engineering. 9:375–385.

C. Li, S. Frolking, T.A. Frolking, 1992. A model of nitrous oxide evolution from soil driven by rainfall events: I. model structure and sensitivity, Journal of Geophysical Research, 97: D9 pp 9759-9776.

I. Shcherbaka, N. Millara, G.P. Robertson, 2014. Global meta analysis of the nonlinear response of soil nitrous oxide (N_2O) emissions to fertilizer nitrogen. Proceedings of the National Academy of Sciences of the United States of America, 111 (25) pp 9199-9204.

U. Skiba and K.A. Smith, 2000. The control of nitrous oxide emissions from agricultural and natural soils. Chemosph. - Glob. Chang. Sci. 2, 379–386.

C.S. Snyder, E.A. Davidson, P. Smith, R.T. Venterea, 2014. Agriculture: Sustainable crop and animal production to help mitigate nitrous oxide emissions. Curr. Opin. Environ. Sustain. 9–10, 46–54.

C. Van Kessel, R. Venterea, J. Six, M.A. Adviento-Borbe, B. Linquist, K. J. Van Groenigen, 2013. Climate, duration, and N placement determine N_2O emissions in reduced tillage systems: A meta-analysis. Global Change Biology, 19 (1) pp 33-44.

THE LIFE CYCLE ASSESSMENT OF DURUM WHEAT YIELD IN CONTRASTING MAGAGEMENT SYSTEMS IN MEDITERRANEAN ENVIRONMENT

IL LIFE CYCLE ASSESSMENT DELLA PRODUZIONE DI FRUMENTO IN DIVERSI SISTEMI GESTIONALI IN AMBIENTE MEDITERRANEO

Sergio Saia[1], Giulio Mario Cappelletti[2], Carlo Russo[2], Giuseppe Martino Nicoletti[2], Michele Carlo Lostorto[1], Pasquale De Vita[*1],

[1] Council for Agricultural Research and Economics, Cereal and Industrial Crops Research Centre (CREA-CI), SS 673 km 25+200, 71122 Foggia, Italy
[2] Department of Economics, University of Foggia, via R. Caggese, 1, 71121 Foggia, Italy
*pasquale.devita@crea.gov.it

Abstract

The ecological impact of durum wheat-based cropping systems in semiarid Mediterranean environments is scarcely studied. In particular, few information is available on the impact at a cropping system level. In this work, we performed a Life Cycle Assessment (LCA) of 5 contrasting scenarios (conventional, organic, high quality, reduced inputs of active ingredients and no tillage) at various degree of intensity of production of durum wheat in southern Italy. As expected, organic system showed the lowest environmental impact, which appeared to be negative (i.e. benefit for the environment) in most of the indicators under study. Application of active ingredients and mineral fertilizers mostly affected the ecological indicators and, in general, the higher their amount, the higher the overall impact of the systems, irrespective of its grain yield. In such condition, reduction of application of active ingredients also reduced impact, and this mostly occurred when other agronomical practices sustained crop yield.

Keywords: environmental impact, environmental indicators, impact for yield tradeoff, durum wheat, pollution.
Parole chiave: impatto ambientale, indicatori ambientali, rapporto impatto-resa, frumento duro, inquinamento.

Introduction

Wheat-based cropping systems in Mediterranean environments have low grain yield and quality stability, and can be subjected to a range of agronomical practices varying for potential impact to the environment. This can results in contrasting trade-offs between yield and ecological impact. However, the information about the role of key management practices on ecological impact per unit area or yield are scarce and this hinder the agronomic and policy intervention at regional level to achieve maximum yield with lowest acceptable impact. Ecological impact of human practices in agriculture can be computed at different levels of organization (field, farm, district, region, etc.) and accounting for various source of pollution and scaling (Brentrup et al., 2004a). Here, we estimated the ecological impact of durum wheat per unit area and unit yield by a life cycle assessment (LCA) at the field level under five contrasting scenarios in southern Italy.

Materials and Methods

The experiment was carried out at CREA-CI (41'28°N, 15'32°E and 75 m a.s.l) during 3 growing seasons (2010-11 to 2012-13). Five durum-wheat cropping systems (replicated twice) were compared. All plots were harvested with the same farm combine in late June and grain samples analized for grain protein content (micro-Kjeldahl method). Crop residues from the previous crop were removed in all systems. The systems studied were: **1) Conventional cropping system (CONV).** CONV received moldboard ploughing and secondary tillage during late summer-early fall. Seed was distributed with a mechanical seed drill with 17-cm inter-row spacing. The crop received 68 kg N ha^{-1} as NH_4NO_3 at the end of tillering and 10 kg ha^{-1} of a foliar fertiliser (20%N, 20% P_2O_5, 20% K_2O, 100 ppm B, 1000 ppm Mn, and 100 ppm Zn) and a strobilurin fungicide at first awns visible. Weeds were controlled by means of herbicides. **2) No-tillage cropping system (NT)**. Crop was sown with a direct seed drill. Weeds were controlled with glyphosate before planting. Pathogens and weed controls during crop cycle were as in CONV. Fertilization consisted of 200 kg ha^{-1} of diammonium phosphate before sowing; 51 kg N ha^{-1} as NH_4NO_3 at top-dressing; and 10 kg ha^{-1} of a foliar fertiliser (see CONV). **3) Organic cropping system (ORG)**. The recommendations and rules of the Italian ministry of Agriculture and Reg. EC N. 834/2007, Reg. EC N. 889/2008, Reg. EU N. 271/2010, Italian D.M. 8 Febbraio 2010 were applied. Soil management and sowing were performed as in CONV. Fertilization consisted of an organic fertilizer (6% N, 15 % P_2O_5, 2% MgO, 10% CaO, 32% organic C) allowed in organic farming under the Italian laws, applied at a rate of 600 kg ha^{-1}. A liquid fertilizer derived from cow's blood was also applied at the beginning of stem elongation according to the rates suggested by the manufacturer. **4) High quality cultivation protocol** (HQ). This system was conducted in agreement of an agreement with pasta industry on the sale price and obligation to provide minimum pre-determined gran quality. Weed control was made according to the agreement (undisclosed) including fertilisers, herbicides and fungicides. Soil management and sowing were performed as in CONV. In total, 195 kg N ha^{-1} and 34 kg P_2O_5 ha^{-1} were given at Stage 29, 31, and 49 of the Zadoks scale. Rate of application of other elements were made as in CONV. **5) Highly homogenous plant spatial distribution (by means of a reduced row distance, RRD)**, achieved with a new seed drill prototype for farm use (SEMINBIO project, RM2013A000332 and/or 202015000006429 see De Vita et al 2017 for further information). Previous experiments suggested that the reduction of row distance increases the crop competitive ability against weed. Soil management was performed as in CONV, except for the harrowing in pre-sowing which was avoided. Fertiliser was applied as 200 kg ha^{-1} of Entec 25+15 before sowing and 68 kg N ha^{-1} as NH_4NO_3 at the end of tillering. Chemical control of pathogen and weeds was performed as in CONV. All field operations in each system were performed with commercial devices, except for RRD sowing. Seed rate was 220 kg seed ha^{-1}. Cv. Aureo was used in HQ cultivation protocol (as specified in the agreement), and Cv. Saragolla in the other systems.The LCA took into account all the phases of the life cycle of the product, from raw materials through production, use and waste management (Brentrup et al., 2004a; Charles et al., 2006). LCA was performed with LCA software GaBi (IKP and PE, 1992) according to the ISO 14040:2006 and ISO 14044:2006 standards. Here we computed the total potential and partial impacts basing on either the unit area or unit yield and referred to the production of the raw grain, without taking into account any post-harvest grain cleaning, milling, transportation and transformation. Various categories of impact were chosen according to the Product Environmental Footprint (PEF) Guide (EC 2016) and analized via a Life Cycle Impact Assessment (LCIA). The LCIA pollution categories took into account were: Acidification midpoint (m.p); Climate change m.p., incl. biogenic carbon; Ecotoxicity freshwater m.p.; Eutrophication freshwater m.p.; Eutrophication marine m.p.; Eutrophication terrestrial m.p.; Human toxicity m.p.: cancer effects; Human toxicity m.p.: non-cancer effects; Ionizing radiation m.p.: human health; Land use: Soil Organic Matter; Ozone depletion m.p.; Particulate matter/Respiratory inorganics m.p.; Photochemical ozone formation m.p.: human health; Resource depletion: water m.p.; Resource depletion: mineral fossils and renewables m.p.. Data of averal impact were presented as data pooled from LCIA.

Results and Discussion

The ecological impact of a crop depends on both its managements and environment of cultivation, both of which modulate the impact of the single management practices and their interaction. When evaluating such an impact, the footprint should thus be scaled both per unit area and unit yield, which are related to different functional units: the landscape and the production pollution potentials, respectively. Charles et al. (2006) also suggested that grain quality should be taken into account in this evaluation, since market need of minimum quality could discard grain batches from human consumption, thus indirectly increasing the overall impact of a crop. In the present work, grain yield strongly varied among systems (Table 1): ORG yielded less than 4 t grain ha^{-1}, whereas other relatively more intensive systems yielded more than 5 t grain ha^{-1}. In addition, grain from ORG also showed very low grain protein concentration (< 120 g kg^{-1}, which is a minimum threshold for high quality pasta production). This was likely due the low N amount and availability from fertiliser in this system if compared to other systems (Saia et al., 2014, 2015).

Tab. 1: Mean yield, grain protein concentration and test weight of the five scenarios.
Tab. 1: Resa in granella (grain yield), concentrazione proteica (grain protein concentration) e peso ettolitrico (test weight) dei cinque scenari valutati.

Scenario	Grain yield	Grain protein concentration	Test weight
	t ha^{-1}	*g kg^{-1}*	*kg hl^{-1}*
CONV	5.11	129.7	84.67
NT	5.22	135.7	84.17
HQ	4.37	152.7	83.67
RRD	5.34	133.0	83.73
ORG	3.60	110.0	80.00

As expected, HQ showed the highest grain quality. In such system, agronomical management is tightly linked to the obtainment of a high quality grain (at least in term of protein concentration and micotoxin residues) for production of high quality pasta, and payment of the grain by the industry depends on grain quality. This mostly occurred due to the use of a mean-to-low yielding, high N accumulating genotype (De Vita et al., 2007). The other systems (CONV, NT and RRD) implying a high yielding Cv. gave similar yields and grain protein concentration. This also occurred in the NT system. In the present experiment, NT was established in previously ploughed plots in all the three growing seasons when grain yield limitation are most likely to occur (Amato et al., 2013; Colecchia et al., 2015). This occurred especially if considering that rainfall were high and well distributed and spring temperatures low during all the three growing seasons, which condition is not conducive to relatively yield in this systems if comparing to ploughed systems (Amato et al., 2013). The environmental footprint of CONV was high when computed for either unit area or grain. This mostly depended on a high risk for eutrophication (data not shown), which was high in all systems exception for ORG. The environmental footprint of ORG was negative (i.e. benefit for the environment) whereas those of the other systems were positive as per both unit area and grain. This result depended on lower values of almost all indicators in ORG than the others when computing indicators per unit area. However, when computing the indicators' value per unit grain, 'Acidification m.p.', 'Particulate matter/Respiratory inorganics m.p.', and

DOI 10.6092/unibo/amsacta/5692

'Photochemical ozone formation m.p.: human health' appeared higher in ORG than others (data not shown). Pooling data of ecological indicators was also applied by Brentrup et al. (2004b), who, in contrast to the present results, found that higher fertilization rates (and thus degree of intensity of the system) reduced the impact per unit yield of many indicators, consisting in an overall impact reduction compared to the non-fertilized treatment. Differences between our experiment and that by Brentrup et al. (2004b) likely depended on the strong ecological difference between the areas under study (UK and Italy, respectively) and need, in its area, to control weeds and pathogens irrespective of the yield potential. Similarly to our experiment, Charles et al. (2006) found few difference in any indicator value among various fertilizer types given at standard amounts, with the exception to those indicators related to acidification and terrestrial and human toxicity. Interestingly, RDD, which allow for a reduced use of pesticides while sustaining high grain yield potential (De Vita et al., 2017), showed an environmental footprint lower than NT. This depended on lower footprints for the environmental releases and higher footprints for natural resource depletion, especially for soil organic matter, the latter of which was likely due to the effect of plowing on soil organic carbon accumulation.

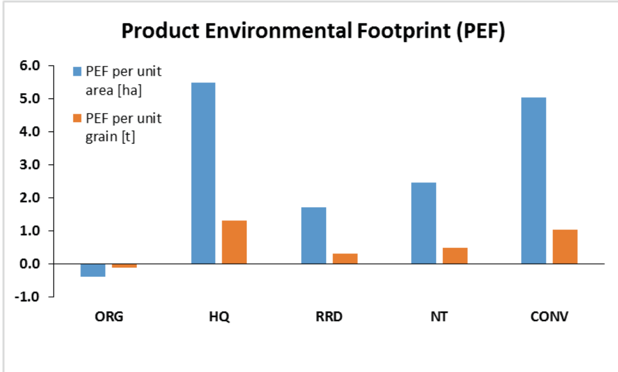


Fig. 1: Product Environmental Footprint per unit area or grain yield as unweighted algebraic sum of ecological indicators in the Life Cycle Impact Assessment (LCIA).
Fig. 1: Footprint ambientale a scala di prodotto per unità di superficie coltivata o granella ottenuta espresso come somma algebrica non pesata degli indicatori ecologici nel Life Cycle Impact Assessment (LCIA),

Conclusions

The LCA depicted how intensity of cropping system affect the outcome of various ecological indicators. As expected, ORG gave the lowest impact and this was due to low values in almost all indicators, with the exception for 'Climate change m.p., including biogenic carbon', which was similar among scenarios. This latter result likely depended on the high energetic cost for production/extraction of some organic fertilizers and their transportation and spreading, which inflates the environmental impact of fertilization for organic systems. However, quality in term of protein concentration of organic grain was very low, calling for a debate on quality per impact tradeoff, especially in considering that low quality can consist in a limited access to the high value market and further repositioning of the grain to non-food or even non-organic markets, where lower impact products could be available. Application of active ingredients and mineral fertilizers mostly affected the ecological indicators and, in general, the higher their amount, the higher the overall impact of the systems, irrespective of its grain yield.

Acknowledgements

This research was supported by the MIUR projects PON01_01145 ISCOCEM "Sviluppo tecnologico e innovazione per la sostenibilità e competitività della cerealicoltura meridionale".

References

Amato, G., P. Ruisi, A.S.A.S. Frenda, G. Di Miceli, S. Saia, A. Plaia, and D. Giambalvo. 2013. Long-Term Tillage and Crop Sequence Effects on Wheat Grain Yield and Quality. Agron. J. 105(5): 1317.

Brentrup, F., J. Küsters, H. Kuhlmann, and J. Lammel. 2004a. Environmental impact assessment of agricultural production systems using the life cycle assessment methodology. Eur. J. Agron. 20(3): 247–264.

Brentrup, F., J. Küsters, J. Lammel, P. Barraclough, and H. Kuhlmann. 2004b. Environmental impact assessment of agricultural production systems using the life cycle assessment (LCA) methodology II. The application to N fertilizer use in winter wheat production systems. Eur. J. Agron. 20(3): 265–279.

Charles, R., O. Jolliet, G. Gaillard, and D. Pellet. 2006. Environmental analysis of intensity level in wheat crop production using life cycle assessment. Agric. Ecosyst. Environ. 113(1–4): 216–225.

Colecchia, S.A.A., P. De Vita, M. Rinaldi, P. De Vita, and M. Rinaldi. 2015. Effects of tillage systems in durum wheat under rainfed Mediterranean conditions. Cereal Res. Commun. 43(4): 704–716.

European Commission. 2013. Organisation Environmental Footprint Guide.

IKP, and PE. 1992. GaBi 4-Software-system and databases for life cycle engineering. Stuttgart Echterdingen, Ger.

Olsen, J., L. Kristensen, J. Weiner, and H.W. Griepentrog. 2005. Increased density and spatial uniformity increase weed suppression by spring wheat. Weed Res. 45(4): 316–321.

Saia, S., E. Benítez, J.M. García-Garrido, L. Settanni, G. Amato, and D. Giambalvo. 2014. The effect of arbuscular mycorrhizal fungi on total plant nitrogen uptake and nitrogen recovery from soil organic material. J. Agric. Sci. 152(3): 370–378.

Saia, S., V. Rappa, P. Ruisi, M.R. Abenavoli, F. Sunseri, D. Giambalvo, A.S. Frenda, and F. Martinellli. 2015. Soil inoculation with symbiotic microorganisms promotes plant growth and nutrient transporter genes expression in durum wheat. Front. Plant Sci. 6: 815.

De Vita, P., S.A. Colecchia, I. Pecorella, and S. Saia. 2017. Reduced inter-row distance improves yield and competition against weeds in a semi-dwarf durum wheat variety. Eur. J. Agron. 85: 69–77.

De Vita, P., O. Li Destri Nicosia, F. Nigro, C. Platani, C. Riefolo, N. Di Fonzo, and L. Cattivelli. 2007. Breeding progress in morpho-physiological, agronomical and qualitative traits of durum wheat cultivars released in Italy during the 20th century. Eur. J. Agron. 26(1): 39–53.

EVALUATION OF GRASS SPECIES FOR ASSISTED PHYTOREMEDIATION OF INDUSTRIAL SOILS AND SOIL WASHING SLUDGES

VALUTAZIONE DI SPECIE PRATENSI PER LA FITORIMEDIAZIONE ASSISTITA DI SUOLI INDUSTRIALI E FANGHI DA SOIL WASHING

Donato Visconti[1*], Nunzio Fiorentino[1], Vincenzo Cenvinzo[1], Armando De Rosa[1], Eugenio Cozzolino[2], Paola Adamo[1], Antonio Caporale[1], Sheridan Woo[1], Massimo Fagnano[1]

[1] Dipartimento di Agraria, Università degli Studi di Napoli Federico II, Via Università 100, 80055, Portici (Na)
[2] Consiglio per la Ricerca in Agricoltura - Unità di Ricerca per la Frutticoltura, Via Torrino 2, 81100, Caserta
*donato.visconti@unina.it

Abstract
In this work the effects of organic ammendment and two commercial biopromoters have been evaluated on growth, EPTs phytoextraction/phytostabilization of a grass commercial mix (*Festuca arundinacea, Poa pratensis and Lolium perenne*). The plants resulted well adapted to the contamination of soils and sludges showing a good growth during the year of experimentation even if there were three harvests. The application of compost and biopromoters, especially the commercial consortium Panoramix, increased the growth of plants and the complete coverage of the soil avoiding the dispersion of contaminated soil particles, thus allowing the securing of a contaminated site.

Keywords: phytoremediation; compost; biopromoters; grass; phytostabilization.
Parole chiave: fitorimedio; compost; biopromotori; prato; fitostabilizzazione.

Introduction

Potential Toxic Elements (PTEs) contamination is one of the most serious environmental problems threatening human's health and ecosystems functioning for their high persistence and possible accumulation in different organisms with the transfer to other systems. Phytoremediation uses plants to remove or to immobilize inorganic contaminants, primarily PTEs (like heavy metals or metalloids) and has emerged as a cost-effective, environmentally friendly in situ remediation technology for soils contaminated with PTEs (Salt et al., 1998; Garbisu and Alkorta, 2001). The natural phytoextraction technique utilizes metal hyperaccumulating plant species with exceptionally high PTEs-accumulating capacities (Kumar et al., 1995). However, hyperaccumulators often accumulate only a specific element, and the efficiency of metal extraction is generally perceived as too slow because of low biomass production or a slow growth rate (Lombi et al., 2001; Zhao et al., 2010). The assisted phytoextraction approach uses high-biomass producing plant species, whose efficiency in phytoextraction is enhanced in the presence of ammendments like compost (Meers et al., 2005; Saifullah et al., 2009) or biopromoters like microorganism. Phytostabilization can also be used with the aim to limit dust lift when poliannual grasses both micro-therm and macro-therm are used. Intercropping these species aims to rapidly cover the soil during the wet-cold season with microtherms as cooksfoot (*Dacylis glomerata L.*), tall fescue (*Festuca arundinacea L.*) and perennial ryegrass (*Lolium perenne L.*) and ensure a high soil coverage during the dry season with drought resistant grass as Bermudgrass (*Cynodon dactylon L.*) or dallisgrass (*Paspalum spp.*). Composted municipal waste may be applied to cropland as a source of nutrients and to improve the physical properties of the soil, leading to improve crop yield and quality (Fagnano et al., 2011) while biompromoters like trichoderma, soil bacteria, endomycorrhiza, humic and fulvic acids can improve plants yield, resistance to environmental stresses and reduce the need for fertilizers. In this work the effects of an organic ammendment and two commercial biopromoters on the growth, EPTs phytoextraction/phytostabilization of a grass commercial mix (*Festuca arundinacea, Poa pratensis* and *Lolium perenne*) have been evaluated.

Materials and Methods

The experiment was performed in 36 pots (V: 0.15 m^3) in open air using a mix of microtermal grass species (*F. arundinacea, P . pratensis, L. perenne*). Two tipes of sediments deriving from an industrial site (Ex ILVA of Bagnoli – Campania Region – Italy) were used: a soil from the site (S) and sludges taken from the soil washing of the same site (F). The ammendment used was compost from Municipal Solid Wastes. The other treatment consisted of two biopromoters: Trianum-P containing *Trichoderma harzianum* - strain T22 (TB) and a consortium called "Panoramix" containing Endomycorrhiza, Bacillus, and Trichoderma species along with humic and fulvic acids (TA). The amendment used was mixed with the soil (0.5% w/w) prior to be added to pots. Biopromoters were added to the seeds prior of the sowing that happened in November 2015 with 20 g of seeds in each pot. Three samplings of the aerial parts and the corresponding soils of each pot were made respectively in May, July and November 2016. Another soil sample was taken before the sowing (T0) for the soil characterization. The pots area covered with vegetation was misured in correspondance of each cut to know if the selected grass plants can be used to avoid dusts dispersion that is the principal risk in heavy contaminated soils like the industrial ones. Plants samples were washed with tap water, rinsed with deionized water, oven dried at 60°C until

DOI 10.6092/unibo/amsacta/5692

constant weight and ground prior to analyse them with acid digestion followed by ICP-MS for Potential Toxic Elements (PTEs) total content determination. Soils were dried at 50°C until constant weight, homogenized and sieved through a 2 mm sieve prior to ultralow ICP-MS analysis. Recorded values were compared to legal PTEs thresholds in plants (REG UE N. 1275/2013) and soils (contamination threshold concentration (CTC), D.Lgs 152/2006, or beckground values (BV). For not regulated metals mean values found in grasses grown on polluted sites were used (Kabata-Pendias, 2011) as reference. PTEs mobility was estimated by a single extraction: 1M NH_4NO_3 extractant was used to assess the readily soluble fraction (DIN 19730, 1995) in correspondence of the first and third cut.

Results and Discussion

From soil analysis of T0 samples (Tab. 1) soil resulted potentially contaminated for residential use for the PTEs Pb, Zn and As.

Tab. 1: Initial PTEs concentration in sediments. F=sludges, S=soils, TA=Panoramix, TB=Trianum-P, NoT=no biopromoters, C=compost, NoC= no compost.

Tab. 1: Concentrazioni iniziali di EPT nei sedimenti. F=fanghi, S=suoli, TA=Panoramix, TB=Trianum-P, NoT=nessun biopromotore, C=compost, NoC= no compost.

	Pb	Zn	As	V	Be
FTA	274.9	1161	48.7	72.3	8.0
FTB	279.6	1147	47.0	78.7	10.7
FNoTNoC	281.2	1208	47.7	74.0	10.0
STA	161.4	366	39.0	120.3	8.3
STB	159.4	391	42.0	122.0	8.0
SNoTNoc	171.0	362	40.7	119.3	8.7
FCTA	269.9	1120	44.0	71.0	11.0
FCTB	279.6	1123	42.0	71.3	11.5
FCNoT	271.4	1113	47.7	76.0	9.3
SCTA	214.0	390	40.7	117.0	7.0
SCTB	183.9	388	40.7	123.3	10.7
SCNoT	236.8	376	39.0	119.3	8.3
CTC	**100.0**	**150.0**	**20.0**	**90.0**	**2.0**
BV			**36.0**	**150.0**	**12.0**

Productive results in the first harvest showed that organic amendment (compost) increased the growth of grass species by 68%. In the second and third harvests there were 27% and 52% increases with compost treatment. The application of TA increased biomass production as compared to TB by 113%, 52% respectively in the first and second harvest. In the third harvest TB showed the best results as compared to TA. Grass species in sludges showed higher growth than in soil probably due to the different fertility. Phytoavailability of Pb, Zn and As were low showing that PTEs were in a stable form not easily assimilale by plants, even if total concentrations were higher than CTC. PTEs concentration in shoots for Pb, As, V and Be were lower like the phytoavailability of these PTEs in soils and similar to values reported by Kabata-Pendias, 2011 in "normal" plants. Zn concentration in shoots was higher in sludges thatn in soils in all the harvests with mean values of 80 mg Kg^{-1} similar to the results reported by Zhao et al., 2013 in *Festuca arundinacea*. Although total soil concentrations of metals are not generally considered a predictor for metal phytoavailability (Tack and Verloo 1995; Peijnenburg et al. 1997; Song et al. 2004), positive correlation ($P<0.01$) between total and extractable concentrations for Zn in the first harvest ($r=0.96$) and in the third ($r=0.92$) were significant. This result is in accord with Abedin et al. (2012) who reported that total soil concentration is a possible phytoavailability indicator for some PTEs. To better study PTEs phyto-availability, total and extracted PTEs concentrations were correlated with metal concentrations in the shoots. Significant positive correlation ($P<0.01$) was found between aerial part and extractable concentrations for Zn in the first ($r=0.83$) and in the third harvest ($r=0.77$) and between aerial part and total Zn concentration in the first harvest ($r=0.90$) and in the third harvest ($r=0.82$).

Soil coverage of grass species used in this work was complete along all the year of experimentation showing that the mix can be successful used to securing the contaminated sites by preventing dispersion of contaminated soil particles.

Conclusions

The study was made with aim to evaluate the effects of organic ammendment and biopromoters on the phytoextraction/phytostabilization capacity of a commercial grass mix. Plant species were well adapted to the contamination of soils and sludges showing a good growth during the year of experimentation. The application of compost and biopromoters, expecially TA, increased the growth of plants. The accumulation of PTEs in the aerial part of plants was low for the considered PTEs except for Zn. So the plant species, in the considered sediments, were good for a phytostabilization purpose reducing the leaching of PTEs in the soil profile. Furthermore the biomass taken from the harvest can be used in no food chains and the complete coverage of the soil prevents the dispersion of the contaminated soil partcles, thus allowing to reduce the risk for human health.

References

Abedin J., Beckett P., Spiers G. 2012. An evaluation of extractants for assessment of metal phytoavailability to guide reclamation practices in acidic soilscapes in northern regions. Can. J. Soil Sci. 92, 253-268.

Fagnano, M., Adamo, P., Zampella, M., Fiorentino, N., 2011. Environmental and agronomic impact of fertilization with composted organic fraction from municipal solid waste: a case study in the region of Naples, Italy. Agr. Ecosyst. Environ. 141, 100–107.

Garbisu, C., Alkorta, I., 2001. Phytoextraction: a cost-effective plant-based technology for the removal of metals from the environment. Bioresour. Technol. 77, 229–236.

Kabata-Pendias A, 2011. Trace elements in soils and plants. Boca Raton, FL: CRC Press Inc..

Kumar, P.B.A.N., Dushenkov, V., Motto, H., Raskin, I., 1995. Phytoextraction: the use of plants to remove heavy metals from soils. Environ. Sci. Technol. 29, 1232–1238.

Lombi, E., Zhao, F.J., Dunham, S.J., McGrath, S.P., 2001. Phytoremediation of heavymetal contaminated soils: natural hyperaccumulation versus chemically enhanced phytoextraction. J. Environ. Qual. 30, 1919–1926.

Meers, E., Ruttens, A., Hopgood, M.J., Samson, D., Tack, F.M.G., 2005. Comparison of EDTA and EDDS as potential soil amendments for enhanced phytoextraction of heavy metals. Chemosphere 58, 1011–1022.

Peijnenburg, W. J. G. M., Posthuma, L., Eijsackers, H. J. P. and Allen, H. E. 1997. A conceptual framework for implementation of bioavailability of metals for environmental management purposes. Ecotoxicol. Environ. Safety 37, 163-172.

Saifullah, R., Meers, E., Qadir, M.P., de Caritat, F., Tack, F.M.G., Laing, D.G., Zia, M.H., 2009. EDTA-assisted Pb phytoextraction. Chemosphere 74, 1279–1291.

Salt, D.E., Smith, R.D., Raskin, I., 1998. Phytoremediation. Annu. Rev. Plant Phys. 49,643–668.

Song J., Zhao F. J., Luo Y. M. McGrath S. P and Zhang H. 2004. Copper uptake by Elsholtzia splendens and Silene vulgaris and assessment of copper phytoavailability in contaminated soils. Environ. Pollut. 128, 307-315.

Tack, F. and Verloo, M. 1995. Chemical speciation and fractionation in soil and sediment heavy metal analysis: a review. Int. J. Environ. Anal. Chem. 59, 225_238.

Zhao, Z., Xi, M., Jiang, G., Liu, X., Bai, Z., Huang, Y., 2010. Effects of IDSA, EDDS and EDTA on heavy metals accumulation in hydroponically grown maize (Zea mays, L.). J. Hazard. Mater. 181, 455–459.

Zhao S. et al., 2013. The use of a biodegradable chelator for enhanced phytoextraction of heavy metals by Festuca arundinacea from municipal solid waste compost and associated heavy metal leaching. Bioresource Technology 129, 249–255.

BIOAGRONOMIC PERFORMANCE OF SICILIAN ORGANIC DURUM WHEAT "TIMILIA"

PERFORMANCE BIOAGRONOMICA DEL FRUMENTO DURO SICILIANO BIOLOGICO "TIMILIA"

Paolo Guarnaccia, Giorgio Testa, Paolo Caruso, Carlo Amato, Salvatore Luciano Cosentino, Umberto Anastasi*
Dipartimento di Agricoltura, Alimentazione e Ambiente (D*i*3A), Via Valdisavoia 5, 95123, Catania
*umberto.anastasi@unict.it

Abstract
In 2013-14 cropping season, an investigation was conducted in eleven organic farms located in representative cereal areas of Sicily, in order to assess the variations of bioagronomic traits in "Timilia", a popular traditional durum wheat cultivar. The comparison of the data evidenced a variability for all the studied traits, which reflects the heterogeneity of the intercepted climatic conditions. The highest grain yield, near to 3 t ha^{-1}, was attained at Butera (CL), Gela (CL) and Caltanissetta (CL), confirming that durum wheat "Timilia" cultivated under organic regime is able to ensure an appreciable production performance.

Keywords: durum wheat; "Timilia", organic crop; grain yield; protein content.
Parole chiave: frumento duro, "Timilia", coltura biologica, resa in granella, contenuto proteico.

Introduction
Durum wheat is the most widely grown cereal crops in Italy, and it is the main source of raw material for making pasta. Lately, some "nieche" products (pasta, bread, pizza and others food specialty), are made with flour of wheat Sicilian populations (so called "ancient wheats"), which have attracted the interest of farmers and consumers, due to its link to the territory and peculiar quality features (Dinelli et al., 2013; Guarnaccia et al., 2015). In Sicily, indeed, more than fifty traditional genotypes of durum and soft wheat were preserved as a part of the genetic resource available until the beginning of 1950, when the replacement with improved varieties began. This precious germplasm could be exploited in organic and low input farming systems, as well as to developing an alternative form of participatory plant breeding in collaboration with farmers. (Newton et al., 2010; Shelton and Tracy, 2016). For these reasons, a study was conducted in organic cereal farms located in different areas of Sicily, in order to evaluate the changes of bioagronomic traits in "Timilia" (also called Tumminia or Diminia), one of the most popular among the traditional durum wheat genotypes.

Materials and Methods
The investigation was conducted in 2013-14 cropping season in organic farms located in representative cereal areas of Sicilian territory, as listed in the table 1. These farms have a total cropping area between 22 and 190 ha. The area cultivated with durum wheat "Timilia" in the year of this study varied from 4 to 44 ha (F.c. 10 and 11, respectively).
The germplasm of "Timilia" was initially provided to the farmers by the "Stazione Consorziale di Granicoltura di Caltagirone". Weather data were acquired by the SIAS (Servizio Informativo Agrometeorologico Siciliano).
The farm involved in the present study adopted the same agronomic management, according to the organic method of cultivation. In particular, the crop was sown using a seed drill at 200 kg ha^{-1} seeding rate. Details on site and cropping management are reported in table 1.

Tab. 1: Farm code, site and altitude, previous crop, sowing and harvest date
Tab. 1: Codice azienda, località e altitudine, precessione colturale, data di semina e di raccolta

Farm code	Site (Province)	Altitude (m a.s.l)	Previous crop	Sowing date	Harvest date	Cropping cycle (d.)
1	Villarosa (EN)	500	vetch	30/12/'13	30/06/'14	182
2	Melilli (SR)	150	vetch	20/12/'13	19/06/'14	181
3	Caltagirone (CT)	450	vetch-oats	09/01/'14	04/07/'14	176
4	Santa ninfa (TP)	550	chickpea	20/02/'14	26/07/'14	156
5	Agira (EN)	650	vetch	20/12/'13	29/06/'14	191
6	Butera (CL)	400	vetch	10/01/'14	30/06/'14	171
7	Gela (CL)	250	vetch	10/01/'14	01/07/'14	172
8	Vittoria (RG)	10	faba bean	10/12/'13	08/07/'14	210
9	Aidone (EN)	800	fallow	10/12/'13	25/06/'14	197
10	Caltanissetta (CL)	600	vetch	20/01/'14	11/07/'14	172
11	Raddusa (CT)	350	vetch	20/12/'13	28/06/'14	190

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

During the crop cycle, four representative sampling areas of 20 m^2 were delimited in each field. At the end of the cropping season, in sub-sampling areas, the height of the plants was measured and ears were counted, and a sample of fifty ears was taken to determine the yield components.
The data, which are presented in a preliminary form, are discussed using descriptive statistics.

Results and Discussion

Overall, during the cropping cycle (December 2013 to July 2014), mean minimum and mean maximum temperatures, never fell below 8°C and never exceeded 25°C, respectively, whereas the amount of rainfall ranged between 265 and 530 mm (data not shown).
The data reported in the table 2 show an appreciable variation for all the studied traits, which reflects the heterogeneity of the intercepted environmental conditions. In particular, plant height was greater at Villarosa (EN) and lower at Melilli (SR). The higher grain yield level, above the mean value, was reached in six sites, Villarosa (EN), Agira (EN), Butera (CL), Gela (CL), Vittoria (RG) and Caltanissetta (CL), compared to that attained in the other localities. Such productive result, which was close to 3 t ha^{-1} at Butera (CL), Gela (CL) and Caltanissetta (CL), can be attributed to a higher number of ears per m^2, but also to a greater fertility of the ear, mainly in terms of number of spikelets and kernels weight. In the same three locations, a grain protein content of almost 11% was achieved, while the highest value, equal to 13%, was obtained at Villarosa (EN). Due to the combination among the different yield components with protein content, protein yields achieved in the six sites that showed the best productive performance were higher and similar, compared to those obtained in the other localities.

Tab. 2: Plant height, productive traits, grain protein content and protein yield of durum wheat "Timilia" (mean vaues ± s.d.)
Tab. 2: Altezza pianta, caratteri produttivi, contenuto proteico della granella e resa in proteine del frumento duro "Timilia" (valori medi ± d.s.)

Farm code	Plant height (cm)	Grain yield (t ha^{-1})	Ears (n/m^2)	Fertile spikelets (n/ear)	Kernels (n/ear)	Kernel weight (mg)	Grain protein content (%)	Protein yield (t ha^{-1})
1	126.8±3.9	2.5±0.2	292±40.5	16.5±1.5	27.3±3.9	37.3±3.7	13.0±0.2	0.33
2	85.9±2.2	1.3±0.1	242±50.6	11.7±0.1	20.1±2.4	32.1±3.2	11.3±0.1	0.14
3	89.3±3.0	1.5±0.1	251±35.5	13.9±0.5	20.9±2.7	33.2±3.3	10.4±0.0	0.16
4	117.0±1.7	1.8±0.2	263±13.2	16.3±0.6	27.6±1.2	28.4±2.8	10.7±0.1	0.18
5	125.9±0.8	2.3±0.2	264±25.5	13.0±1.7	26.9±2.9	38.5±3.9	10.3±0.0	0.25
6	123.1±11.1	2.7±0.2	288±16.3	14.3±1.2	28.4±3.6	38.6±3.9	10.6±0.1	0.30
7	120.4±7.9	2.6±0.2	288±14.2	15.3±1.1	25.9±1.3	40.9±4.1	10.9±0.1	0.29
8	125.4±5.6	2.4±0.1	255±69.7	17.0±0.2	29.7±3.9	37.6±3.8	11.3±0.1	0.29
9	97.6±8.2	1.5±0.1	261±51.3	12.3±0.5	20.9±1.1	31.7±3.2	11.1±0.0	0.15
10	123.4±4.5	2.6±0.2	288±32.2	13.7±1.1	24.4±1.6	43.0±4.3	10.8±0.1	0.33
11	97.1±2.5	1.3±0.1	214±21.0	11.0±1.7	19.3±4.2	37.6±3.8	11.8±0.1	0.14
Mean	*112.00*	*2.0*	*264*	*14.1*	*24.7*	*36.3*	*11.2*	*0.23*
Max	*126.8*	*2.7*	*292*	*17.0*	*29.7*	*43.0*	*13.0*	*0.33*
Min	*85.9*	*1.3*	*214*	*11.0*	*19.3*	*28.4*	*10.2*	*0.14*
Range	*40.9*	*1.4*	*78*	*6.0*	*10.4*	*14.6*	*2.8*	*0.20*

Conclusions

The results of the present study, although presented in a preliminary form, highlight that in different representative cereal areas of Sicily, the traditional cultivar of durum wheat "Timilia" cultivated under organic regime is able of achieving a satisfactory production performance. Nevertheless, further research is needed to acquire scientific information on the development of sustainable agronomic models to allow this genotype to optimize the yield level as well as on the qualitative characteristics of the grain.

References

Dinelli G., Marotti I., Di Silvestro R., Bosi S., Bregola V., Accorsi M., Di Loreto A., Benedettelli S., Ghiselli L., Catizone P., 2013. Agronomic, nutritional and nutraceutical aspects of durum wheat (*Triticum durum* Desf.) cultivars under low input agricultural management. Italian J Agron 8:85–93.

Guarnaccia P., Blangiforti S., Spina A., Caruso P., Amato C., Mattiolo E., Anastasi U., 2015. Old Sicilian wheat genotypes as a tool to optimize organic and low-input farming systems. Proceedings of 10^{th} AISTEC Conference "Grains for feeding the world". Jointly organized with ICC on the occasion of the World EXPO Milan 1-3 July 2015: 112-115

Newton A.C., Akar T., Baresel J.P., Bebeli P.J., Bettencourt E., et al. 2010. Cereal landraces for sustainable agriculture. A review. Agron. Sustain. Dev. 30: 237-269.

Shelton A.C, Tracy W.F. 2016. Participatory plant breeding and organic agriculture: A synergistic model for organic variety development in the United States. Elem Sci Anth.; 4: 143.

DOI 10.6092/unibo/amsacta/5692

RISK ASSESSMENT OF CONTAMINATION OF AGRICULTURAL PRODUCTION
VALUTAZIONE DEL RISCHIO DI CONTAMINAZIONE DELLE PRODUZIONI AGRICOLE

Luigi Giuseppe Duri[1], Eugenio Cozzolino[2], Vincenzo Leone[2], Ida Di Mola[1], Lucia Ottaiano[1], Nunzio Fiorentino[1], Mauro Mori[1], Massimo Fagnano[1*]

[1] Dipartimento di Agraria, Università degli studi di Napoli Federico II, Via Università 100, 80055, Portici
[2] CREA-Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria,Laboratorio di Caserta
*massimo.fagnano@unina.it

Abstract
In consideration of the fact that the specific regulation for agricultural areas, planned by art. 241 of Italian Environmental Law (D.Lgs 152/06), has not yet enacted, it is necessary to evaluate the direct assimilation by the plant for analyzing the risks of food contamination and the consequent indirect risks for consumer health. The approach to follow is the so called "worst case", that means to grow and analyze the edible parts of a crop that is able to accumulate high concentrations of one or more Potentially Toxic Elements (PTE). The aim of this trial is to analyze health risks for consumers of food crops produced in a potentially contaminated site, and declare it suitable or not for agricultural use.

Keywords: Health risks; Potentially Toxic Elements, Agricultural soils.
Parole chiave: Rischi per la salute; Elementi Potenzialmente Tossici, Suoli agricoli.

Introduction
Considering that plants have the ability to remove and store PTEs in various organs, and because PTEs are persistent and non biodegradable, they can cause harmful effects to human health. In Italy there are no specific regulations for defining soil suitability for agricultural use, and the model of the regulation proposed to the government provide the evaluation of the indirect risks for the consumers by using biological tests (i.e. cultivation of vegetables in potentially contaminated soils and analysis of edible organs).
For a conservative risk estimation, the worst-case scenario has to be adopted. This means to consider the worst situation that is possible (i.e. to select the hot spots with the highest PTE concentrations of a site and to select crops well known for accumulating high concentrations of one or more PTEs).
The accumulation of PTEs has to be compared with the thresholds of European regulations (for Cd and Pb), while for nor-regulated PTEs, the Hazard Quotient from Huang et al. (2008) can be used.
The aim of this study is to investigate the possible health risks related to nutrition with the food crops cultivated in a potentially contaminated site.

Materials and Methods
The experiment was carried out for assessing the risk of contamination of food-chain of a potentially contaminated site in Giugliano (NA). Approximately 80 kg of soil from 0-30 cm layer of hot spots with the highest concentrations of Arsenic, Chrome, Zinc, Lead and Cadmium were collected. This soil was homogenized and distributed in pots in which crops well known for their metal uptake capacity (radish, spinach, lettuce, chicory, rocket, lettuce baby leaf) were cultivated until commercial maturity. 5 replications per crop were used. At harvest, plants were washed with deionized water to remove any residual soil from the samples and the edible organs were separated. These samples were sent to laboratory for analyzing the PTEs concentrations. These values were compared with the thresholds of Pb and Cd (CE Reg 1881/2006) and As (CE Dir. 32/2002). As regards toxicological risks due to the not- regulated PTEs (Cr, Zn), the Hazard Quotient (Huang et al., 2008) was used. The Hazard quotient is the ratio between the average daily dose (ADD) of a PTE (based on the concentration of a certain element and on the Intake Rate (IR) of a specific food) and the Reference Dose (maximum acceptable oral dose of a toxic substance). If HQ > 1 there could be a potential risk to human health.

Results and Discussion
In Table 1 the PTEs concentrations are shown. Yield data (tab. 2), showed that there were no limiting conditions for growth due to PTEs contamination, since yield losses were not correlated with PTEs concentrations. Yields of the different crops were rather related with the different soil organic matter content of the 4 plots (data not showed).
PTEs concentrations of the used crops allowed to exclude any risk for consumer health, confirming the results of other surveys made in the same area (Esposito et al., 2015; Agrelli et al., 2017). These results confirmed also the findings of Adamo et al., (2014) who highlighted the uselessness of total content of PTEs in the soil for assessing their environmental and agronomic riskiness.

ID	As	Cr	Zn	Cd	Pb
			mg kg^{-1}		
A7	19	81	108	nd	50
C13	**20**	**391**	**488**	nd	**114**
F2	**24**	**1034**	**532**	**17**	66
F4	**23**	**299**	**239**	**19**	66

Tab. 1: *PTEs concentrations in the 4 sampling points. In bold the values exceeding the screening values (D.Lgs.152/06)*
Tab. 1: *Concentrazioni degli EPT nei 4 punti di prelievo. In grassetto i valori superiori alle CSC (D.Lgs.152/06)*

Tab. 2: *Harvest of species (g* pot^{-1} fw)
Tab. 2: *Produzioni delle specie coltivate (g* vaso^{-1} pf)

	Radish		Spinach		Lettuce		Chicory		Rocket I		Rocket IV		Lettuce B.l.	
							g pot^{-1}							
A7	16.7	± 7.5	20.8	±2.9	95.1	±35.6	37.3	± 9.1	16.3	±3.5	20.1	±14.4	28.0	±19.9
C13	60.2	±12.7	33.3	±4.8	51.1	±19.4	47.7	±11.8	26.3	±5.6	34.9	±25.2	37.7	±21.4
F2	32.8	± 8.3	28.6	±5.9	93.9	±22.9	53.5	± 5.5	15.4	±4.5	41.0	± 9.4	34.7	±17.6
F4	39.4	± 5.5	25.6	±2.9	113.0	±24.1	42.1	± 6.9	19.0	±2.9	32.1	±15.4	27.3	±18.2

Conclusions

This trial analyzed the relationships between the total concentrations of various PTEs in soils and vegetables. The results of this experiments confirmed the uselessness of total content of PTM in the soils. They also allowed to exclude any risk due to PTEs accumulation in vegetables produced in a site classified as potentially contaminated.

Finally, we should highlight the absolute need to improve the existing legislation by considering the bioavailability and then the accumulation of PTEs in metal accumulating crops (worst case) as the proper method for assessing the suitability of soils for the agricultural use.

References

Adamo P., Iavazzo P., Albanese S., Agrelli D., De Vivo B., Lima A., 2014. Bioavailability and soil-to-plant transfer factors as indicators of potentially toxic element contamination in agricultural soils. Sci. Total Environ. 500-501: 11-22.

Agrelli D., Adamo P., Cirillo T., Duri L.G., Duro I, Fasano E., Ottaiano L., Ruggiero L., Scognamiglio G., Fagnano M. 2017. Soil versus plant as indicators of agroecosystem pollution by potentially toxic elements. Journal of Plant Nutrition and Soil Science. In press.

Esposito M., Picazio G., Serpe P., Lambiase S., Cerino P., 2015.: Content of Cadmium and Lead in Vegetables and Fruits Grown in the Campania Region of Italy. J. Food Protect. 78: 1760-1765

Huang M., Zhou S., Sun B., Zhao Q., 2008. Heavy metals in wheat grain: Assessment of potential health risk for inhabitants in Kunshan, China. Science The Total Environment 405: 54-61.

Osaili T.M., Al Jamali A.F., Makhadmeh I.M., Taha M., Jarrar S.K., 2016. Heavy metals in vegetables sold in the local market in Jordan. Food Additives Contaminants 9: 223-229.

BIOMASS YIELD AND WATER USE EFFICIENCY OF DIVERSE PERENNIAL GRASSES IN SEMI-ARID MEDITERRANEAN ENVIRONMENT
PRODUZIONE DI BIOMASSA ED EFFICIENZA D'USO DELL'ACQUA DI DIVERSE GRAMINACEE PERENNI IN AMBIENTE SEMI-ARIDO MEDITERRANEO

Danilo Scordia[1*], Giorgio Testa[1], Venera Copani[1], Giovanni Scalici[1], Sarah Sidella[1], Giancarlo Patanè[1], Cristina Patanè[2], Salvatore L. Cosentino[1,2]

[1] Dipartimento di Agricoltura, Alimentazione e Ambiente (Di3A), Università degli Studi di Catania, via Valdisavoia 5, 95123 Catania
[2]Consiglio Nazionale delle Ricerche, Istituto per la valorizzazione del legno e delle specie arboree (CNR-IVALSA), via Gaifami 18, 95126 - Catania
*dscordia@unict.it

Abstract
The main objective of the present study was to assess the biomass dry matter yield (DM) and water use efficiency (WUE) of several perennial grasses grown at the experimental farm of the University of Catania. Field trials of *Arundo donax*, *Miscanthus* x *giganteus*, *Saccharum spontaneum* spp. *aegyptiacum*, *Sorghum halepense*, *Oryzopsis miliacea* and *Cymbopogon hirthus* grown under low-input practices (i.e., rainfed, unfertilized, etc.) in an autumn and winter harvesting regime were used. Harvest time was significant only for WUE across the average of species (2.79 and 1.67 g L^{-1} in autumn and winter harvest, respectively). Across harvest time, *Saccharum* showed the highest DM and WUE (23.1 Mg ha^{-1} and 5.6 g L^{-1}, respectively) followed by *Arundo* (13.5 and 3.3 g L^{-1}, respectively). The other species showed the lowest traits.

Keywords: Perennial grasses, Biomass production, WUE, Mediterranean environment.
Parole chiave: Graminacee perenni, produzione di biomassa, WUE, Ambiente mediterraneo.

Introduction
Sustainable biomass production mostly relies on cultivation practices employing low external input supply. In Europe, research activities deemed a few perennial grasses for biomass production, in relation to the variable climatic conditions. The C4 perennial grasses, *Miscanthus* x *giganteus* and *Panicum virgatum*, are high-yielding in temperate environments of northern and central Europe (Lewandowski et al., 2003), while the C3 *Arundo donax* is reported to be more productive in southern Europe (Mantineo et al., 2009; Cosentino et al., 2014; 2016). In the Mediterranean basin, however, there is a remarkable plant diversity still largely unexplored. The investigation of site-specific wild germplasms for biomass production would mitigate the effect of land use competition and might provide new genetic resources for breeding programs aiming at the development of relevant varieties able to thrive under limiting conditions.
The aim of the present work was to assess the biomass dry matter yield (DM) and water use efficiency (WUE) of several perennial grasses already established at the experimental farm of the University of Catania.

Materials and Methods
Field trials employing *Arundo donax*, *Miscanthus* x *giganteus*, *Saccharum spontaneum* spp. *aegyptiacum*, *Sorghum halepense*, *Oryzopsis miliacea* and *Cymbopogon hirthus* established at the Experimental farm of the University of Catania, Italy (37°25' N., 15°03' E., 10 m a.s.l.) were used. Trial main characteristics are shown in Table 1.

Tab. 1: Field-trial main characteristics.
Tab. 1: Caratteristiche principali delle prove in campo.

Species	**Establishment**	**Main treatment**	**Reference**
Miscanthus x *giganteus*	1993	Harvest time (from 2011)	Cosentino et al. (2007)
Arundo donax	1997	Harvest time (from 2011)	Cosentino et al. (2014)
Saccharum spontaneum, *Sorghum halepense*, *Oryzopsis miliacea*, *Cymbopogon hirthus*	2010	Harvest time	Scordia et al. (2017)

Throughout the 2014/2015 growing season, main meteorological parameters, as maximum and minimum temperatures, and rainfall, were measured by a weather station connected to a data logger (Delta-T, WS-GP1 Compact) located nearby the field trials. The reference crop evapotranspiration (ET_0) was calculated from the evaporation pan (mm d-1) by the pan coefficient of 0.80.
The crop water use efficiency (g L^{-1}) was calculated as the ratio between dry biomass yield and crop water use from regrowth up to harvest, in both winter and autumn growing seasons.
Biomass yield and WUE were subjected to a two-way analysis of variance (ANOVA) with species and harvest time as main effects. The Duncan's post-hoc test was used for mean separation at 95% confidence level.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Results and Discussion

METEOROLOGICAL CONDITIONS

In autumn growing season (from September to September) temperatures averaged 24.2°C for maximum, 13.0°C for the minimum and 18.6°C for the mean (Figure 1).

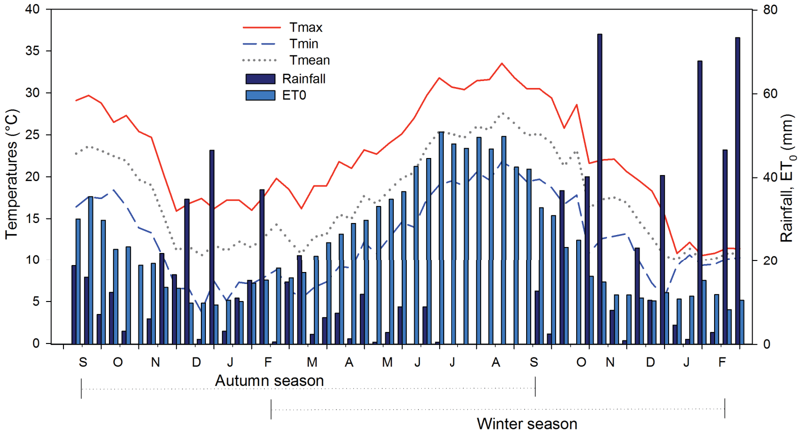


Fig. 1: Main meteorological parameters registered in autumn and winter growing season at the Experimental farm of the University of Catania, Italy (37°25' N., 15°03' E., 10 m a.s.l.).

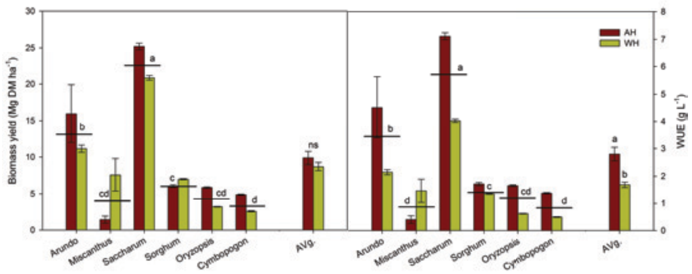
Fig. 1: Principali parametri meteorologici registrati durante la stagione autunnale ed invernale presso l'Azienda Sperimentale dell'Università di Catania, Italia (37°25' N., 15°03' E., 10 m a.s.l.).

Winter growing season (February to February) was cooler, 22.8°C and 18.1°C for the maximum and mean temperatures, whilst minimum temperatures were warmer, 13.4°C. Rainfall was much lower in autumn than winter, 354.1 and 518.5 mm, respectively. It was 102 mm between September and November and only 87.6 mm in the period March to September, namely the period that covers the main growth phases of perennial grasses. Overall ET_0 was higher in autumn than winter season (1101.2 and 985.5 mm, respectively), averaging at 2.89 and 2.59 mm day^{-1} in autumn and winter seasons. Obviously the period with the highest ET_0 was from late spring to the end of summertime (4.21 mm day^{-1}). The dryness index (R/ET), according to the criteria and thresholds set in the Regulation EU(1305)2013, was much lower in autumn (0.32) than winter season (0.53) and both are lower than the threshold of 0.6 suggested. Thus, the environment where the trials are carried out can be considered constrained by drought.

BIOMASS YIELD AND WATER USE EFFICIENCY

Fig. 2: Biomass dry matter yield (Mg ha^{-1}) and water use efficiency (g L^{-1}) of perennial grasses. Different letters indicate significantly different means (p≤0.05).

Fig. 2: Produzione di biomassa secca (Mg ha^{-1}) ed efficienza d'uso dell'acqua (g L^{-1}) di graminacee perenni. Lettere differenti indicano differenze significative tra le medie (p≤0.05).



Across the average of species, harvest time main effect was not significant for biomass dry matter yield (DM) and averaged 9.9 and 8.7 Mg ha^{-1} in autumn and winter harvest, respectively. On the other hand, it was significant different on WUE (2.79 and 1.67 g L^{-1} in autumn and winter harvest, respectively). Across the average of harvest time, species main effect was significant on both DM and WUE ($p \leq 0.05$). There were significant harvest time x species interactions ($p \leq 0.05$).

Saccharum showed the highest DM and WUE (23.1 Mg ha^{-1} and 5.6 g L^{-1}) followed by *Arundo* (13.5 Mg ha^{-1} and 3.3 g L^{-1}). *Cymbopgon* showed the lowest DM and WUE (3.7 Mg ha^{-1} and 0.9 g L^{-1}), however did not differ from *Miscanthus* and *Oryzopsis* for DM and *Miscanthus* only for WUE (Figure 2). *Sorghum* was at the middle range for both DM and WUE (6.5 Mg ha^{-1} and 0.9 g L^{-1}).

Conclusions

Saccharum spontaneum spp. *aegyptiacum* was clearly the species showing the highest biomass dry matter yield and water use efficiency. It is worth to note, however, that stands present different age, with *Miscanthus* and *Arundo* being older (22 and 18 years, respectively) than the other species (4 years). This might represent a bias in the present calculations as perennial grasses are characterized by an upward trend in the first 2–4 years, then fluctuating yields during the maturity stage (4 to 10 years), and finally a gradual decrease [illegible] Nonetheless, species widespread in semi-arid Mediterranean environment were able to produce similar (*Oryzopsis* and *Cymbopogon*) or higher (*Saccharum*, *Arundo* and *Sorghum*) biomass yield than *Miscanthus* x *giganteus*, which is more suited to colder and wetter

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

environments (as indicated by the dryness index). Further research is needed on native Mediterranean perennial grasses as biomass crops or as candidate species for breeding programs in environments characterized by severe drought.

References

Confalonieri, R., Jones, B., Van Diepen, K., Van Orshoven, J., 2014. Scientific contribution on combining biophysical criteria underpinning the delineation of agricultural areas affected by specific constraints. Editors: JM. Terres, A. Hagyo, A. Wania. European Commission, Joint Research Centre, Institute for Environment and Sustainability. JRC92686, EUR 26940 EN, ISBN 978-92-79-44340-4.

Cosentino, S.L., Patanè, C., Sanzone, E., Copani, V., Foti, S., 2007. Effect of soil water content and nitrogen supply on the productivity of *Miscanthus* × *giganteus* in Mediterranean environment. Industrial Crops and Products 25(1),75–88.

Cosentino, S.L., Patanè, C., Sanzone, E., Testa, G., Scordia, D., 2016. Leaf gas exchange, water status and radiation use efficiency of giant reed (*Arundo donax* L.) in a changing soil nitrogen fertilization and soil water availability in a semi-arid Mediterranean area. European Journal of Agronomy 72, 56–69.

Cosentino, S.L., Scordia, D., Sanzone, E., Testa, G., Copani, V., 2014. Response of giant reed (*Arundo donax* L.) to nitrogen fertilization and soil water availability in semi-arid Mediterranean environment. European Journal of Agronomy 60, 22–32.

Lewandowski, I., Scurlock, J.M.O., Lindvall, E., Christou, M., 2003. The development and current status of perennial rhizomatous grasses as energy crops in the US and Europe. Biomass and Bioenergy 25, 335–361.

Mantineo, M., D'Agosta, G.M., Copani, V., Patanè, C., Cosentino, S.L., 2009. Biomass yield and energy balance of three perennial crops for energy use in the semi-arid Mediterranean environment. Field Crops Research 114, 204–213.

Scordia, D., Testa, G., Copani, V., Patanè C., Cosentino, S.L. Lignocellulosic biomass production of Mediterranean wild accessions (*Oryzopsis miliacea*, *Cymbopogon hirtus*, *Sorghum halepense* and *Saccharum spontaneum*) in a semi-arid environment. Field Crops Research, IN PRESS.

ENERGY CONTENT AND ENERGY RETURN ON INVESTMENT OF DIVERSE PERENNIAL GRASSES IN SEMI-ARID MEDITERRANEAN ENVIRONMENT
CONTENUTO ENERGETICO E RITORNO ENERGETICO SULL'INEVESTIMENTO DI DIVERSE GRAMINACEE PERENNI IN AMBIENTE SEMI-ARIDO MEDITERRANEO

Danilo Scordia[1*], Giorgio Testa[1], Venera Copani[1], Silvio Calcagno[1], Andrea Corinzia[1], Santo Virgillito[1], Sebastiano Scandurra[1], Cristina Patanè[2], Salvatore L. Cosentino[1,2]

[1] Dipartimento di Agricoltura, Alimentazione e Ambiente (Di3A), Università degli Studi di Catania, via Valdisavoia 5, 95123 Catania
[2]Consiglio Nazionale delle Ricerche, Istituto per la valorizzazione del legno e delle specie arboree (CNR-IVALSA), via Gaifami 18, 95126 - Catania
*dscordia@unict.it

Abstract
The main objective of the present study was to assess the energy content (EC) and the energy return on investment (EROI) at the farm gate of several perennial grasses grown at the experimental farm of the University of Catania. Field trials of *Arundo donax*, *Miscanthus* x *giganteus*, *Saccharum spontaneum* spp. *aegyptiacum*, *Sorghum halepense*, *Oryzopsis miliacea* and *Cymbopogon hirthus* grown under low-input practices (i.e., rainfed, unfertilized, etc.) in an autumn and winter harvesting regime were used. Species main effect was significant on both EC and EROI ($p \leq 0.05$), while harvest time did not. Across harvest time, *Saccharum* showed the highest EROI (120) but together with *Arundo* and *Oryzopsis* the lowest EC (15.3, 15.1 and 14.9 MJ kg^{-1}, respectively). The highest EC was shown by *Miscanthus* (15.9 MJ kg^{-1}), however, it did not differ from *Sorghum* and *Cymbopogon* (15.8 and 15.7 MJ kg^{-1}, respectively).

Keywords: Perennial grasses, Energy content, EROI, Mediterranean environment.
Parole chiave: Graminacee perenni; Contenuto energetico, EROI, Ambiente mediterraneo.

Introduction
Lignocellulosic biomass is the most abundant and low-cost raw material on earth, tailored to develop a competitive, resource efficient and low-carbon economy in Europe (Scarlat et al., 2015). Biomass quality is of paramount importance to optimize bioconversion processes. One of the major determinant of biomass productivity, stand longevity and quality of perennial grasses is the harvest time (Monti et al., 2015). At the same time high-resource-use-efficient species could maximize natural resources, thus limiting the use of external input meeting in this way the environmental sustainability by achieving positive energy balances (Tillman et al., 2006). The aim of the present work was to assess the energy content (EC) and the energy return on investment (EROI) at the farm gate of several perennial grasses already established at the experimental farm of the University of Catania.

Materials and Methods
Field trials employing *Arundo donax*, *Miscanthus* x *giganteus*, *Saccharum spontaneum* spp. *aegyptiacum*, *Sorghum halepense*, *Oryzopsis miliacea* and *Cymbopogon hirthus* established at the Experimental farm of the University of Catania, Italy (37°25' N., 15°03' E., 10 m a.s.l.) were used. Trial main characteristics are shown in Table 1.

Species	Establishment	Main treatment	Reference
Miscanthus x *giganteus*	1993	Harvest time (from 2011)	Cosentino et al. (2007)
Arundo donax	1997	Harvest time (from 2011)	Cosentino et al. (2014)
Saccharum spontaneum, *Sorghum halepense*, *Oryzopsis miliacea*, *Cymbopogon hirthus*	2010	Harvest time	Scordia et al. (2017)

Tab. 1: Field-trial main characteristics.
Tab. 1: Caratteristiche principali delle prove in campo.

Oven-dried samples (whole aboveground biomass) collected at the autumn (AH) or winter (WA) harvest were ground through a 1-mm screen in an IKA mill (IKA-WERFE, Gmbh & Co., KG, Staufenim Breisgau, Germany). Cellulose, hemicellulose, acid detergent lignin (ADL), proteins, lipids and ash were determined by a near-infrared spectrometer (NIR, SpectraStar™ 2500XL-R, Unity Scientific) provided with a tungsten halogen lamp as light source and a high performance ultra-cooled InGaAs extended range detector. Samples were placed in small powder cups and scanned in duplicate in diffuse reflection measurement mode, wavelength range of 680-2500 nm and accuracy < 0.1 nm. A previous calibration developed by the Ucal complete chemometric calibration software (InfoStar 3.11.0 version) was adopted. The calibration consisted of a regression that correlates spectra and analytic determinations of 240 different lignocellulosic raw materials of *Arundo donax* clones and *Miscanthus* species (stems, leaves or the whole biomass) grown under different agronomic practices and growing seasons. Following a first scan run, spectra of *Oryzopsis, Cymbopogon, Sorghum* and *Saccharum* were also used for further calibration development in the Ucal software. Biomass energy content (MJ kg^{-1}) was determined as biomass composition in terms of carbohydrates, proteins and lipids by using energy conversion factors proposed by Odum (1988). Carbohydrate energy conversion factor was also applied for lignin (ADL). Energy input referred only to harvesting, accounting for 2.94 GJ ha^{-1}. The energy return on investment (EROI) was calculated as the ratio of usable energy (output) to the amount of energy used to obtain that resource. Energy content and EROI were subjected to a two-way analysis of variance (ANOVA) with species and harvest time as main effects. The Duncan's post-hoc test was used for mean separation at 95% confidence level.

Results and Discussion

BIOMASS ENERGY CONTENT AND ENERGY RETURN ON INVESTMENT

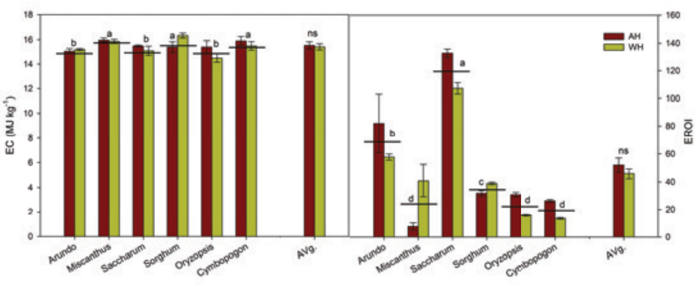


Fig. 1: Energy content (MJ kg^{-1}) and EROI of perennial grasses. Different letters indicate significantly different means ($p \leq 0.05$).
Fig. 1: Contenuto energetico (MJ kg^{-1}) ed EROI di graminacee perenni. Lettere differenti indicano differenze significative tra le medie ($p \leq 0.05$).

Across the average of species, harvest time main effect was not significant on both energy content (EC) and energy return on investment (EROI). Across the average of harvest time, species main effect was significant on both parameters ($p \leq 0.05$). There were significant harvest time x species interactions ($p \leq 0.05$). Across harvest time, *Miscanthus*, *Sorghum* and *Cymbopogon* showed the highest EC and not statistically different (15.9, 15.8 and 15.7 MJ kg^{-1}, respectively). *Saccharum*, *Arundo* and *Oryzopsis* showed the lowest and not different EC (15.3, 15.1 and 14.9 MJ kg^{-1}, respectively). On the contrary, *Saccharum* showed the highest EROI (120) followed by *Arundo* (69.8) and *Sorghum* (35.4) across the average of harvest time. *Cymbopgon*, *Oryzopsis* and *Miscanthus* showed the lowest and not statistically different EROI (20, 23.3 and 24.3, respectively) (Figure 1).

Conclusions

The energy content of perennial grasses, although significant, was in the range of 1.0 MJ kg^{-1} between the most (*Miscanthus,* 15.9 MJ kg^{-1}) and the least (*Oryzopsis,* 14.9 MJ kg^{-1}) species. This indicate that perennial grasses are characterized by a quite similar composition, which is a positive feature in a bioenergy chain. Indeed, a stable biomass composition delivered at the bioconversion site avoids continual modifications to processing operations, in turn avoiding to incur in costly and risky operations. All species can be considered sustainable from the energy point of view as evidenced by the EROI value which was the highest in *Saccharum* (120:1), and the lowest, but still positive, in *Cymbopogon* (20:1).

References

Cosentino, S.L., Patanè, C., Sanzone, E., Copani, V., Foti, S., 2007. Effect of soil water content and nitrogen supply on the productivity of *Miscanthus × giganteus* in Mediterranean environment. Industrial Crops and Products 25(1),75–88.

Cosentino, S.L., Scordia, D., Sanzone, E., Testa, G., Copani, V., 2014. Response of giant reed (*Arundo donax* L.) to nitrogen fertilization and soil water availability in semi-arid Mediterranean environment. European Journal of Agronomy 60, 22–32.

Monti, A., Zanetti, F., Scordia, D., Testa, G., Cosentino, S.L., 2015. What to harvest when? Autumn, winter, annual and biennial harvesting of giant reed, miscanthus and switchgrass in northern and southern Mediterranean area. Industrial Crops and Products, 75, 129–134.

Odum, E.P., 1988. Basi di ecologia. Piccin, Padova, 584.

Scarlat, N., Dallemand, J.F., Monforti-Ferrario, F., Nita, V., 2015. The role of biomass and bioenergy in a future bioeconomy: Policies and facts. Environmental Development, 15, 3–34

Scordia, D., Testa, G., Copani, V., Patanè C., Cosentino, S.L. Lignocellulosic biomass production of Mediterranean wild accessions (*Oryzopsis miliacea*, *Cymbopogon hirtus*, *Sorghum halepense* and *Saccharum spontaneum*) in a semi-arid environment. Field Crops Research, IN PRESS.

Tilman, D., Hill, J., Lehman, C., 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. Science 314, 1598-1600.

YIELD OF NEW BURLEY TOBACCO VARIETIES IN DIFFERENT AREAS OF CAMPANIA REGION

VALUTAZIONE DI NUOVE VARIETA' DI TABACCO IN DIVERSE AREE DELLA REGIONE CAMPANIA

*Eugenio Cozzolino, Francesco Raimo, Massimo Abet, Mariarosaria Sicignano, Giovanni Scognamiglio, Antonio Mosè, Tommaso Enotrio, Luisa del Piano

Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria- Centro di ricerca in Cerealicoltura e Colture Industriali (CREA-CI), Laboratorio di Caserta

[*] eugenio.cozzolino@crea.gov.it

Abstract

Burley tobacco varieties, resistant to black shank, were tested in different areas of Campania region. The following tobacco varieties KT206LC, KT209LC, KT210LC and KT212LC, very popular in U.S. but never tested in Italy, and tobacco BMS101 line, from CREA, were grown, at Calvi (BN, farm 1e 2) and Vitulazio (CE, farm 3). In the fields of the trial blank shank has not been observed. Cured tobacco yield at BN farm 1 ranged from 1.8 to 2.7 t ha^{-1}, at farm 2 ranged from 2.2 to 3.3 t ha^{-1}, at farm 3 ranged from 2.6 to 3.9 t ha^{-1}. These yields are comparable to that reported in North Caroline official variety test. Among the U.S. Burley tobacco varieties tested, KT212LC showed the worst performance at each location. BMS101 lines had good yield only topped at Calvi (BN).

Keywords: Burley tobacco varieties, black shank, *Phytophthora parasitica var. nicotianae*.
Parole chiave: Burley tabacco, marciume nero, *Phytophthora parasitica var. nicotianae*.

Introduction

In the last years a widespread incidence of black shank (*Phytophthora parasitica var. nicotianae*) was observed in some areas of Campania region, causing severe reduction in tobacco yields (Lahoz et al., 2011). Also in United States there is a widespread incidence of this disease throughout the burley growing region. Recently variety improvements have resulted in resistant varieties with yields comparable to the best yielding black shank-susceptible varieties, very popular in U.S.. In Italy commercial Burley tobacco varieties, resistant to black shank, are not utilized.
Aim of this study was to evaluate, for yield, the newest and most popular tobacco varieties, in U.S., resistant to black shank, under different cultural practices and pedoclimatic conditions in Campania region.

Materials and Methods

A field trial was conducted with six varieties, with three replicates, at three farms, two located in Calvi (BN) and the other one in Vitulazio (CE). Four commercial tobacco varieties KT206LC, KT209LC, KT210LC, KT212LC (ProfiGen), utilized in U.S., BMS101 line from CREA, resistant to black shank, and PM35 variety, susceptible to black shank, usually utilized in the region, were compared. Plants were grown under cultural practices, plant density, topping, harvesting and curing, usual for the farmers. At farm1, located in Calvi (BN), plant population was 15.000 plants ha^{-1}, plants were topped and the entire plants were harvested by cutting the stalks near the ground level and air cured in typical barns. At farm 2 located in Calvi (BN) plant population was 15.000 plants ha^{-1}, plants were not topped, harvesting was carried out in three primings, leaves were arranged in strings and air-cured in typical barns. At farm 3 located in Vitulazio (CE) plant population was 38.000 plants ha^{-1}, plants were not topped, harvesting was carried out in four primings, leaves were arranged in strings and air-cured in typical barns. Biometric and yield data of examined tobacco lines were registered. Analysis of variance (ANOVA) was performed using the software "STATISTICA" (StatSoft, Inc., 2005).

Results and Discussion

In each field, the six the tobacco varieties grew in the absence of black shank pressure. In table 1 the biometric data of the examined lines grown at the three farms are reported. Cured tobacco yield at BN farm 1 ranged from 1.8 to 2.7 t ha^{-1}. Significant differences among the varieties were observed for cured leaf yield. KT210LC had maximum yield while KT212LC had the lowest one (Figure 1). Cured leaf yield at BN farm 2 ranged from 2.2 to 3.9 t ha^{-1}. Statistical analysis showed significant differences among the varieties. PM35 and KT209LC had the highest, while KT212LC and BMS101 the lowest average values of cured leaf yield (Figure 2). Cured tobacco yield at CE farm 3 ranged from 2.6 to 4.6 t ha^{-1}. Significant differences among the lines were observed for cured leaf yield. PM35 had maximum yield while KT212LC and BMS101 had the lowest ones (Figure 3).

*Tab.1: Biometric parameters of the six varieties at the three farms, two neighboring located in Calvi (BN) e the other one in Vitulazio (CE), under cultivation practices (topping, harvesting and curing) usual for the farmer. Values within columns followed by the same letter were not significantly different at P< 0,05 according to Tukey's HSD test. *= plant height at last usable leaf; **=diameter at half plant height.*
*Tab.1: Principali parametri biometrici delle sei cultivar allevate presso tre aziende, due limitrofe, site a Calvi (BN) e una a Vitulazio (CE), utilizzando le pratiche colturali (cimatura, raccolta e cura) usuali per l'azienda. I valori seguiti dalla stessa lettera non sono statisticamente differenti per P< 0,05 secondo il test di Tukey's HSD. *=altezza della pianta all'ultima foglia utilizzabile; **=diametro del fusto a metà altezza della pianta.*

SITE	CV	PLANT						MIDDLE LEAF			
		HEIGHT (*)		STALK DIAMETER (**)		KNOTS		LENGHT		WIDTH	
		cm		mm		n°		cm		cm	
BN *TOPPED*	KT206	108,1	ns	36,8	a	-		62,6	ns	29,9	ns
	KT209	113,3		34,7	ab	-		63,2		29,7	
	KT210	105,9		37,5	a	-		63,0		31,3	
	KT212	111,8		30,5	bc	-		61,2		29,7	
	BMS101	105,5		28,7	c	-		58,16		27,2	
	PM35	111,5		33,3	abc	-		62,2		30,5	
BN *UNTOPPED*	KT206	211,7	ab	36,2	ab	40,2	b	62,1	b	27,8	c
	KT209	199,4	ab	36,9	ab	38,2	bc	63,6	ab	29,3	bc
	KT210	189,4	b	33,4	c	35,6	c	63,1	ab	31,1	ab
	KT212	169,6	c	32,5	d	30,7	d	63,1	ab	29,4	bc
	BMS101	200,0	ab	37,6	a	29,5	d	53,7	c	27,1	c
	PM35	215,5	a	34,9	bc	50,5	a	66,8	a	32,7	a
CE *UNTOPPED*	KT206	224,7	a	21,2	a	34,6	b	55,1	ns	24,1	ns
	KT209	215,3	a	21,5	a	36,1	b	51,0		23,5	
	KT210	196,7	b	18,6	c	37,7	b	50,0		22,8	
	KT212	183,0	b	21,1	ab	27,6	c	55,0		24,4	
	BMS101	190,9	b	18,8	bc	37,7	b	48,1		22,6	
	PM35	227,7	a	20,3	abc	42,3	a	54,2		22,9	

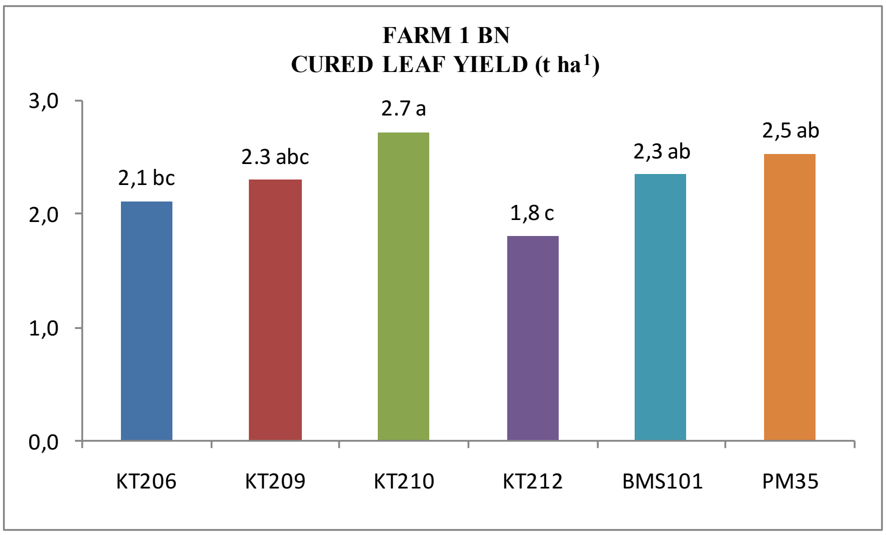


Fig.1: Average values of cured leaf yield of six the tobacco varieties at farm 1 located in Calvi (BN). Values with different letter were significantly different at P<0.05 according to Tukey's HSD test.
Fig.1: Valori medi di resa in tabacco curato delle sei varietà allevate presso l'azienda 1 sita a Calvi (BN). I valori seguiti dalla stessa lettera non sono statisticamente differenti per P<0,05 secondo il test di Tukey's HSD.

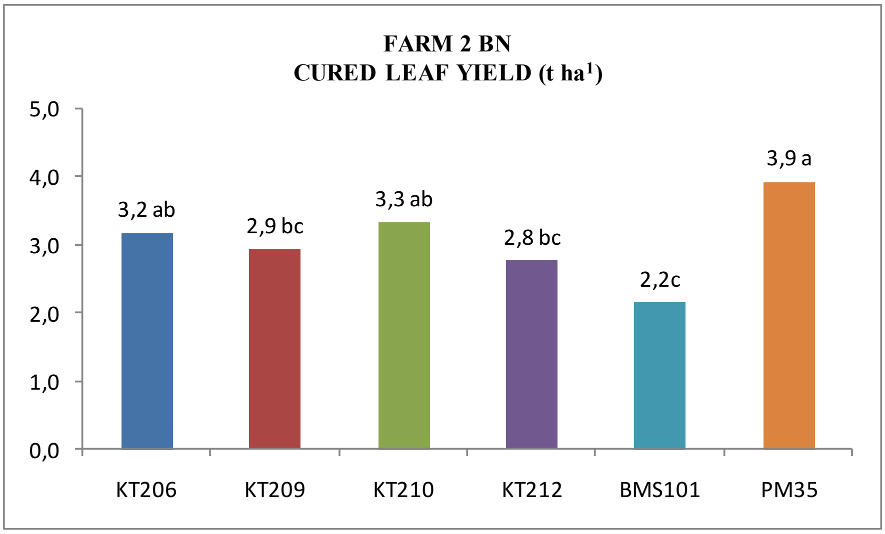


Fig.2: Average values of cured leaf yield of the six tobacco varieties grown at farm 2 located in Calvi (BN). The plants were untopped and three leaf primings were made. Values with different letter were significantly different at P<0.05 according to Tukey's HSD test.

Fig.2: Valori medi di resa in tabacco curato delle sei varietà allevate presso l'azienda 2 sita a Calvi (BN). I valori seguiti dalla stessa lettera non sono statisticamente differenti per P< 0,05 secondo il test di Tukey's HSD.

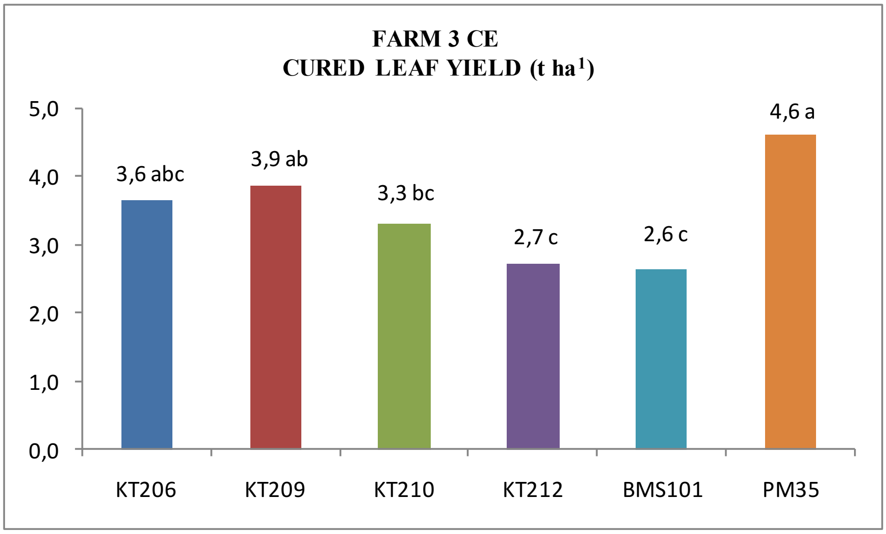


Fig.3: Average values of cured leaf yield of the six tobacco varieties grown at farm 3 located in Vitulazio (CE). Plants were untopped and four leaf primings were made. Values with different letter were significantly different at P<0.05 according to Tukey's HSD test.

Fig.3: Valori medi di resa in tabacco curato delle sei varietà allevate presso l'azienda sita a Vitulazio (CE). E' stata effettuata la raccolta e la cura a foglia su piante non cimate. I valori seguiti dalla stessa lettera non sono statisticamente differenti per P<0,05 secondo il test di Tukey's HSD.

Conclusions

In the year of trial, the black shank has not been observed in the fields where the varieties were grown. Performance of KT206LC, KT209LC, KT210LC and KT212LC varieties in North Caroline official variety test, ranged from 2.4 to 2.9 t ha^{-1} (Pearce et al., 2014). These yields are comparable to that obtained in this preliminary study. Among them, KT212LC showed the worst performance at each location, while the others showed average yields comparable to PM35. BMS101 line revealed good yield only when topped, at Calvi (BN).

References

Caiazzo et al.: Qualità del tabacco e difesa sostenibile contro i patogeni fungini. In. "Sostenibilità della coltura del tabacco in Italia". F. Ventura Editors, AMP Edizioni, 61-69, 2011.

StatSoft, Inc. (2005). STATISTICA (data analysis software system), version 7.1. www.statsoft.com.

Pearce, Robert C et al., "2015-2016 Burley and Dark Tobacco Production Guide" (2014). Agriculture and Natural Resources Publications. 162. http://uknowledge.uky.edu/anr_reports/1622015-2016 Burley and Dark tobacco production guide

ANALYSIS OF GRAIN YIELD IN THIRTY YEARS OF SOYBEAN CULTIVATION IN NORTH-EAST ITALY

TRENT'ANNI DI COLTIVAZIONE DELLA SOIA IN FRIULI: TREND PRODUTTIVO

Danuso F.[1*], Patat I. [1], Signor M. [2], Valdevit F. [1], Ceccon P.[1], Baldini M. [1]

[1] Department of Agrifood, Environmental, and Animal Sciences University of Udine, via delle Scienze 206, 33100 Udine
[2] ERSA – Agenzia Regionale per lo Sviluppo Rurale del Friuli Venezia Giulia, Servizio fitosanitario e chimico, ricerca, sperimentazione e assistenza tecnica, via Sabbatini 5, 33050 Pozzuolo del Friuli (UD).
[*] francesco.danuso@uniud.it

Abstract
This study analyses grain yields of soybean monitored in the variety trials performed in North-East Italy from 1983 to 2015 by ERSA FVG in order to evaluate the existence of yield trends and how inter-annual yield oscillation could be explained either by meteorological, genetic or agronomic factors. In this period, about 400 varieties have been tested and, despite of agricultural inputs reduction and little change of genotypes, statistical analysis underlines an average yield increase of about 30 kg ha^{-1} year^{-1}. The regression analysis suggests that the average daily thermal excursion explains inter-annual yield variations much more than other environmental variables (rain and soil characteristics). In conclusion, the higher yields observed in the last years seem mostly due to both environmental conditions and improved cultivation techniques.

Keywords: soybean yield, trend, climate, agricultural practices, variety.
Parole chiave: resa soia, trend, clima, tecniche agronomiche, varietà.

Introduction
In Italy, soybean cultivation heavily started only after the recognition of its strategic importance by the EU during the '70. Ten years later, crop management techniques were deeply studied and adapted to most Italian environments in the framework of "Progetto Oleaginose", funded by MAF (now MIPAAF, Ministero delle Politiche Agricole Alimentari e Forestali). Since 1983, Friuli Venezia Giulia (North-East of Italy) was among the Italian regions with the highest densities of soybean cultivation, as well as the highest grain yield per ha. Moreover, together with an intensive testing of soybean varieties, ERSA (Agenzia Regionale per lo Sviluppo Rurale del Friuli Venezia Giulia) also carried out breeding programs leading to the release of several successful soybean varieties.
This work provides an analysis of the thirty-year ERSA results of soybean variety trials, with the purpose of investigating trends and variability in soybean grain yield. Another topic of the work is to improve the knowledge about the driving forces of these variations, considering that soybean yields are the result of multiple interactions of genetic, pedo-climatic and agronomic factors.

Materials and methods
Experimental trials
Soybean yield data (t ha^{-1}, 13% of moisture), of the national variety trials carried out from 1983 to 2015, were recovered from the archives of ERSA FVG. The trial sites were located in the Friuli Venezia Giulia plain, in the provinces of Udine and Pordenone. The trial locations and their soil characteristics are reported in figure 1 and table 1, respectively. The experimental plots were arranged in either randomized blocks (4 replications) or complete randomization (5-6 replications) design. Plant density ranged from 35 to 45 plants m^{-2}. The sowing date ranged from 24/04 (Palazzolo, 2007) to 12/06 (Palazzolo, 2013), with most of the sowing times in May; harvest occurred from 22/09 (Palazzolo, 2011) to 17/11 (Pozzuolo, 1994) with most of the harvests in October. Irrigation was generally applied two or three times (supplementary irrigation), depending on the rainfall frequency and amount. Treatments for pests control were occasionally applied. Weed control was performed by pre- and post-emergence herbicide treatments. Soil fertilization (about 25 kg ha^{-1} N, 100-120 kg ha^{-1} P_2O_5 and 100-120 kg ha^{-1} K_2O) was made until 1998; in the following years, no fertilizers were applied. Seeds were always inoculated with the specific rhizobium, in order to ensure a good nodulation and N-fixation.

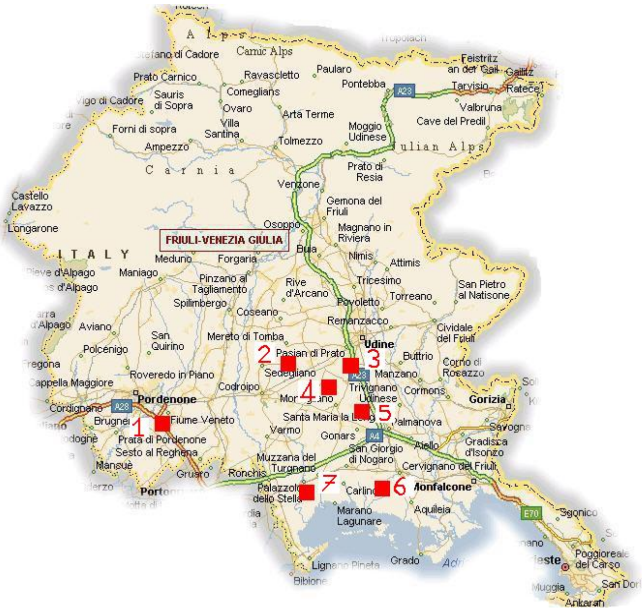


Fig. 1: Location of the trial sites.
Fig. 1: Localizzazione dei siti sperimentali.

In most cases, previous crop was maize; less frequently, sugar beet, soybean, barley and wheat. About 400 varieties, selected from those registered in the Italian Registry of varieties, were tested in the thirty-year period; until 2000, tested varieties belonged to maturity groups ranging from 00 to II, afterwards, to maturity groups ranging from 0+ to I+.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Meteorological and soil data

The following meteorological variables have been retrieved from the regional meteorological service (OSMER) dataset: daily rainfall (mm d^{-1}), daily minimum and maximum air temperature (°C); daily thermal excursion (°C) has been calculated as a proxy for solar radiation, not available for all years. Cumulated rainfall (*Rain*, mm/period) and mean thermal excursion (*ΔT*, °C) for each month from April to August, and for the whole period, have been calculated per each experiment (year x site).

Tab. 1: Trial sites and main soil properties.
Tab. 1: Siti di prova e principali caratteristiche pedologiche.

Trial site	Organic matter [% v/v]	Wilting point [% v/v]	Field capacity [% v/v]	Max. water content [% v/v]	CSC [mEq/ 100g]	Texture class (USDA)
1 FiumeVeneto	2.6	21.8	28.1	48.2	30.3	silty-loam
2 Basiliano	2.6	14.1	19.1	42.0	26.5	loam
3 Pozzuolo d.F.	2.6	22.0	28.8	48.2	36.0	clay-silty-loam
4 Mortegliano	2.3	15.0	21.1	41.2	26.0	silty-loam
5 Bicinicco	6.6	17.7	24.4	51.3	37.4	loam
6 Torviscosa	2.4	15.9	22.0	43.8	30.4	loam
7 Palazzolo d.S.	2.4	16.6	24.1	47.2	29.8	silty-loam
Mean	3.1	17.6	23.9	46.0	30.9	-

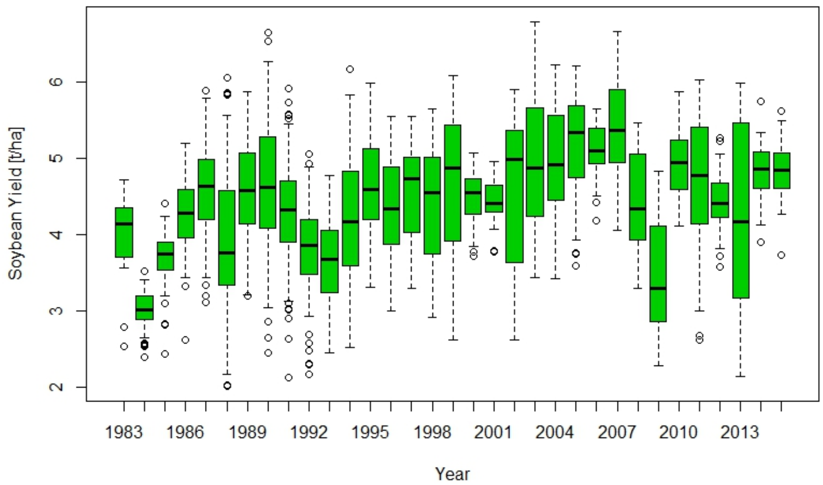


Fig. 2: Boxplot of soybean grain yield distribution (t ha^{-1}) of all cultivar tested in all the sites, in each year.
Fig.2: Boxplot delle distribuzioni delle rese (t ha^{-1}) di tutte le varietà di soia in prova per tutti gli ambienti, per ciascun anno.

Statistical analysis

In figure 2, boxplots return the variability of soybean yields per year, for all varieties and sites. The lower and upper limits of each box represent, respectively, to the first and third quartile of yields, while the black strip indicates the median. Dots represent the outliers. The graph emphasizes a large variability of soybean yields in the period. In some years (e.g. 1983, 1997, 1999 and 2010), the upper half of the boxes is shorter that the lower, meaning that in these years high yield values are more similar than the lower ones. In other years (e.g., 1988, 2001, 2009) a reverse behaviour occurred. For these reasons, in the present study only the third quartile of soybean yields (*Yield3q*) has been tested to underline the presence of a trend over the years. These values were analysed using multiple regression models involving the variable *Year* and the available meteorological variables, calculated for each month of the soybean growing season (April-August) and for the whole period, as previously described, in order to better understand the role of these variables.

Furthermore, three indexes have been calculated in order to evaluate the rate of cultivars turn-over in the years: (a) rate of drop (*Raba*=*Na*/*Nv*), (b) rate of introduction of new varieties (*Rnew*=*Nn*/*Nv*), and (c) rate of cultivar change (*Rcvc*=(*Na*+*Nn*)/*Nv*), where, for each year, *Na* is the number of varieties no more tested, *Nn* the number of newly introduced varieties and *Nv* the total varieties tested each year.

Results and discussion

A first order regression model between the third quartile of soybean yields and the variable *Year* provides the evidence of an annual trend (figure 3). Both the intercept and the explicative coefficients are significant (p-values are respectively 0.0007 and 0.0003) even if the explained variability is very low (R^2 = 0.17). The estimated regression coefficient for the variable *Year* indicates an average yield increase of about 31 kg ha^{-1} per year. This result agrees with data obtained in USA, showing a mean annual yield increase of 25 kg ha^{-1} (Irwin and Good 2014).

To assess the effect of meteorological conditions on yield variations (beside year), a multiple regression model, calculated per each month of the soybean growing season, has been estimated.

[illegible]

The significance of the estimated coefficents and the RMSE of regression models are presented for each month in table 2. As expected, the estimated coefficients for the variable *Year* are always significant, accordingly to the trend described before. The estimated coefficients for the variable *Rain* are significant only in the months of April and May and not in June and July. This result could be explained considering that soybean is sensitive to drought even at the early stages (mainly due to the symbiosis with rhizobium) and that the supplemental irrigations were usually applied during the flowering and accumulation stages, occurring from late spring to summer, when the correlation with rain was not found. Thermal excursion ([illegible]) significantly contributes to the explanation of yields in all months other than August. Considering that thermal excursion is correlated to the

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

availability of solar radiation, this variable could be considered as a proxy of this physical quantity. Actually, in the last years, an increase of global solar radiation from maximum values of 25 to about 30 MJ m^{-2} d^{-1} was observed due to climatic changes.

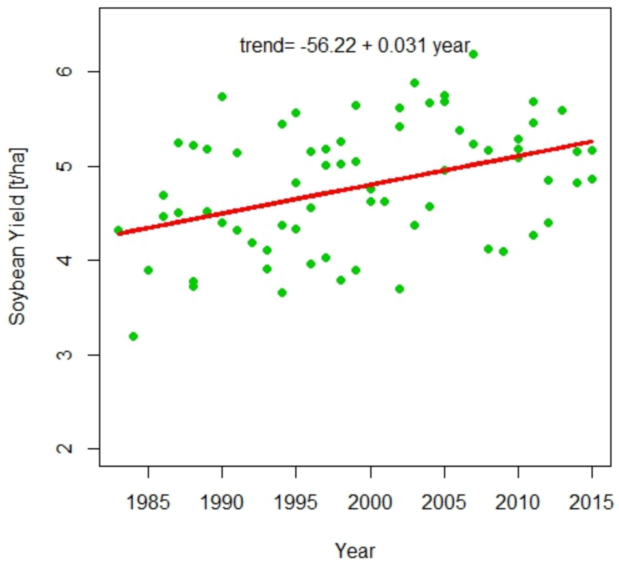


Fig. 3: Yield trend of third quartile.
Fig. 3: Andamento della produttività negli anni (terzo quartile).

Tab. 2: Statistical significance of the multiple regression parameters related to the different meteorological variables.
Tab. 2: Significatività statistica dei parametri della regressione multipla relativi alle diverse variabili meteorologiche.

Month	Year	Rain [mm $month^{-1}$]	ΔT [°C]	RMSE [t ha^{-1}]
April	***	**	***	0.576
May	***	*	**	0.596
June	***	ns	*	0.613
July	*	ns	***	0.597
August	***	ns	ns	0.626

Varietal changes are represented in figure 4 with the indexes *Rcvc*, *Raba* and *Rnew*. During the '80 and the early '90 a wide introduction of new soybean varieties occurred, as demonstrated by high values of all indexes. Since 2000, the number of dropped varieties and new introductions in the trials decreased. It is likely to argue that this reveals the identification of the most suitable soybean varieties for FVG environmental conditions.

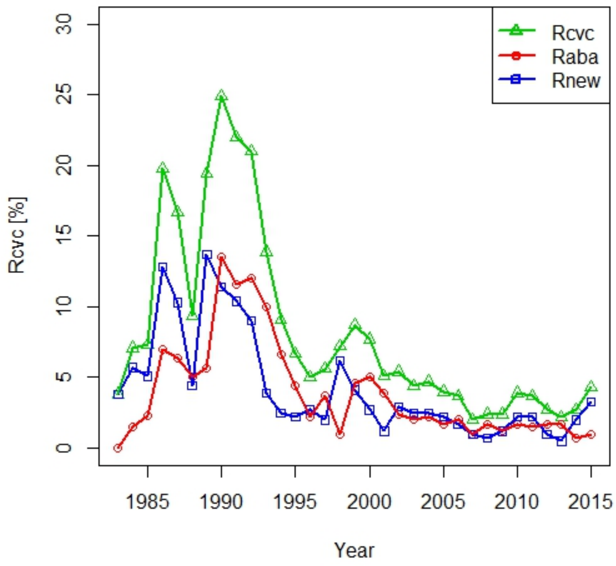


Fig. 4: Rate of varietal change (Rcvc), varietal abandon (Raba), and varietal new introduction (Rnew) per year.
Fig. 4: Tasso di cambio varietale, abbandono varietale e di nuove introduzioni per anno.

Conclusions

A first attempt to analyze the evolution of soybean yields in the last 30 years in Friuli Venezia Giulia region has been made. It highlights the presence of an increasing annual trend in soybean yields. Regression analysis showed the importance of water availability in April (owing to soybean sensitivity to water shortage in the early stages due to less N-fixing activity) and of global radiation in summer.
Statistical models developed to explain the variability of yields around the trend contribute in defining the role played by the explicative variables, even if a satisfying level of knowledge is not still completely achieved. Future perspectives can involve other meteorological, soil and agronomic variables towards a better understanding of the phenomenon.
In conclusion, the significant yield increase observed in the last thirty years seems not be due to the genetic improvement (with a limited variety change after 2000), but mainly to better agricultural practices and, perhaps, to increased solar radiation. Moreover, the validation of meteorological datasets could represent a starting point for future improvements of the regression models and for new related approaches.

References

Irwin S., Good D., 2014. The 2014 U.S. Average Corn Yield: Big or Really Big?. Farmdoc Daily, 4: 127.

Acknowledgements

Many thanks are due to ERSA (Ente Regionale per lo Sviluppo Rurale del Friuli Venezia Giulia) for making available the original data of the soybean variety trials, obtained in the years by Marco Signor, Giorgio Barbiani, Mariolino Snidaro (✝) and Stefano Barbieri. Moreover, OSMER-ARPA is to be acknowledged for meteorological data and the kind promptness of Andrea Cicogna.

MODELLING AUTUMN PRODUCTION OF MEDITERRANEAN PASTURES UNDER VARIABLE RAINFALL REGIMES

SIMULAZIONE DELLA PRODUZIONE AUTUNNALE DEI PASCOLI MEDITERRANEI A DIFFERENTI REGIMI PLUVIOMETRICI

Antonio Pulina*, Laura Mula, Giovanna Seddaiu, Pier Paolo Roggero

Dipartimento di Agraria e Nucleo di Ricerca sulla Desertificazione, Università degli Studi di Sassari
* anpulina@uniss.it

Abstract
Grasslands considerably contribute to agricultural production under Mediterranean conditions. In extensive dairy sheep grazing systems based on autumn-lambing, autumn pasture production is important for feed availability in the farms, with relevant consequences for farming management choices. In this study, a multi-year simulation ensemble of PaSim and EPIC models was performed in order to assess the impacts of three different autumn rainfall regimes (present, SCN1; -20%, SCN2; -50%, SCN3) on autumn pasture production. A 50% reduction of autumn rainfall could severely constrain the autumn pasture production (-48% than SCN1) and interannual variability (24.6% and 56.3% in SCN1 and SCN3, respectively). The analysis put in evidence that a severe reduction of rainfall regimes could result in changes of dairy sheep farms management. The results of this study highlight the suitability to use simulation models as tools able to identify and evaluate adaptation options in a climate change context.

Keywords: Mediterranean Grassland; EPIC; PaSim; Scenario Analysis; Climate Changes
Parole chiave: Pascoli mediterranei; EPIC; PaSim; Analisi di Scenario; Cambiamenti Climatici

Introduction
Grassland systems, which cover 50% of European Mediterranean areas (Cosentino et al., 2014), significantly contribute to provide livestock feed and ecosystem services (EIP-AGRI, 2016) in the Mediterranean basin. The grassland vegetation is dominated by therophyte species, characterized by a long-term persistence mechanism relying on autumn self-reseeding under varying rainfall and temperature patterns (Porqueddu et al., 2016). The annual biomass production is strongly related to the autumn production (Cavallero et al., 1992). The autumn growth rates and forages availability are constrained by summer drought duration and by the high variability of autumn precipitation regimes (Golodets et al., 2015). Furthermore, the autumn pasture production has considerable importance in the context of dairy sheep farms based on autumn-lambing (Molle et al., 2008). The high interannual variability of autumn grassland productivity required further insights on the relationship between biomass production and climatic predictors as rainfall patterns, also considering the uncertainty linked to the ongoing climate change. The use of predictive models allows to assess at a large temporal scale how the interaction of the multiple environmental sources affects the autumn biomass production under different climatic scenarios (Kipling et al., 2016). The aim of this study is to assess how different rainfall patterns scenarios in Mediterranean grassland systems can influence i) the autumn biomass production and its variability and ii) the relationship between rainfall distribution and the herbage offer to grazing animals in autumn.

Materials and Methods
The study site was the Berchidda-Monti Long Term Observatory (NE Sardinia, Italy) (40° 49’ N, 9° 18’ E, 300 m a.s.l.). The mean annual rainfall is 632 mm, concentrated from October to March, and the mean annual temperature is 14.2 °C. Soil type is *Typic Dystroxerept* (Seddaiu et al., 2013). In the study site, grassland is the prevalent land use including dairy sheep grazing systems (Caballero et al., 2009).
A simulation study was performed using two different models: the biogeochemical grassland-specific PaSim model (Riedo et al., 1998) and the crop model EPIC (Williams, 1995), both properly calibrated and validated in previous studies (Mula, 2014; Pulina et al., 2017). Starting from the current historical daily weather time-series (1973-2013), three daily weather scenarios of 50 years were generated (Table 1) from the climate generator WXGEN (Nicks et al., 1990).
Models were run in a multi-year simulation to generate daily values of standing dry matter biomass (DM, Mg ha^{-1}) and 0.03 m depth soil water content (SWC, m^3 m^{-3}). The autumn pasture yield (APY) was considered as the simulated DM at December 21st of each year. For each year, the day of the year after September 1st when the SWC started to be higher than the 50% of soil total available water (0.12 m^3 m^{-3}) for at least four consecutive days (Start Day, STD) was identified. The obtained values from both PaSim and EPIC of APY and STD were aggregated by using the average value of simulated data for each scenario. For each scenario, indices of central tendency, coefficient of variation (CV) and relative frequency distribution of APY were computed. The relationship between APY and STD were evaluated by interpolating a linear regression model. The ANOVA was performed in order to test the regression significance and the differences between models.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Tab.1 – Characteristics of 50-years weather scenarios used in the simulation processes and WXGEN involved parameters
Tab. 1 – Caratteristiche degli scenari climatici e parametri di WXGEN considerati

	WXGEN Parameters		
Name	**Monthly PRCP**	**Monthly PW|D**	**Monthly PW|W**
Stable Weather (SCN1)	present	present	present
Weather Scenario 2 (SCN2)	-20% actual	+20% actual	-20% actual
Weather Scenario 3 (SCN3)	-50% actual	+50% actual	-50% actual

PRCP: Monthly amount of precipitation (mm)
PW|D: Monthly probability of wet day after dry day
PW|W: Monthly probability of a wet day after a wet day

Results and Discussion

A rainfall reduction of 28% and 56% was observed in the autumn months (Sep-Dec) in SCN2 and SCN3, respectively. The differences between scenarios in terms of average values of monthly maximum and minimum temperatures were negligible (Fig.1).

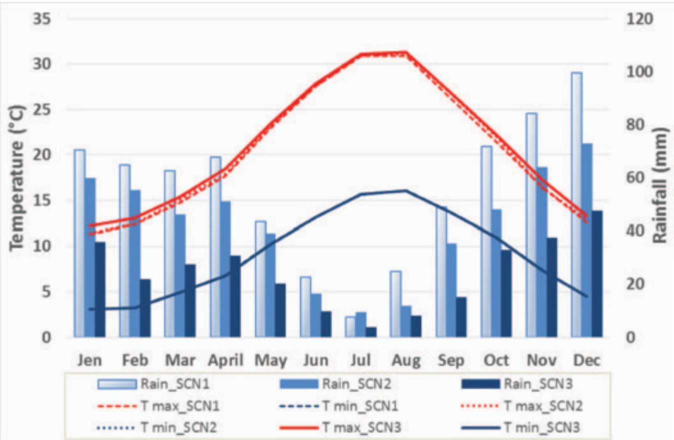


Fig.1 – Monthly average values of maximum and minimum air temperature (T max and T min, °C) and rainfall (Rain, mm) in the three climatic scenarios
Fig. 1 – Medie mensili delle temperature massime e minime (T max e T min, °C) e precipitazioni (Rain, mm) nei tre scenari climatici)

The average APY in the 50-years scenarios was 1.30±0.3, 1.22±0.4 and 0.67±0.4 Mg ha^{-1} in SCN1, SCN2 and SCN3, respectively (Fig.2). The APY frequency distribution highlighted a higher interannual variability in terms of CV in SCN3 (56.3%) than SCN2 (CV=35.4%) and SCN1 (CV=24.6%) and (Fig.3).

The median values of STD were 20 (September 20th), 26 (September 26th) and 42 (October 12th) in SCN1, SCN2 and SCN3, respectively. A significant linear regression (P<0.001) between APY and STD were observed for each treatment. The scenarios did not affect the slope of the regression, while the intercept value in SCN3 function was significant lower than SCN1 and SCN2.

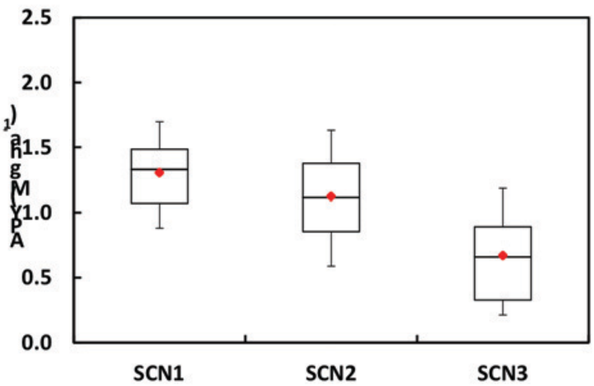


Fig.2 – Values of mean (red point), median (line), 1st and 3rd quartile (box) and 95% upper and lower confidence interval (bars) of Autumn Pasture Yield (APY, Mg ha^{-1}) in the considered climatic scenarios
Fig. 2 – Media (punti rossi), mediana (linea), primo e terzo quartile (box) e limite superiore e inferiore dell'intervallo di confidenza al 95% (barre di errore) della produzione autunnale del pascolo (APY, Mg ha^{-1}) negli scenari climatici considerati.

These results confirmed that different autumn rainfall patterns can affect the autumn herbage offer to grazing animals as observed previously by other scholars (Gea-Izquierdo et al., 2009). Under Mediterranean conditions, a reduction of about 20% of monthly rainfall amount could not represent a severe limitation in terms of average APY (-13%), but the greater interannual variability than SCN1 could lead to a higher uncertainty in terms of available fresh forage provision. A rainfall reduction of about 50% resulted in a APY reduction of 48%. Furthermore, the rainfall amount decrease caused a 20-days shift in the occurrence of useful rain, which in turn could lead to both a lower biomass

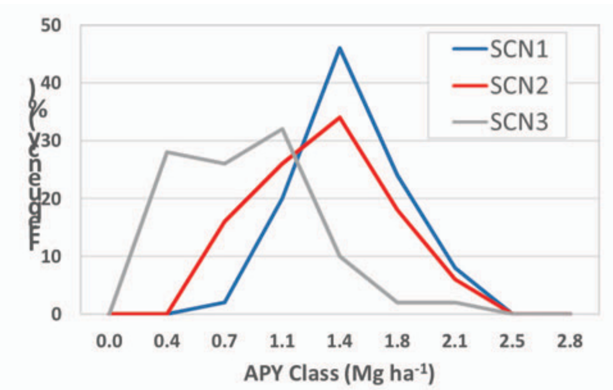


Fig.3 – Frequency distribution (%) of Autumn Pasture Yield (APY, Mg ha^{-1}) in the considered climatic scenarios
Fig. 3 – Distribuzione di frequenza (%) della produzione autunnale del pascolo (APY, Mg ha^{-1}) nei tre scenari climatici considerati.

production and a larger yield variability. In fact, as the 20% of rainfall reduction did not cause changes in the relationship between APY and STD, the stronger aridity under SCN3 determined a different response in terms of pasture production to the increase of SWC availability. This result suggested that under Mediterranean conditions a 50% reduction of rainfall regimes could have strong impacts on management options in the context of the dairy sheep farms based on autumn-lambing (Todaro et al., 2015).

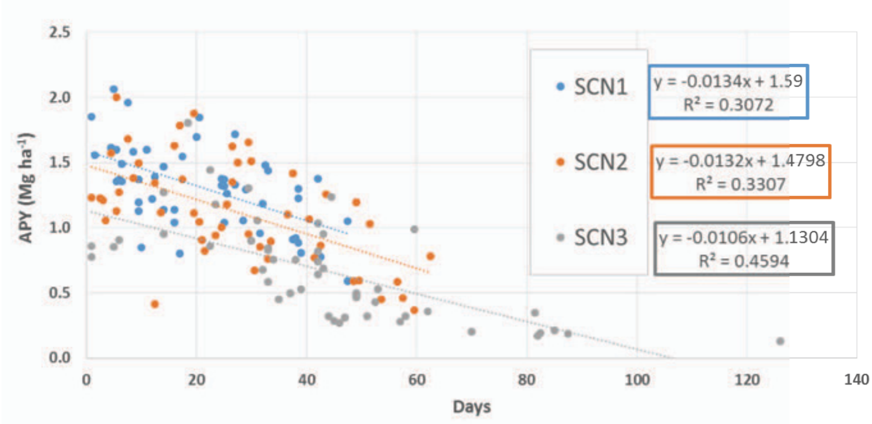


Fig.4 – Relationship between Autumn Pasture Yield (APY, Mg ha^{-1}) and STD Day (days) in the considered climatic scenarios.
Fig. 4 – Relazione tra produzione autunnale del pascolo (APY, Mg ha^{-1}) e n. giorni STD nei tre scenari climatici considerati.

Conclusions

The 50% reduction of the rainfall patterns in Mediterranean environment could lead to severe changes in autumn biomass production. This result highlights the need to identify adaptation options for the dairy sheep farms in a context of climate change. This contribution put in evidence the suitability of models as supporting decision tools for their ability to explore wider temporal ranges and their variability.

References

Caballero R., Fernandez-Gonzalez F., Badia R. P., ..., 2009. Grazing systems and biodiversity in Mediterranean areas: Spain, Italy and Greece. Pastos, 39: 9-152.

Cavallero A., Talamucci P., Grignani C., …, 1992. Caratterizzazione della dinamica produttiva di pascoli naturali italiani. Rivista di Agronomia, 26: 325-343.

Cosentino S.L., Porqueddu C., Copani V., …, 2014. European grasslands overview: Mediterranean region. In "Grassland Science in Europe, Vol. 19 - EGF at 50: The Future of European Grasslands". Proceedings of the 25th General Meeting of the European Grassland Federation, Aberystwyth, Wales (UK), 7-11 September 2014" (Hopkins A., et al., eds.), Vol. 50, pp. 41-56.

EIP-AGRI, 2016. Profitability of permanent grasslands. Final Report. https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eipagri_fg_permanent_grassland_final_report_2016_en.pdf

Gea-Izquierdo, G., Montero G., Cañellas I., 2009. Changes in limiting resources determine spatio-temporal variability in tree–grass interactions. Agroforestry Systems, 76: 375-387.

Golodets C., Sternberg M., Kigel J., …, 2015. Climate change scenarios of herbaceous production along an aridity gradient: vulnerability increases with aridity. Oecologia, 177: 971-979.

Kipling R.P., Bannink A., Bellocchi G., …, 2016. Modeling European ruminant production systems: Facing the challenges of climate change. Agricultural Systems, 147: 24-37.

Molle G., Decandia M., Cabiddu A., …, 2008. An update on the nutrition of dairy sheep grazing Mediterranean pastures. Small Ruminant Research, 77: 93-112.

Mula L., 2014. Adaptation strategies of Mediterranean cropping systems to climate change. PhD Thesis, University of Sassari, Sassari, IT.

Nicks A., Richardson C., Williams J., 1990). Evaluation of the EPIC model weather generator. In "EPIC—erosion/productivity impact calculator" (Sharpley A. and Williams J. eds.), Vol. 1, pp. 105-124.

Porqueddu C., Ates S., Louhaichi M., …, 2016. Grasslands in 'Old World' and 'New World' Mediterranean-climate zones: past trends, current status and future research priorities. Grass and Forage Science, 71: 1-35.

Pulina A., Lai R., Salis L., …, 2017. Modelling pasture production and soil temperature, water and carbon fluxes in Mediterranean grassland systems with the Pasture Simulation Model. Grass and Forage Science, in press, DOI:10.1111/gfs.12310

Riedo M., Grub A., Rosset M., …, 1998. A pasture simulation model for dry matter production, and fluxes of carbon, nitrogen, water and energy. Ecological Modelling, 105: 141-183.

Seddaiu G., Porcu G., Ledda L., …, 2013. Soil organic matter content and composition as influenced by soil management in a semi-arid Mediterranean agro-silvo-pastoral system. Agriculture, Ecosystems & Environment, 167: 1-11.

Todaro M., Dattena M., Acciaioli A., …, 2015. Aseasonal sheep and goat milk production in the Mediterranean area: Physiological and technical insights. Small Ruminant Research, 126: 59-66.

Williams J., 1995. The EPIC model. In "Computer models of watershed hydrology" (Singh V., ed.), pp. 909-1000. Water Resources Publications, Highlands Ranch.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

WHICH PROSPECTS FOR LIGNOCELLULOSIC CROPS FORBIOGAS IN ITALY?

QUALI PROSPETTIVE PER IL BIOGAS DA COLTURE LIGNOCELLULOSICHE IN ITALIA?

Federico Dragoni[1a*], Ricardo Villani[1a], Alberto Mantino[1], Enrico Bonari[1,2], Giorgio Ragaglini[1,2]

[1] Istituto di Scienze della Vita, Scuola Superiore Sant'Anna, P.zza Martiri della Libertà 33, 56127 Pisa, Italy
[2] CRIBE - Centro di Ricerche Interuniversitario Biomasse da Energia, Via Vecchia Livornese 748, 56122 Pisa, Italy
[a] - These authors equally contributed to this study
*federico.dragoni@santannapisa.it

Abstract

A GIS-based study was carried out to assess the spatial correlation of anaerobic digestion with livestock raising in Italy and to highlight where it is weaker, and to compute biomass demand basing on the former biogas Italian regulation and on its evolution (DM 18/12/2008, DM 6/7/2012). The aim was to estimate the land use under various scenarios and to estimate potential needs for alternative feedstock (i.e. *Arundo donax* L.) to partially replace annual crops. The analysis was carried at NUTS-3 scale taking into account experimental data (i.e. biochemical methane potentials), statistical data and giant reed yields modeled over arable lands in Italy.

On average, the land use for biogas ranged from 1.55% to 5.43%. Considering animal effluents, it was found that they were sufficient to fulfill the demand for primary energy only in a few provinces, while they were not sufficient in most part of Italy. Generally, crops would need to cover less than 30% of the required feedstock. In some provinces a wider gap between energy demand and availability (effluents + crops) existed. About 68,000 hectares of giant reed, mostly spread in parts of the Po Valley, Friuli-Venezia Giulia, Tuscany and Southern Italy, would cope with this gap.

Keywords: perennial grasses; anaerobic digestion; GIS; cropping scenarios
Parole chiave: colture erbacee perenni; digestione anaerobica; GIS; scenari colturali

Introduction

The agricultural sector can supply biomass to be transformed into energy and bioproducts, in order to supply raw materials for a bio-based and circular economy. In this context, anaerobic digestion (AD) is one of the most mature technologies for bioenergy, well widespread and very suited for byproducts reuse. However, not only byproducts, but also biomass from arable crops is widely used for AD in Italy and in Europe, which may arise concerns about the sustainability of green maize and other annual crops for feeding AD plants. This is particularly so in Mediterranean countries, because maize requires from 3,000 up to 5,000 m^3 ha^{-1} of irrigation water in order to achieve acceptable yields (Noya et al., 2015). Moreover, those high demanding crops require very fertile soils, thus increasing the direct competition with food crops and opposing the need for "biomass from marginal lands" expressed by the European 'Bioeconomy Strategy' (EC, 2012). Although AD is particularly suited for energy production from animal slurries and other agricultural wastes, many AD plants in Italy have been oversized compared with the actual availability of these feedstocks, due to encouraging subsidies provided for by the Italian regulation until 2013. As a consequence, green maize became an important resource also where it is not cultivated under optimal conditions, but the circular economy provided by AD in these areas is at risk for economic (i.e. rising costs), environmental (i.e. lacking water) and regulatory reasons (i.e. regulatory shifts).

In the last few years, several studies addressed the question whether the use of perennial grasses for AD could allow to reduce costs for feedstock supply and to mitigate the competition with food and feed crops (Barbanti et al., 2014; Corno et al., 2015; Ragaglini et al., 2015). The objectives of this work were: (i) to assess the spatial correlation of AD with livestock raising in Italy and to highlight where this correlation is weaker; (ii) to calculate biomass budgets in compliance with the Italian regulation (DM 18/12/2008 *vs* DM 6/7/2012, i.e. pre- *vs* post-2013) and estimate the land use due to arable crops dedicated to AD; (iii) to estimate the potential future need for alternative feedstock, considering giant reed (*Arundo donax* L.) as a candidate lignocellulosic crop for AD.

Materials and Methods

Correlations between farming and husbandry data and AD plants per province (NUTS-3 level) were elaborated from ISTAT (2012) and GSE (2016) data. The land used to produce green maize and triticale for AD in Italy was estimated at province level, considering the installed power of the AD plants operating until 2016 and the potential biomethane yield per hectare of each crop, computed from the biochemical methane potential obtained from batch assays and from statistical crop yield data obtained from ISTAT. A similar approach was used for the estimation of biomethane potentials from animal manures and slurries per province: livestock data (i.e. cattle and pigs) were considered along with biochemical potentials of these substrates. The amount of animal effluents produced by livestock was calculated according to ENAMA (2012). Since little information is available about giant reed yields across Italy, forecasted yields from this crop were considered (Ragaglini et al., 2015). The biochemical potential of ensiled giant reed obtained under single harvest management was also taken into account.

All these data considered, three land use scenarios were defined at province scale, according to the framework defined by the Italian regulation:

* SC1 – biomass from dedicated annual crops (maize = SC1m; triticale = SC1t) does not exceed 30% of the feedstock needed to fuel the installed power, as stated by the DM 6/7/2012;
* SC2 - biomass from dedicated annual crops (maize = SC2m; triticale = SC2t) does not exceed 50% of the feedstock needed to fuel the installed power in pre-2013 plants (DM 18/12/2008), while it does not exceed 30% in newer plants (DM 6/7/2012);
* SC3 – biomass from dedicated crops was considered in the case animal effluents are not sufficient to fuel the installed power; where not sufficient, dedicated annual crops are grown up to 30% of the feedstock needed to fuel the installed power; where an energy gap is still observed, modeled giant reed yield are taken into account and land use for giant reed (Tab. 1-B of the DM 6/7/2012) is calculated.

Results and Discussion

As expected, the highest biogas installed power is located where intensive livestock farming systems are prevailing. Thus, a positive correlation was observed between installed power and most of livestock categories, with the exception of those that are less intensively raised. Moreover, positive correlations were found also with average green maize yields per province and arable land used for green maize per province (Table 1). From 2013 to 2016, an increase in the number of plants was observed (+ 16%), but the most part of the new plants was set up in Northern Italy, while in Central and Southern Italy older plants (pre-2013) are prevailing. Moreover, from 2013 to 2016 the total installed power grew by 3.5% only, since the average power of the new plants was rather low (<250 kWe)(Figure 1).

Tab. 1: Correlation matrix between farming and husbandry data and AD plants per province (elaborated from ISTAT, 2012).
Tab. 1: Matrice di correlazione (r tra attività agricole e zootecniche e potenza installata dei digestori anaerobici a scala provinciale (elaborato da ISTAT, 2012)

	Correlation coefficients	p-value
Green maize hectares	0.54	***
Green maize yields	0.55	***
Livestock units[1] - cattle	0.45	***
Livestock units[1] - dairy cattle	0.47	***
Livestock units[1] - pigs	0.72	***
Livestock units[1] - buffaloes	0.12	ns
Livestock units[1] - sheeps	-0.03	ns

[1] Unità di Bestiame Adulto
***p< 0.001, **p< 0.01, *p< 0.05

In the most conservative maize-based scenario (SC1m), the land used for AD never exceeded 10% of the available arable land per province, owing to the 30% limit to dedicated biomass crops and to the high yielding potential of maize. This threshold is potentially exceeded only in provinces where the installed power is very low (<5 MWe) and the available arable land is the lowest (<30,000 ha). Considering the other provinces (>5 MWe), the highest percentages of use of arable land for biogas production was found in the provinces of Pavia, Lodi, Cremona and Novara, ranging from 5% to 10%.

In SC1, the rest of the Northern Italy showed land use percentages below 5%, while Central and Southern Italy always showed values below 2.5%. Overall, approximately 125,500 hectares of arable land out of a total of 8.1 million hectares would be addressed to biomass production for biogas under this scenario (~1.55%). In the triticale-based scenario (SC1t), a large part of Northern Italy approached the 10% threshold, while it was consistently exceeded in the provinces where biogas production is more relevant. In the Southern Italy, only Caserta province showed a high land use level (about 9%). At national level, up to 270,000 hectares of arable land would be involved in biogas production under this scenario (~3.30%) (Figure 2). Although land use would be higher than in SC1m, triticale was also considered in this analysis because, as a winter crop, it does not require irrigation and it can be rotated with maize. Moreover, this species can be

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

grown in double cropping with maize or other spring crops, although such an intensification of the cropping system is very dependent on local conditions (e.g. availability of irrigation water, availability of machinery and tillage timeliness) and was not considered in this study.

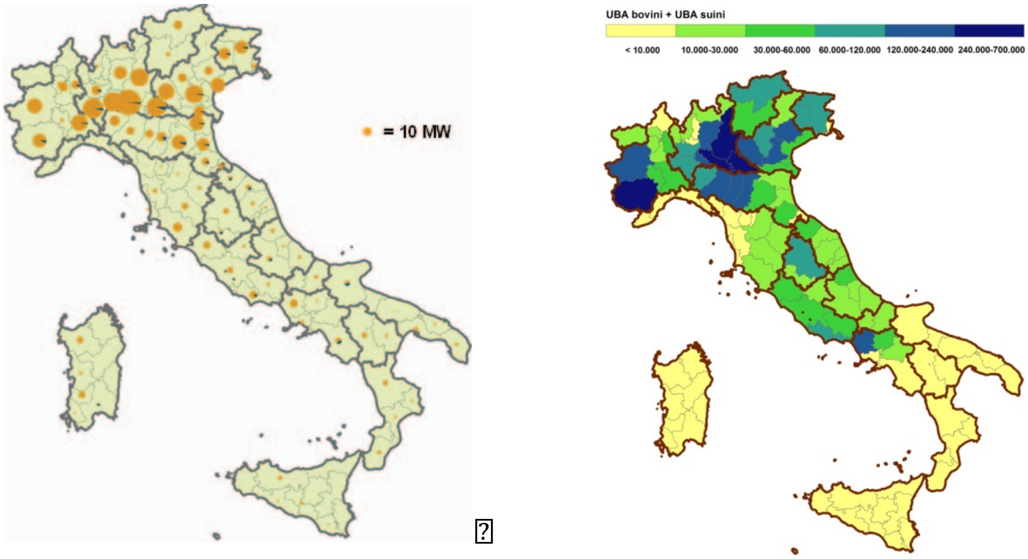


Fig. 1: Left – Biogas installed power at province scale in Italy; plants set-up before 2013 are in orange, while the installed power of the newer ones is in blue; right – Number of Livestock Units (bovine and pigs)
Fig. 1: Sinistra – Consistenza provinciale delle potenze elettriche installate degli impianti a biogas in Italia; in arancio le installazioni precedenti il 2013, in blu quelle successive; destra – Unità Bestiame Adulto (bovini e suini).

In SC2 scenarios, the potential land use was generally much higher. By using maize silage up to 50% of the biomass demanded by pre-2013 plants, several provinces approached the 10% threshold, while some provinces in the North (Cremona, Novara, Lodi and Brescia) largely exceed it. In SC2m scenario, the arable land used at national level would be about 206,600 hectares (~2.55%). Due to its lower yields, the adoption of triticale to fully replace maize would increase the land use. In Central and Southern Italy, the arable land use for biogas generally approached 5%. In particular, a potential land use of about 10% was found in Latina, Sassari and Salerno provinces, while Caserta was the only province in which this threshold was exceeded and the installed biogas power was >5 MWe. In SC2t scenario, the arable land used in Italy would be about 440,000 hectares (~5.43%) (Figure 2).
Considering future developments of the biogas sector, we can hypothesize that the land use of the SC1 scenarios will not be exceeded, while the use of byproducts and slurries will be maximized, thus potentially leading to different outcomes depending on the availability of such products at local scale. In fact, the Italian provinces largely differ for their availability of animal effluents. The highest biogas potentials from livestock effluents were found in the provinces of Brescia, Cuneo, Mantova, Cremona and Torino. In these provinces, the potential from animal effluents exceeded the primary energy demand from biogas plants, with the only exception of Cremona, in which 51% of the energy demand was reached. In fact, in the SC3 scenario animal effluents were not sufficient to fulfill the demand for primary energy of the biogas plants in the most part of Italy, thus leading to crop cultivation, although generally below the 30% threshold. However, in some provinces a gap between energy demand and energy availability from residues plus ordinary cropping (arable crops ≤30%) existed.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

At national scale, the cultivation of about 68,060 hectares of giant reed would cope with this gap. Its cultivation would be required mostly in some parts of the Po Valley (mostly Alessandria, Pavia, Lodi, Cremona, Padova, Venezia, Bologna, Ferrara, Ravenna), in Friuli-Venezia Giulia, in Tuscany and in some provinces of Southern Italy. It must be noted that in the considered Northern provinces the installed biogas power is >10 MWe per province, while in Central and Southern provinces there are considerably less biogas plants, but also markedly lower amounts of animal effluents (Figure 3).

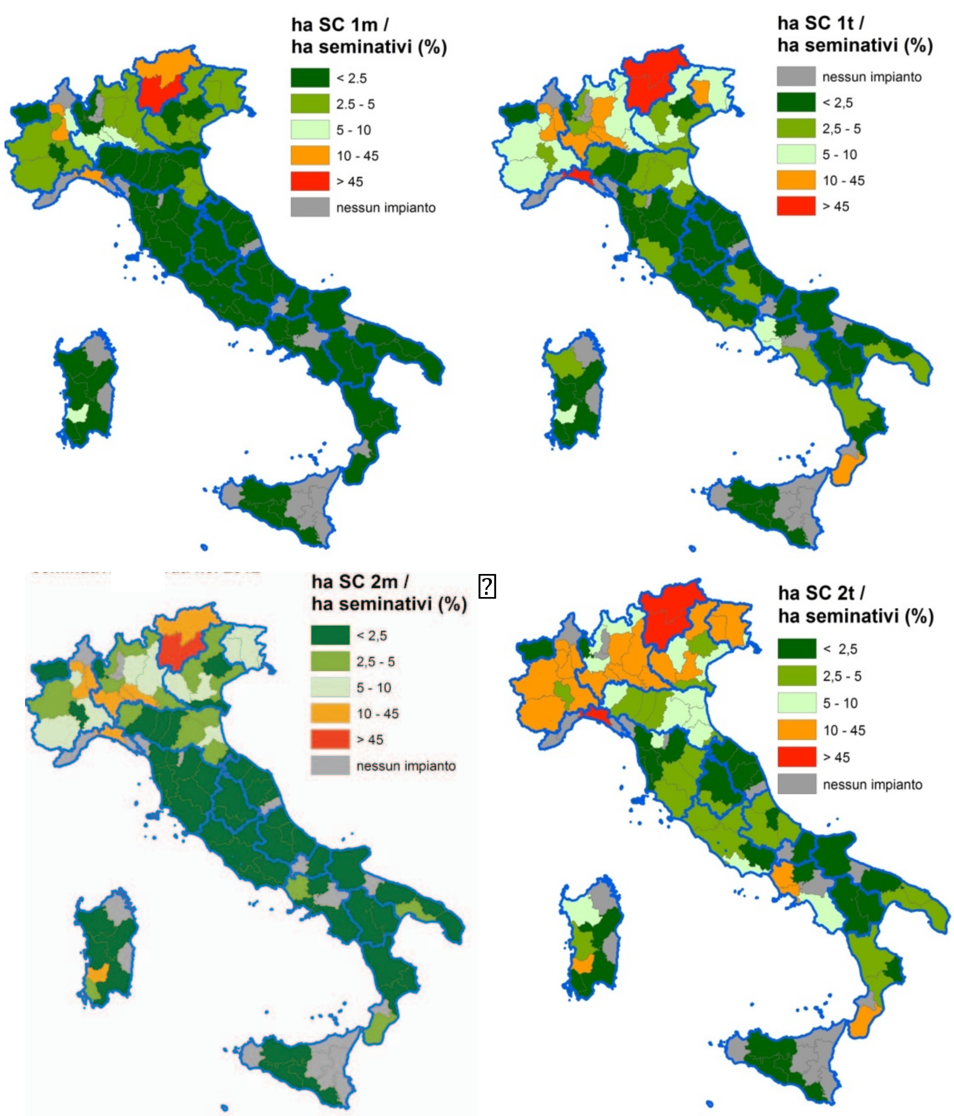


Fig. 2: Percentage of arable land use in the scenarios SC1m, SC1t, SC2m and SC2t.
Fig. 2: Percentuale d'uso dei seminativi negli scenari SC1m, SC1t, SC2m and SC2t.

Conclusions

Up to 2013, the national subsidy scheme did not distinguish among different feedstocks used to supply the plants. Afterwards, the use of crops that are in direct competition with the food sector has been partially discouraged, while the use of wastes, residues and alternative crops was prioritized. Since giant reed has shown a good suitability for AD, an increase in land use for this crop is expected. Nevertheless, AD plants are generally not located in marginal areas, since they usually

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

operate in the most developed agricultural areas of the country, in which maize can well fulfill the feedstock demand of the biogas plants.

Annual crops are usually preferred over perennial ones, as they allow for flexible crop choices and they are generally better known and accepted. For these reasons, giant reed cultivation is not expected to spread biogas production in marginal areas, while it is expected to supplement the most suitable feedstock (i.e. byproducts and residues) where needed and to partially replace the biomass from annual crops.

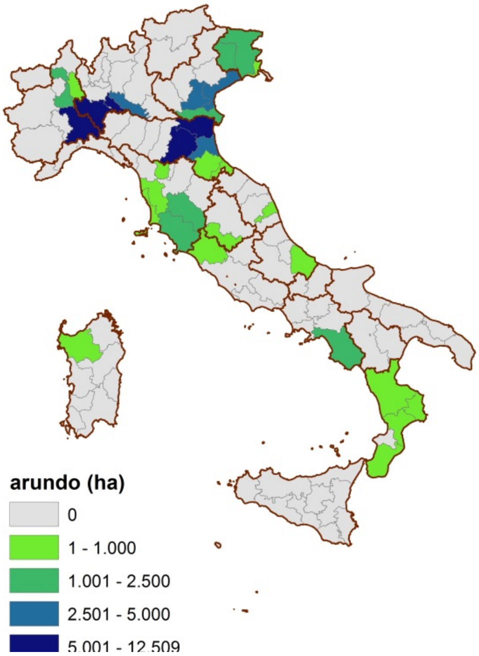


Fig. 3: Land use for giant reed cultivation under SC3 scenario.
Fig. 3: Uso del suolo per la coltivazione della canna comune secondo lo scenario SC3.

References

Barbanti L, Di Girolamo G, Grigatti M, Bertin L, Ciavatta C. 2014. Anaerobic digestion of annual and multi-annual biomass crops. Industrial Crops and Products 56:137–144.

Corno L, Pilu R, Tambone F, Scaglia B, Adani F. 2015. New energy crop giant cane (Arundo donax L.) can substitute traditional energy crops increasing biogas yield and reducing costs. Bioresource Technology 191:197–204.

ENAMA. 2012. Biomasse ed Energia, Capitolo 2 - Disponibilità delle biomasse.

European Commission (EC). Innovating for Sustainable Growth: A Bioeconomy for Europe; European Commission: Brussels, Belgium, 2012.

Noya I, González-García S, Bacenetti J, Arroja L, Moreira M T. 2015. Comparative life cycle assessment of three representative feed cereals production in the Po Valley (Italy). Journal of Cleaner Production 99:250–265.

Ragaglini, G., Dragoni, F., Corneli, E, Triana, F., Villani, R., Nassi o Di Nasso, N, Bonari, E. 2015. Enhancing the sustainability of anaerobic digestion in Italy: A GIS based investigation for assessing the potential of giant reed in saving land compared with maize.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

CHARACTERIZING CROPPING SYSTEMS AFFECTED BY FLUORIDE CONTAMINATION IN EASTERN AFRICAN COUNTRIES
CARATTERIZZAZIONE DEI SISTEMI COLTURALI CONTAMINATI DA FLUORO NEI PAESI DELL'EST AFRICA

Rizzu M.[12], Akuno M.H. [12], Roggero P.P.[12], Wambu E.W.[3], Mtei K.M.[4], Seddaiu G.[12]

[1] Dip. di Agraria, Univ. Sassari, IT, gseddaiu@uniss.it
[2] Nucleo Ricerca Desertificazione, Univ. Sassari, IT, pproggero@uniss.it
[3] Department of Chemistry and Biochemistry, University of Eldoret, Eldoret, Kenya
[4] Department of Water and Environmental Science and Engineering, Nelson Mandela African

Abstract
Fluoride food chain and drinking water contamination is at the base of severe diseases, such dental and skeletal fluorosis, in the Eastern African countries of the Great Rift Valley. However, available information on fluoride uptake and its effects on crops cultivated and irrigated in contaminated environments is still limited. To developed effective agronomic mitigation strategies, also easy-to-use for the farmers, is necessary to ground it on local specific agricultural contexts.
This preliminary study aimed to obtain a characterization of fluoride contaminated cropping systems through the implementation of *ad hoc* surveys in two case study areas of the Rift Valley in Kenya and Tanzania. A total of 512 questionnaires (383 in Kenya and 129 in Tanzania) were administrated in order to have an overview on the "business as usual" agricultural practices of these areas, that could guide the design of research trials on affordable and desirable fluoride mitigation measures for cropping systems.

Keywords: Agriculture; East Africa; Fluoride mitigation; Land use; Soils.
Parole chiave: Agricoltura; Clima; Est Africa; Mitigazione del fluoro; Uso del suolo; Suoli.

Introduction
Excessive fluoride intake in the human diet can lead to severe pathologies such as dental and skeletal fluorosis (Frencken, J., 1992) as well as neurotoxicity in developing foetus leading to reduced IQ and behavioural disorders (Lu et al. 2000). High fluoride levels, exceeding the World Health Organization (WHO) limit for drinking water (<1.5 mg/l) (WHO, 1984), have been observed in various African countries particularly in the Great East African Rift Valley (Malago et al, 2017). This area is an active volcanic region where bedrock contain high concentrations of fluoride and fluorapatite which solubility is also accelerated by high hydrothermal activity (Tekle-Haimanot, R et al, 1985). About 90% of the population in that region shows symptoms of fluorosis at various stages (Yoder et al. 1998). According to the Tanzania Food and Drugs Authority, dental fluorosis is the 5th most common nutritional disorder in the country (Ministry of Health and Social Welfare, United Republic of Tanzania, 1988).
The main source of fluoride contamination for humans is drinking water and food. However, there is still limited knowledge on fluorine uptake and its effects on crops cultivated in contaminated soils and/or irrigated by high fluoride water. Furthermore, agronomic strategies to mitigate crop contamination by fluoride need to be developed and tested.
Any mitigation strategy has to be designed on the basis of local specific agricultural contexts in order to be easy-to-use and also meaningful for the farmers.
The main objective of this preliminary study was to perform *ad hoc* surveys on the fluoride contamination in agricultural systems in two areas of the Rift Valley of Kenya and Tanzania. The outcomes are intended to guide the design and implementation of experiments on fluoride mitigation measures in cropping systems in order to identify agricultural practices that are grounded on local knowledge, replicable, desirable and feasible under the specific local contexts. The study was developed within the activities of the H2020 project FLOWERED "de-FLuoridation technologies for imprOving quality of WatEr and agRo-animal products along the East African Rift Valley in the context of aDaptation to climate change" which main goal is to contribute to the development of a sustainable water management system in areas affected by fluoride contamination in water, soils and food with the aim of improving the living standards of local population in the Eastearn African countries.

Materials and Methods
The methodological approach was based on the submission of a questionnaire on dietary behavior of the household members, aiming to connect consumption with own food production, and on cropping and livestock systems at household scale. The questionnaire was translated into the local language to easily be understood by the enumerators and the interviewee. A web-application was applied for data entering. Several datasets were then extracted and analysed to characterize cropping systems at household level.

Two case study areas were identified in the Eastern African Rift Valley, one in the Nakuru county in Kenya and one in the Arumeru District, Arusha Region, in northern Tanzania. Both areas are generally characterized by a bimodal rainfall patterns alternating a long (Feb/Mar - May) and a short rainy season (Oct - Dec) with the remaining months dry. Annual rainfall can range between about 500 mm to over 1000 mm depending on the altitude and physical features. Therefore, some areas can be quite arid and this influence the movement and accumulation of salts in the soils. Storms during the rainy season are often associated to intense surface water flow, which is also influencing fluoride contamination of soils downward the water streams. In general, the higher levels of fluoride in the soils, plant materials and water are associated with areas of lower rainfall, elevated average temperatures, low altitude, low slopes which reduce the rate of drainage and long distances of drainage. While data on fluoride content of different water sources are available for both case study areas, apparently no data or very limited are available for soils. This calls for soil studies especially on properties related to fluoride levels in soils and to establish fluoride levels in specific soil types and in specific agricultural systems.

Results and Discussion

A total of 512 questionnaires were submitted, 383 in Kenya and 129 in Tanzania.

CROPPING SYSTEMS

The survey highlighted that most of the agricultural land is occupied by maize as first crop, followed by tomato, pulses, potatoes, cabbages in both study areas (Fig. 1).

The fate of these crops is mainly human consumption but in the Kenyan study area about 50% of the product is sold fresh to local market whereas in Tanzania over 90% is consumed within the household. Intercropping is applied on 80% of the surveyed plots in Kenya and 58% in Tanzania. In both countries respectively 88% and 91% of the plots in which intercropping is applied is based on maize and beans, in rotation or associated with other crops or alone.

When intercropping is not applied (20% of plots Kenya, 42% of plots Tanzania), rotation between two or more crops in the same year is the most common practice (86% and 70% of the plots within the cases without intercropping). In Kenya 14% of the cases are characterized by a specialized cropping system in which only one crop is cultivated, while in Tanzania this percentage is greater (30%). Tanzanian specialized cropping system are based on tomato (53% of the plots), maize (25%) and bean (19%). Other less important crops grown as monoculture are sunflower and finger millet.

Pesticides are largely applied in both case study areas, while herbicides are common only in Kenya, particularly for potato. Irrigation is rarely used in the surveyed households of Kenya while in Tanzania is more frequent and is mainly based on flooding and/or canals as irrigation systems.

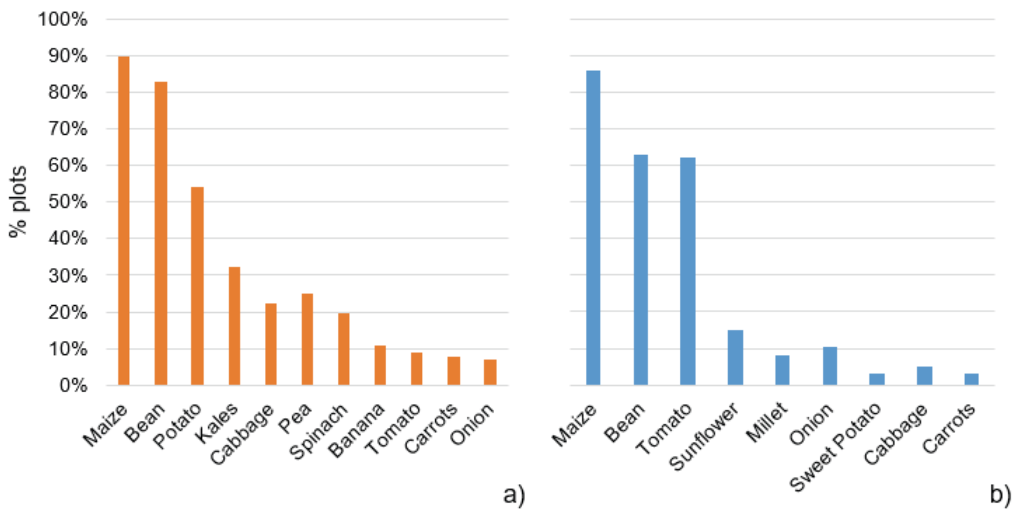


Fig. 1: Percentage of occurrence of different crops in the surveyed plots in Kenya (a) and Tanzania (b).
Fig.1: Percentuale di parcelle coltivate con differenti colture a) Kenya, b) Tanzania.

DOI 10.6092/unibo/amsacta/5692

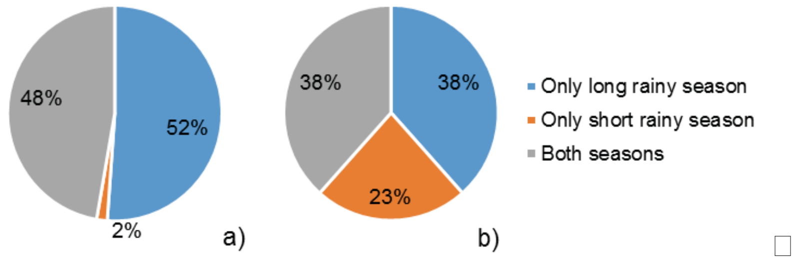


Fig.4. Percentage of plots cultivated during the long or short rainy season or during both seasons, a) Kenya, b) Tanzania
Fig.4. Percentuale di parcelle coltivate durante la stagione delle piogge breve o lunga o durante entrambe, a) Kenya, b) Tanzania

HOUSEHOLD CHARACTERISTICS AND SOIL QUALITY PERCEPTION
The mean size of surveyed households was 9.3 acres in surveyed Kenyan farms and 3.5 in Tanzania, with on average 1.02 and 1.32 number of plots per household, respectively. Plots were on average at walking distance from home and at relatively short distance from roads and market. The average plot size is relatively small as expected in such small farming systems.
The percentage of respondents that considered as "good" the soil quality of their plot is greater in Kenya (65%) than in Tanzania (19%). In Tanzania 80% of the respondents perceive the soil quality of their plot as "average" whilst in Kenya only 34%. Concerning soil texture, in both countries most of the plots were considered loamy (74% Kenya, 50% Tanzania), sandy (17% Kenya, 30% Tanzania) or clayey (6% Kenya, 14% Tanzania)
The majority of interviewees described their soils as slightly sloped or flat, a minor part irregular or very steep (4% Kenya). Soil depth was described to be less than 40 cm in more the 50% of the cases.

Conclusions
The case study areas are likely exposed to a high risk of fluoride contamination since the farming systems are occupying fluoride-rich soils and are using water sources from rivers and stream known as being highly contaminated with fluoride. However, the very limited use of irrigation water in the Kenyan case study area for the most important crops suggest that the food products may be less affected by fluoride even if it cannot be excluded a negative role of fluoride-rich soils in the crop productivity and food security. On the contrary, the surveyed Tanzanian farms are highly relying on irrigation and, therefore, they can be considered more vulnerable to fluoride contamination. In fact, Tanzanian farms with soils of high fluoride levels are locally known as salt accumulation areas, with lower crop yield and some of these farms have been abandoned or shifted to more tolerant crops such as potatoes.
The findings here reported can provide relevant information that have been valorized to identify which crops are worth to be studied for assessing sensitivity to fluoride in the soil and in the irrigation water.

Acknowledgments
This study was carried out in the context of the international cooperation project FLOWERED - *de-FLuoridation technologies for imprOving quality of WatEr and agRo-animal products along the East African Rift Valley in the context of aDaptation to climate change* (www.floweredproject.org).

References
Frencken J. E., 1992. Endemic fluorosis in developing countries: causes, effects and possible solutions. TNO Institute for Preventive Health Care.
Lu, Y., Sun, Z.R., Wu, L.N., Wang, X., Lu, W., Liu, S.S., 2000. Effect of high-fluoride water on intelligence in children. Research Report Fluoride, 33, 2, 74-78.
Malago, J., Makoba, E., Muzuka, A. N. N., 2017. Fluoride Levels in Surface and Groundwater in Africa: A Review. American Journal of Water Science and Engineering. Vol. 3, No. 1, pp. 1-17.
Ministry of Health and Social Welfare, United Republic of Tanzania, 1988. National Plan for Oral Health 1988–2002, 14–15.
Tekle-Haimanot, R, Fekadu, A., Bushera, B., and Mekonnen, Y., 1995. Fluoride levels in water and endemic fluorosis in Ethiopian Rift Valley. Ngurdoto, Tanzania October 18-21, 1998, 12.
WHO, 1984. Guidelines for Drinking-Water Quality, vol. 1: Recommendations and vol. 2: Health Criteria and Other Supporting Information. Geneva.
Yoder, K., Mabelya, L., Robison, V., Stookey, G., Brizendine, E., Dunipace, E., 1998. Severe dental fluorosis in a population consuming water with negligible fluoride concentration. Commun. Dent. Oral. Epidemiol, 26, 382–393.

LONG TERM EVALUATION OF DURUM WHEAT CROPPING SYSTEMS
VALUTAZIONI DI LUNGO PERIODO SU SISTEMI COLTURALI CEREALICOLI

Salvatore Luciano Cosentino, Paolo Guarnaccia, Venera Copani, Danilo Scordia, Santo Virgillito, Sebastiano Scandurra, Giorgio Testa*

Dipartimento di Agricoltura, Alimentazione e Ambiente (Di3A), Via Valdisavoia 5, 95123, Catania
*gtesta@unict.it

Abstract
In the Mediterranean environment, and especially in Sicily, where the hot and dry climate force the farmers to use autumn-winter crops, such as durum wheat; this determines a lack of soil covering during the first rains that occur in early autumn and winter (Cosentino et al., 2004, 2006, 2007a). These crops are usually deep tilled (Cosentino et al., 2007b) and may promote soil erosion and then loss of soil fertility. In the eighteen years study the adopted cropping systems highlighted a slightly increasing trend of soil organic matter in both studied soil layers (0-30 cm and 31-60 cm). At the same amount of rain the legumes as preceding crops allows an appreciable increase in durum wheat yield. Soil organic matter did not affected durum wheat yield while the legumes as preceding crop did. The rotation fallow-wheat-wheat allows to increase yield in the first year after fallow (2.57 tha^{-1} and 0.98 $t\ ha^{-1}$, for wheat after fallow and with after wheat, respectively).

Keywords: Durum wheat; long term evaluation; soil organic matter.
Parole chiave: Frumento duro; valutazioni di lungo periodo; sostanza organica del terreno;

Introduction
The soil management plays a key role to the conservation of soil fertility. This is very important in area where rainfall distribution and orography of the soil along with unsuitable soil management leads to soil erosion e consequently to loss of soil fertility. Several authors reported that labile carbon is the first fraction to be depleted by continuous cultivation and that this fraction is more sensitive to land use change than total carbon (Martinez-Mena et al., 2008; Blair et al., 1995; Chan et al., 2002; Chantigny et al., 2003; Azevedo, 2005). Plant covers play a significant role in regulating hydrological processes and changes in soil properties (Duràn-Zuazo et al., 2013). These issues are particularly important in Sicily due to the orography of the territory (62% hill, 24% mountain). The maintenance and the possibility to increase soil organic carbon are very important in this area where the content is low and farmers, in dry farming conditions, perform deep soil tillage before establishing autumn-winter annual crops. This management and the subsequent heavy autumn rainfalls on a not covered soil determine a severe soil erosion and a consequent nutrient and organic matter losses.
In the present work long-term results of 5 different cropping systems involving durum wheat in order to evaluate their effects on soil organic matter and durum wheat yield are reported.

Materials and Methods
The experiment was carried out at the cropping systems and soil erosion experimental field of the "Dipartimento di Agricoltura, Alimentazione e Ambiente (Di3A)", of the University of Catania, set up in 1996 in a representative area of the hilly inland of Sicily, Italy (37°21' N, 14°16' E, 550 m a.s.l.) mainly devoted to the durum wheat cultivation. The experimental plots are located on a slope of about 27%. The experimental field consist of 12 plots of 320 m^2 each (40m x 8m) equipped with a series of devices, in order to determine the amount of runoff and sediments (Figure 1).
Cultivation practices were those as used by farmers in this area. Soil tillage was performed by means of disk-harrow at 25 cm depth following the steepest slope lines, in order to expose the soil to the worst conditions for erosion, and to simulate, in any case, the most frequent conditions of cultivated fields.
For the soil sampling, in each cropping system, the main plot was split in three sub-plots from which, during fall (from 1996 to 2014), three soil samples were collected at 0-30 cm and 31-60 cm depth in order to measure the organic matter content (Walkley-Black method).
In table 1 are reported the five studied cropping systems involving durum wheat (Plot 2, 3, 4, 5, 7).

Figure 1. Cropping systems and soil erosion experimental field.
Figura 1. Campo sperimentale per la valutazione di si sistemi colturali ed erosione.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Tab.1 – Durum wheat cropping systems studied in a representative internal hill (27% slope) of Sicily.
Tab.1 – Sistemi colturali cerealicoli studiati in un'area rappresentativa della collina (27% di pendenza) interna siciliana.

#	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14
2	fallow	wheat	wheat	fallow	wheat	wheat	fallow	wheat	wheat	fallow	wheat	wheat	fallow	wheat	fallow	wheat	fallow	wheat
3	wheat	wheat	wheat	wheat	wheat	wheat	wheat	wheat	wheat	wheat	wheat	wheat	b.carinata	wheat	fallow	wheat	wheat	fallow
4	set aside	wheat	wheat	set aside	wheat	wheat	set aside	wheat	wheat	set aside	wheat	wheat	b.carinata	barley	fallow	wheat	fallow	barley
5	s.sorghum	sunflower	wheat	f.bean+vetch	wheat	f.bean	wheat	rapeseed	wheat	f.bean	wheat	b.carinata	wheat	sulla	sulla	switchgrass	miscanth	cardoon
7	f.bean	wheat	f.bean+vetch	wheat	f.bean	wheat	vetch	wheat	rapeseed	wheat	f.bean	b.carinata	wheat	f.bean	fallow	pea	wheat	wheat

Risults and Discussion

During the eighteen years of experiment the variation of soil organic matter (SOM) content was measured in order to evaluate its variations on time in relation to the different cropping systems. The five cropping systems involving durum wheat showed variations in SOM content (Figure 2). The cropping systems number 2 representing a typical Mediterranean crop rotation (wheat-wheat-fallow) showed a slightly increase in SOM content at both soil depth (0-30 and 31-60 cm) (Figure 2). A higher increase in SOM content was observed in the plot 4 and 5where more crops are included in the crop rotations (Figure 2). In plot 7 the SOM content was almost constant on the average of the eighteen-year. The cropping system durum wheat – durum wheat (Plot 3) showed a different trend in relation to the two soil layers. An increase was observed in the first soil layer (0-30 cm) while a decrease in the second (31-60 cm).

Generally the succession of annual crops kept constant the soil organic matter while the introduction of a legume crops, such as field bean, helped to increase soil organic matter. Moreover the SOM content increases after fallow due to the organic matter buried in the soil.

Regarding the durum wheat productivity in the crop rotation durum wheat-durum wheat-fallow an increase in crop productivity was observed after fallow.

The rotation fallow-wheat-wheat allowed an higher yield in the first years after fallow (2.57 tha^{-1} and 0.98 t ha^{-1}, for wheat after fallow and with after wheat, respectively) (Figure 3). In the first year after fallow the yield of wheat was, in the average, equal to 2.57 tha^{-1} while after wheat was equal to 0.98 t ha^{-1}. The monoculture of durum wheat lead to a constant decrease in grain yield from 3.62 to 1.16 t ha^{-1}, in the first and after twelve year of monoculture of durum wheat (Figure 3). The break of the monoculture of wheat with B.carinata allowed an increase of the yield from 1.16 t ha^{-1} to 2.54 t ha^{-1}. (Figure 3). As for the rotation with fallow, in the sixteen years of this cropping system, the rotation set aside-wheat-wheat allows an increase of the yield in the first years of the rotation (2.14 t ha^{-1} and 1.12 t ha^{-1}, in the average of the first and second years of crop rotations, respectively).

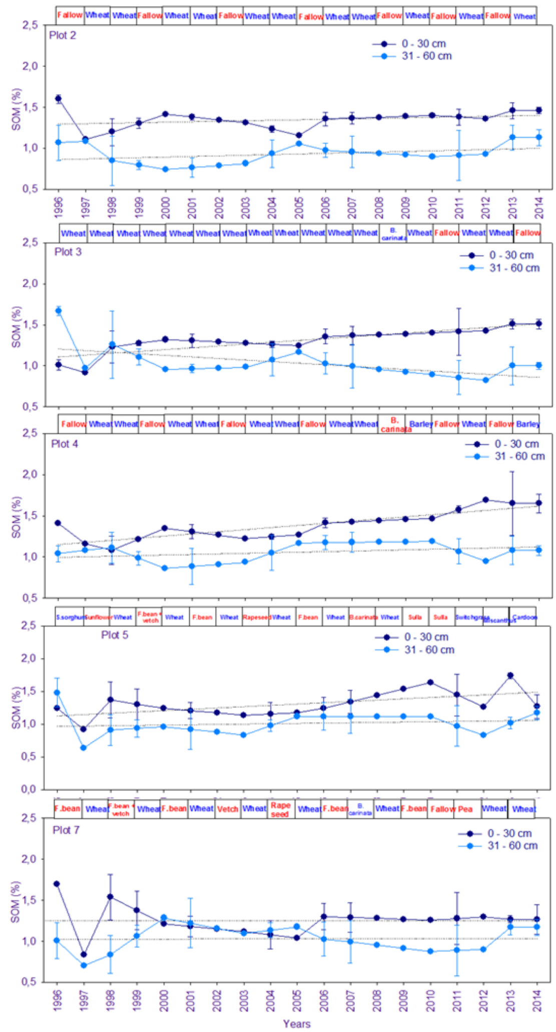


Figure 2. Soil organic matter (SOM) content in the first two soil layers (0-30 cm and 31-60 cm).
Figura 2. Contenuto di sostanza organica nei primi due strati di suolo (0-30 cm and 31-60 cm).

The relations between wheat yield and rainfall (period October-January) highlighted differences between the yield after wheat and legume crops. At the same amount of rainfall the yields were considerably higher after legume than after wheat. In average of the eighteen years, the relations between rainfall and grain yield highlighted a yield almost 1 t ha^{-1} higher after legume than after wheat (Figure 4).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Conclusions

This paper, which analyzed in semi-arid Mediterranean environment the trend of soil organic matter content in different cropping systems involving durum wheat and the yield of durum wheat, highlighted that the yield is mainly affected by the rainfall amount and distribution during the wheat growing season and the preceding crops.
During the eighteen years of study, the evaluated cropping systems highlighted a slight increase in soil organic matter content.
The SOM content of the first two soil layer was affected by the period and depth of soil tillage.
In fact, to a decrease of SOM content in the first soil layer corresponded an increase in the second layer, probably due to the organic matter buried in the soil.
The durum wheat monoculture even if increased slightly the SOM, did not result in a corresponding increase or maintenance in grain yields but in a reduction of it. So the grain yield was not affected by SOM content.
Conversely, crop rotation mainly with legumes, and the rainfall amount and distribution during the durum wheat growing season affected the grain yield.

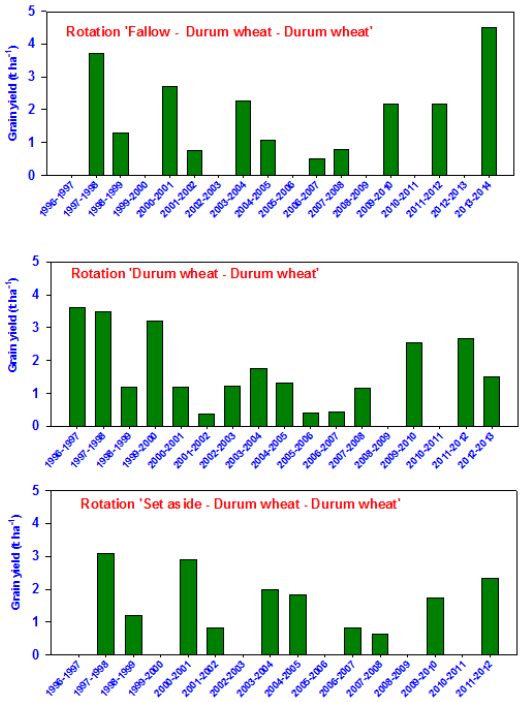


Figure 3. Durum wheat grain yield in relation to the different cropping systems.
Figura 3. Resa del frumento duro in relazione ai diversi sistemi colturali.

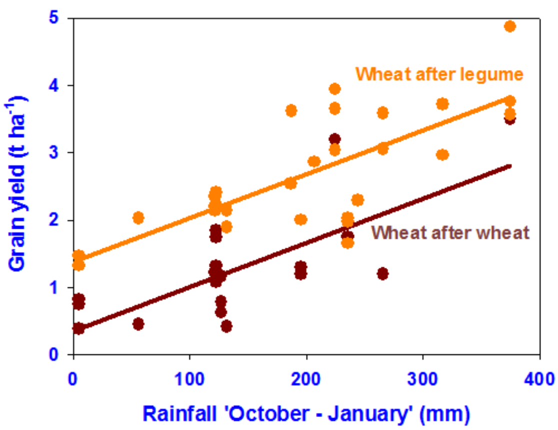


Figure 4. Relations between rainfall and yield of wheat after wheat and wheat after legumes.
Figura 4. Relazione tra piovosità e resa nel frumento dopo frumento e nel frumento dopo leguminosa.

References

Azevedo Silverira ML (2005). Dissolved organic carbon, bioavailability of N and P as indicators of soil quality. Sci. Agric. 62 (5), 502-508

Blair JG, Rod DB, Lisle L (1995). Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. Aust. J. Agric. Res. 46, 1459-1466.

Chan KY, Heenan DP, Oates A (2002). Soil carbon fractions and the relationship to soil quality under different tillage stubble management. Soil Till. Res. 63, 133-139.

Chantigny MH (2003). Dissolved and water-extractable organic matter in soils: a review on the influence of land use and management practices. Geoderma 113, 357-380.

Cosentino S.L. et al. 2007a. Effetti di sistemi colturali erbacei sul contenimento dei fenomeni erosivi nella collina interna siciliana. Atti XXXVII Conv. SIA. Catania 13-14 settembre 2007, , 37-38

Cosentino S.L. et al. 2007b. Il contributo della ricerca agronomica all'innovazione dei sistemi colturali mediterranei. Atti XXXVII Conv. SIA. Catania, 13-14 settembre 2007, 37-38.

Cosentino et al 2011. Sistemi Colturali ed Erosione nella Collina Interna Siciliana. Atti XL Convegno SIA Teramo, 7-9 settembre 2011, 352-353.

Cosentino S.L. et al. 2008. Sod Seeding and Soil Erosion in a Semi-arid Mediterranean Environment of South of Italy. Italian Journal of Agronomy, 3:47-48.

Duràn-Zuazo VH, Francia-Martinez JR, Garcia-Tejero I, Cuadros Tavira S (2013). Implications of land-cover types for soil erosion on semiarid mountain slopes: Towards sustainable land use in problematic landscapes. Acta Ecologica Sinica 33 272-281

Martinez-Mena M, Lopez J, Almagro M, Boix-Fayos C, Albaladejo J (2008). Effect of water erosion and cultivation on the soil carbon stock in a semiarid area of South-East Spain. Soil & Tillage Research 99 119-129.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

MULTI-METHODOLOGY ANALYSIS OF GLUTEN QUALITY IN OLD AND MODERN DURUM WHEAT GENOTYPES
ANALISI MULTI-METODOLOGICA SULLA QUALITA' DEL GLUTINE IN GENOTIPI ANTICHI E MODERNI DI FRUMENTO DURO

Michele A. De Santis, Marcella M. Giuliani, Luigia Giuzio, Zina Flagella*

University of Foggia – Department of SAFE, via Napoli 25 – 71122 Foggia (IT)
* zina.flagella@unifg.it

Abstract
While it is well known that durum wheat breeding has modified gluten composition for improving technological properties, very little is known about the supposed healthier value of old genotypes. Four genotypes, representative of different ages of Italian breeding and grown in a two-year field trial, were evaluated for protein composition by a multi-methodology approach analysis (2DE SDS-PAGE, amino acid composition, monoclonal antibody G12) in order to investigate the effect of breeding on gluten quality in relation to both technological and healthy (gluten related disorders) aspects. Genetic and environmental differences were found. The modern variety Saragolla showed the highest cysteine content, associated to the highest expression of sulphur-rich LMW-GS type B. as observed by 2DE SDS-PAGE. As for QPQLPY (G12) concentration in gliadin fraction, genetic differences were found. No increase in modern genotypes was observed, while the highest value was found in the old landrace Dauno III.

Keywords: Durum wheat, breeding, 33-mer, amino acids, 2DE SDS-PAGE
Parole chiave: Frumento duro, miglioramento genetico, 33-mer, aminoacidi, elettroforesi bidimensionale

Introduction
The recent interest on the effect of gluten in human diet has determined an increasing attention on the impact of breeding on wheat protein composition and quality. Protein concentration and composition have a key role in determining pasta quality. The selection of durum wheat lines for superior gluten strength, directly measured by higher gluten index and alveographic W and P/L, was mainly due to the indirect selection for favourable alleles at *Glu-B1* (6+8, 7+8) and *Glu-B3* (type 2) genes (De Vita et al., 2017). Furthermore the improvement in gluten quality was also due to a higher expression of some particular glutenin sub-units (B-type LMW-GS) and a lower gliadin to glutenin ratio in the modern varieties; on the other hand, a great difference in ω-5 gliadin expression has been observed between old and modern durum wheat genotypes (De Santis et al., 2017). This S-poor protein fraction is not relevant in gluten quality; however, its important role in wheat allergy is well known (Matsuo et al., 2015).

Materials and Methods
Four durum wheat genotypes were chosen on the basis of the year of release: Dauno III, a line coming from an old landrace cultivated in Apulia at the beginning of the 20th century; Cappelli, introduced by Nazareno Strampelli in 1915; Simeto, a durum wheat variety released in 1985 and Saragolla, a modern variety introduced in 2004. Raw material was obtained from a two-year field crop trial, as described in De Santis et al. (2017). Briefly, plants were grown at Foggia, by applying 80 kg ha^{-1} and 70 kg ha^{-1} of N and P, respectively. The two consecutive crop seasons, 2012/13 (2013) and 2013/14 (2014) were characterised by a similar thermal trend and rainfall distribution, with the exception of grain filling period characterized by higher rainfall in 2014. Gliadins and glutenins were extracted and separated by 2DE SDS-PAGE, as described in De Santis et al. (2017). Gels were digitally acquired and analysed by ImageMaster 6.0 (GE-Healthcare, Uppsala Sweden). Free amino acid content was determined by HPAEC, according to the protocol described by Rombouts et al. (2009), on 100 mg of digested semolina samples (6N HCl, 24h). On gliadin fraction, the analysis by a commercial competitive enzyme-linked immunosorbent assay (ELISA) kit (G12 AgraQuant, RomerLabs) was performed. The measurement was performed by a monoclonal antibody raised against the 33-mer α-gliadin peptide, an immune-stimulatory fraction containing QPQLPY epitope sequence involved in celiac disease, as described by Shan et al. (2001). Protein spots, concentration of cysteine and of G12 (gliadin) were statistically analysed by two-way ANOVA considering genotype and crop season as factors. Tukey's test was adopted as *post hoc* with a significance level of $P \leq 0.05$.

Results and Discussion

Differences in protein and amino acid composition were observed among the investigated samples. As for 2DE SDS-PAGE analysis, spot overlapping was not possible for HMW-GS since each genotype was characterised by a different allelic combination of *Glu-B1* and *Glu-A1* gene. Instead significant differences were observed for LMW-GS, with a marked over-expression of B-type LMW-GS in cultivar Saragolla (Figure 1), followed by Cappelli, Simeto and Dauno III, respectively. Moreover, the analysis of amino acid composition showed a significant interaction genotype x crop season. In this contribution, only the variability in Cys concentration is reported (Figure 2). Briefly, the highest Cys concentration was observed in modern cultivar Saragolla that showed also a significantly higher value in 2013. A similar trend was observed in a previous study for gluten index as reported in De Santis et al. (2017). The presence of 8 Cys in LMW-GS (D'Ovidio and Masci, 2004) might explain the higher Cys concentration in Saragolla, since this variety showed the highest expression of LMW B-type (31% and 26.4% in 2013 and 2014, respectively). Instead the modern cultivar Simeto, even if characterised by good *Glu-B1* allele combination (7+8), showed an intermediate B-type spot protein expression and Cys concentration, that might explain its lower gluten index (47%, as reported in De Santis et al., 2017).

As for gliadin fraction, the four genotypes were previously investigated in relation to ω-5 gliadin expression in a screening including other old and modern durum wheat genotypes. A marked decrease in ω-5 gliadin expression was observed due to modern breeding, with Dauno III and Saragolla showing the highest and lowest content, respectively (De Santis et al., 2017). Also, for the response to monoclonal antibody G12, the highest concentration was found in Dauno III and the lowest one in Saragolla (Figure 3). The QPQLPY sequence is abundant in gluten proteins, and it represents a good estimation of gluten content in food. However a measure of its proportion might give information on the differences in immune-stimulatory potential within durum wheat genotypes. Our preliminary results showed the highest content in Dauno III, in particular in 2013, when a slight water stress during grain filling occurred. This genotype showed also an elevated α-type and γ-type content in that conditions (De Santis et al., 2017).

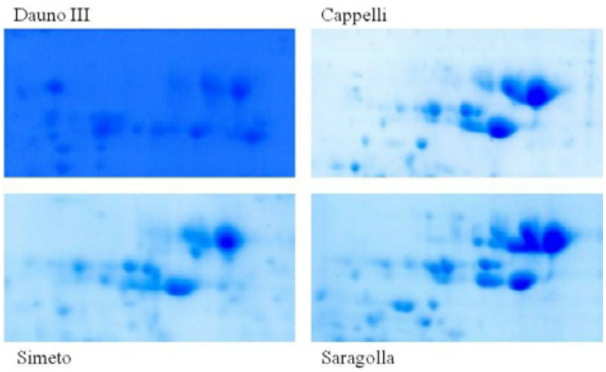


Figure 1. B-type LMW-GS protein spot in old and modern durum wheat genotypes.
Figura 1. Spot proteici di LMW-GS di tipo B in vecchi e moderni genotipi di frumento duro.

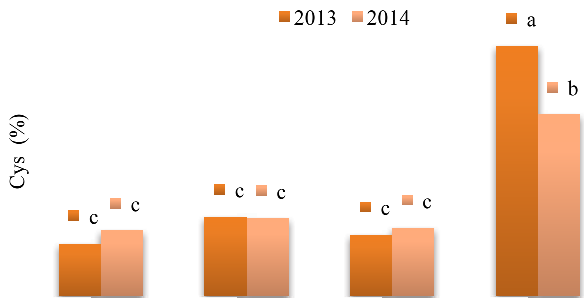


Figure 2. Cysteine concentration in old and modern durum wheat genotypes cultivated in 2013 and 2014. Different letters are significantly different at P ≤ 0.05 according to Tukey's test.
Figura 2. Concentrazione di cisteina in genotipi vecchi e moderni di frumento duro coltivati nel 2013 e nel 2014. Lettere diverse corrispondono a valori significativamente diversi per P ≤ 0.05 secondo il test di Tukey.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

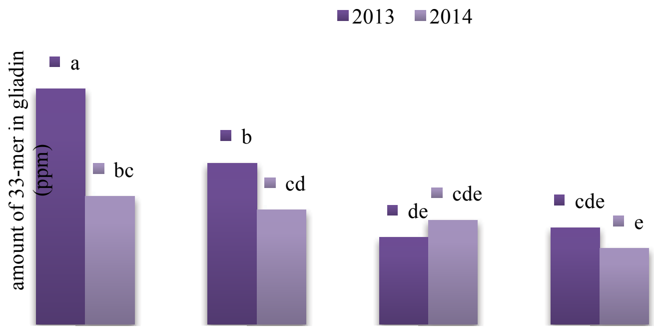


Figure 3 Response of monoclonal antibody G12 in old and modern durum wheat genotypes cultivated in 2013 and 2014. Different letters are significantly different at $P \leq 0.05$ according to Tukey's test.
Figura 3. Risposta all'anticorpo monoclonale G12 in genotipi vecchi e moderni di frumento duro coltivati nel 2013 e nel 2014. Lettere diverse corrispondono a valori significativamente diversi per $P \leq 0.05$ secondo il test di Tukey.

Conclusions

Breeding activity on durum wheat quality was mainly addressed to increase gluten strength for improving pasta quality. In addition to a favourable allele composition also a higher B-type LMW-GS expression was recently observed by our research group in modern durum wheat genotypes. These changes were confirmed by 2DE SDS-PAGE in this study where the highest B-type LMW-GS expression was observed in modern cultivar Saragolla characterised by a superior technological aptitude consistently with a markedly highest cysteine content. On the other hand, previous study carried out by our group showed a higher ω-5 gliadin expression (wheat allergy) in old durum wheat genotypes with respect to modern ones. Also in this study, the use of a marker adopted for celiac disease (QPQLPY epitope included in 33-mer) showed a similar trend, with a higher prevalence in the old genotypes, in particular Dauno III. Further multi-methodology investigation by combining proteomic and immunological approach and the evaluation of the whole amino acid profile on a wider set of durum wheat genotypes, might deep insight into the effect of modern breeding on gluten protein composition and healthy quality in durum wheat.

References

De Santis, M.A.; Giuliani, M.M.; Giuzio, L.; De Vita, P.; Lovegrove, L.; Shewry, P.R.; Flagella, Z. 2017. Differences in gluten protein composition between old and modern durum wheat genotypes in relation to 20th century breeding in Italy. Europ. J. Agron. 87, 19-29.

De Vita, P.; Li Destri Nicosia, O.; Nigro, F.; Platani, C.; Riefolo, C.; Di Fonzo, N.; Cattivelli, L. 2007. Breeding progress in morpho-physiological, agronomical and qualitative traits of durum wheat cultivars released in Italy during the 20th century. Europ. J. Agron. 26, 39−53.

D'Ovidio R, Masci S. 2004. The low-molecular-weight glutenin subunits of wheat gluten. J. Cereal Sci. 39, 321–339.

Matsuo H., Yokooji T., Taogoshi T. 2015. Common food allergens and their IgE-binding epitopes. Allergology International 64, 332-343.

Shan, L.; Molberg, O.; Parrot, I.; Hausch, F.; Filiz, F.; Gray, G. M.; Sollid, L. M.; Khosla, C. 2002. Structural basis for gluten intolerance in celiac sprue. Science, 297, 2275−2279.

OPPORTUNITIES AND CHALLENGES OF CLIMATE CHANGE ADAPTATION ACROSS EUROPE: A CASE STUDY ANALYSIS FROM THE MACSUR KNOWLEDGE HUB

OPPORTUNITA' E SFIDE DELL'ADATTAMENTO AI CAMBIAMENTI CLIMATICI IN EUROPA: ANALISI DI CASI STUDIO DAL PROGETTO MACSUR KNOWLEDGE HUB

Roggero P.P.*[1], Bellocchi G.[2], Bojar W.[3], Cammarano D.[4] Daalgard T.[5], Dono G.[6] Lehtonen H.[7], Mula L.[1], Øygarden L.[8], Schönhart M.[9], Seddaiu G.[1]

1 University of Sassari, Italy
2 INRA Clermont Ferrand, France
3 University of Bydgoszcz, Poland
4 James Hutton Institute, UK
5 Aahrus University, Denmark
6 Università della Tuscia, Italy
7 Luke, Finland
8 NIBIO, Norway
9 Boku University, Wien
*pproggero@uniss.it

Abstract
Designing adaptive pathways to climate change in agriculture under uncertainty is a multidimensional, context-sensitive process with implications for researchers and stakeholders. We report the outcomes of a European case-study analysis across Europe conducted in the context of the MACSUR project. Crop, livestock and grassland and trade modelling, stakeholder engagement and co-researching with farmers were used differently by each research team depending on the available data or local skills. Adaptive responses ranged from changing sowing date to crop diversification or change farm structure. Despite the diversity of climates, methods and local contexts, many converging outcomes emerged, including the need for farmers to learn to perceive climate change, for policy makers to invest private-public partnerships and for researchers to identify adaptation options by investing on long-term experiments and on integrating education and communication in adaptation research.

Keywords: Adaptive capacity, integrated analyses, modelling, stakeholders, wicked issues
Parole chiave: Capacità adattativa, analisi integrate; modellizzazione; portatori di interesse; questioni complesse

Introduction
Uncertainty reduction is not needed to design adaptive responses to climate change in agriculture. Farmers are used to design cropping and farming systems under uncertainty. However, to do so, farmers rely on their personal (past) local experience about how their crops or animals respond to climatic pressures. Climate change poses an additional challenge to such a perspective as probability distributions of the variables indicating crop and animal performance may substantially shift because of climate change and past experience may be misleading (Dono et al., 2016). Same happens at all levels, from the field to the policy making scale. In this work, developed in the context of the MACSUR project (www.macsur.eu), we explore the opportunities and challenges posed by climate change adaptation in a variety of situations across Europe. Our hypothesis is that case studies can provide the ground for addressing the complexity, interdependences and uncertainties that require context-specific responses, i.e. considering the mix of local and global constraints. Integrated analysis tools, stakeholder engagement processes and quantitative modelling were used to identify the convergent and diverging outcomes across a wide range of European situations. The general hypothesis of the work done was that exploring adaptive responses to climate change in well contextualized situations can assist decision making at different (e.g. agricultural practice, research, policy) levels even under uncertainty. We summarize here the lessons learned from the case studies and briefly discuss the implications for research and policy developments.

Materials and Methods
Of the twenty-four MACSUR case studies (http://macsur.eu/index.php/regional-case-studies) we here report two examples in detail (Sardinia and Finland) and a synthesis of the converging outcomes from all the others. A variety of methods were used to address each case study, depending on local skills and site-specific situations. In almost all cases an assessment of the climate change impacts on crop or livestock production was performed using process-based models integrated with stakeholder engagement approaches and economic and policy analyses (e.g. Dono et al., 2016; Liu et al, 2016; Nguyen et al., 2016; Schönhart et al 2016). Models were calibrated and evaluated by relying on local

DOI 10.6092/unibo/amsacta/5692

datasets and field experiments. Semi-structured interviews with key stakeholders were designed to identify the most critical issues on climate responses and to aid the design of structured surveys at larger scale. In some cases, the adaptive capacity was quantitatively assessed through expert surveys and fuzzy analyses (Metzger et al., 2006), statistical analysis using large datasets (Peltonen-Sainio et al. 2016) or the re-staging of traditional forms of conflict mediation (Ruiu et al., 2017). Adaptive actions types were framed following Vermeulen et al 2013.

Results

The climatic pressures and impacts differed across cases, but convergent similarities emerged in the type of adaptive responses identified (Table 1). The forecasted shifts in rainfall patterns (wetter in Northern European countries and drier in the Mediterranean region) and increased temperature will result into impacts on agricultural water management, soil fertility, animal and plant pest and diseases in almost all countries. When the impact is positive on crop yield, it may result into increased environmental threats (Schönhart et al 2016, Huttunen et al. 2015). Water will be a common key driver across areas with contrasting impacts. However, the type of adaptive actions identified were quite similar in Mediterranean and northern European countries. For example, crop breeding and more diverse crop rotations are emphasized as core means of adaptation (Rötter et al. 2013, Peltonen-Sainio et al. 2016).

Table 1 – Examples of site specific climatic pressures, impacts, actions identified and constraints in two contrasting case studies across Europe. Type of action (Vermeulen et al 2013): I = Incremental; S = Systemic; T = Transformational

Tabella 1 – Esempi di pressioni climatiche, impatti, azioni sito specifiche e vincoli in due casi di studio contrastanti in Europa. Tipo di azione ((Vermeulen et al 2013): I = Incrementale; S = Sistemica; T = Trasformativa

Site specific outcomes	**North Savo (Finland)**	**Oristanese (Italy)**
Climate	- Increased T - Increase rainfall and rainy days	- Increased heat wave frequency - Drought, extreme rainfall
Impacts	- Soil compaction, poor drainage - More pests and diseases - Potential for higher yields and nitrogen use efficiency	- Animal welfare and feeding systems - Animal and plant pest and diseases, weeds - Soil erosion on slopes - Lower rainfed crop production - Potential for higher yields in irrigated crops
Adaptive options	- Crop diversification (S) - Shift to protein crops (S) - Improve drainage and soil structure (I) - Intensification on best fields, very low input in marginal land (T)	- Crop diversification (S) - Change crop (S) - Improve irrigation system (I) - Change animal breed (T) - Improve animal diet and welfare (I)
Constraints	- Current ag-policy does not fit farmers' ideas	- Poor water governance and agricultural and environmental policy implementation

Discussion and conclusive remarks

Climate change adaptation requires decision making at different levels under uncertainty. When moving from incremental (e.g. change sowing date) to systemic (e.g. change crop rotation) to transformative (e.g. change land use) adaptation (Vermeulen et al 2013), the system boundaries for agronomy research must be increasingly extended to integrated assessments involving other scientific domains and local knowledge (Nguyen et al, 2014). Exploring well contextualized case studies focusing on farming systems typologies using a variety of methodological approaches can offer a rich-picture of the situations to improve our understanding of what is needed in different contexts to improve the response-ability of agricultural systems to climate change pressures (Peltonen-Sainio et al. 2016). Despite the variety of methodologies and contexts considered in this study, many converging outcomes emerged with relevant implications for agricultural policy and agronomy research. The development of a network of regional cases combining integrated assessment modelling (Ewert et al., 2016) with interactive stakeholder engagement (Ison et al., 2014) proved to be effective in generating support for decision making for agricultural policy and future directions for agronomy research.

Table 2 – Some key converging outcomes and related implications for policy and agronomy research emerging from MACSUR case-study integrated assessments across Europe in relation to improving climate change adaptive capacity.

Tabella 2 – Convergenze e relative implicazioni per le politiche e la ricerca agronomica che scaturiscono dalla valutazione integrata di casi di studio europei sul miglioramento della capacità adattativa ai cambiamenti climatici.

Outcomes from case studies	**Implications for agricultural policy**	**Implications for agronomy research**
Model outputs (ex ante assessment) and surveys (ex post) are often convergent in identifying adaptation options	To be informed by scientific quantitative assessments on impacts and effective adaptation options	Invest on modelling performances and robust long term experimental or monitoring field datasets and networks to improve the quality of model input data

DOI 10.6092/unibo/amsacta/5692

Farmers' perceptions of climate changes are misleading; design praxes at the policy implementation level call for new professional skills	Invest on "learning to perceive" climate changes towards volunteer adaptive behaviors at farm and community levels and towards improved design praxes at the practitioners level.	Include farmers' perception analysis in integrated adaptation studies; use existing databases and statistical analysis to show evidence on the adaptation challenges and needs, concerning e.g. harmful weather events.
Farmers' perceptions of climate change depend on farming system (Nguyen et al 2016)	Adaptation policies to be contextualized to the farming system typology rather than just on a regional basis	To improve contextualization of scenario analysis to identify agronomic options through participatory processes targeted to specific farmers' production system
Farmers adaptive actions are driven by socio-economic factors but are triggered by extreme climatic events	Effective adaptation policies to address systemic and transformational adaptation which implies long term structural investments	Research on climate change adaptation to extend its scope from just incremental to systemic and transformational adaptation (e.g. through long term experiments)
Farmers claim less bureaucracy and slow implementation and payments	To shift from procedural to performance assessment and to participatory monitoring as a mean for enhancing farmers' environmental identity and responsibility	Integrated research results to explore the policy and economic implications of adaptive agronomic options, e.g. what are the benefits, e.g. yields, stability, flexibility, and costs
Public-private partnerships (PPP) can help spreading innovation	Policy to facilitate PPP in agriculture by improving the implementation process quality e.g. ensuring technical and administrative support and balance between farming types	Invest on co-researching (with farmers and stakeholders) for innovation e.g. European Innovation Partnership programs

References

Dono G., Cortignani R., Dell'Unto D., Deligios P., Doro L., Lacetera N., Roggero P.P., 2016. Winners and losers from climate change in agriculture: Insights from a case study in the Mediterranean basin. Agr Syst, 147: 65-75.

Ewert, F., Rötter, R.P., Bindi, M., Webber, H., Trnka M., Kersebaum K.C., ... Semenov M.A., 2015. Crop modelling for integrated assessment of risk to food production from climate change. Environ Modell Softw, 72: 287-303.

Huttunen I., Lehtonen H., Huttunen M., Piirainen V., Korppoo M., Veijalainen N., Viitasalo M., Vehviläinen B., 2015. Effects of climate change and agricultural adaptation on nutrient loading from Finnish catchments to the Baltic Sea. Sci Total Environ, 529:168-181.

Ison R., Grant A., Bawden R., 2014. Scenario praxis for systemic governance: a critical framework. Environ Plann C, 32(4): 623-640.

Liu X., Lehtonen H., Purola T., Pavlova Y., Rötter R., Palosuo, T., 2016. Dynamic economic modelling of crop rotations with farm management practices under future pest pressure. Agr Syst, 144: 65-76.

Metzger M.J., Rounsevell M.D.A., Acosta-Michlik L., Leemans R., Schröter, D., 2006. The vulnerability of ecosystem services to land use change. Agr Ecosyst Environ, 114(1): 69-85.

Nguyen T.P.L., Seddaiu G., Roggero P.P., 2014. Hybrid knowledge for understanding complex agri-environmental issues: nitrate pollution in Italy. Int J Agric Sustain, 12(2): 164-182.

Nguyen T.P.L., Seddaiu G., Virdis S.G.P., Tidore C., Pasqui M., Roggero P.P., 2016. Perceiving to learn or learning to perceive? Understanding farmers' perceptions and adaptation to climate uncertainties. Agr Syst, 143: 205-216.

Peltonen-Sainio P, Venäläinen A, Mäkelä HM, Pirinen P, Laapas M, Jauhiainen L, ... Virkajärvi P. 2016. Harmfulness of weather events and the adaptive capacity of farmers at high latitudes of Europe. Clim Res, 67:221-240.

Rötter, R. P., Höhn, J., Trnka, M., Fronzek, S., Carter, T. R., & Kahiluoto H. 2013. Modelling shifts in agroclimate and crop cultivar response under climate change. Ecol Evol, 3: 4197–4214.

Schönhart M., Schauppenlehner T., Kuttner M., Kirchner M., Schmid E., 2016. Climate change impacts on farm production, landscape appearance, and the environment: Policy scenario results from an integrated field-farm-landscape model in Austria. Agr Syst, 145: 39-50.

Vermeulen S. J., Challinor A. J., Thornton P. K., Campbell B. M., Eriyagama N., Vervoort J. M., ... Nicklin, K. J. 2013. Addressing uncertainty in adaptation planning for agriculture. PNAS, 110(21): 8357-8362.

EVALUATION OF HEMP GENOTYPES FOR A DUAL PURPOSE PRODUCTION IN A SEMI-ARID MEDITERRANEAN ENVIRONMENT
VALUTAZIONE DI GENOTIPI DI CANAPA PER LA PRODUZIONE A DUPLICE SCOPO IN AMBIENTE SEMI-ARIDO MEDITERRANEO

Paolo Guarnaccia, Giorgio Testa*, Silvio Calcagno, Giancarlo Patanè, Danilo Scordia, Salvatore Luciano Cosentino

[1] Dipartimento di Agricoltura, Alimentazione e Ambiente (Di3A), Via Valdisavoia 5, 95123, Catania
*gtesta@unict.it

Abstract
Hemp (*Cannabis sativa* L.) is a multiuse crop that can be grown under a wide range of agro-ecological conditions. The present study evaluates the adaptation and productivity of different monoecious hemp genotypes developed in Central-Northern and Southern Europe to the semiarid Sicilian environment. The field experiment was carried out with the aim of assessing the potential yields in terms of stems and seeds of four hemp genotypes (Futura 75, Uso 31, Fedora, Felina). All the studied genotypes were evaluated at the experimental field of the Catania University, while one or two of them were evaluated in four farms located in Catania and Palermo province. In terms of stem dry biomass yield, in Catania, the most productive variety was Futura 75 that yielded 6.98 t ha^{-1}, while the lowest Uso 31 with 2.38 t ha^{-1}. Even for seed yield, in Catania, Futura 75 yielded the most (1.0 t ha^{-1}), followed by Felina (0.89 t ha^{-1}), Fedora (0.83 t ha^{-1}) and Uso 31 (0.67 t ha^{-1}).

Keywords: *Cannabis sativa* L.; Hemp; Biomass yield; Seed yield.
Parole chiave: *Cannabis sativa* L.; Canapa; Resa in biomassa; Resa in seme.

Introduction
Hemp (*Cannabis sativa* L.) is considered one of the oldest crops known to Man (Amaducci et al., 2015). During the centuries hemp has been used as fibre and medicinal plant. The information regarding its use as food crop are very limited.
In recent years it was observed a renewed interest to hemp cultivation, both as industrial and food crop. The interest as food crop is related to the nutritional values of hemp seeds mainly related to the high-quality oil and proteins contained in the seeds (Carus et al., 2013). As reported by Amaducci et al. (2015) hemp fibre can also be used as reinforcement in composite materials, to produce insulation mats, car interior panels, and requested in bio-building sector to form concrete too. The possibility to cultivate hemp as a dual-purpose use could improve the farmer revenue.
The information regarding the adaptability of hemp genotypes to Mediterranean environment are poor and even more are the information regarding the dual-purpose cultivations. In this respect, the present study evaluated the adaptability of four hemp genotypes under the Mediterranean conditions of Southern Italy (Sicily).

Materials and Methods
The field trials were carried out between spring and summer 2016 both at the Experimental farm of the University of Catania, Italy (37°25' N., 15°03' E., 10 m a.s.l.) and in four private farms located in Caltagirone and Randazzo (Catania province), Petralia Sottana and Sclafani Bagni (Palermo province).
At the experimental field of Catania University were evaluated four monoecious varieties (Futura 75, Uso 31, Felina, Fedora) in a randomized block design three times replicated. The single plot size was 54 m^2 (5.4 x 10 m).
In order to evaluate the adaptability in other Sicilian areas, in the four private farms that cultivated hemp in large fields, three plots (10 x 10 m each) per varieties were delimited in order to evaluate morpho-biometrics parameters and biomass yield.
The varieties, locations, sowing and harvest time are reported in table 1.
Only at the experimental farm of the Catania University, after sowing, irrigation was applied only until crop establishment (160 mm).

Tab. 1: Site, varieties, seeding rate, sowing and harvest time in the five locations.
Tab. 1: Località, varietà utilizzata, densità di semina, data di semina e di raccolta nelle 5 località.

Site (Province)	Altitude (m asl)	Varieties	Seeding rate	Sowing time	Harvest
Petralia Sottana (Palermo)	600	Futura 75	45 kg ha^{-1}	29/04/2016	02/08/2016
Randazzo (Catania)	750	Uso 31	45 kg ha^{-1}	24/04/2016	27/07/2016
Caltagirone (Catania)	500	Futura 75, Uso 31	45 kg ha^{-1}	19/03/2016	14/07/2016
Sclafani Bagni (Palermo)	700	Futura 75	45 kg ha^{-1}	18/04/2016	09/8/2016
Catania	10	Futura 75, Uso 31, Felina, Fedora	45 kg ha^{-1}	28/04/2016	10/8/2016

In the different sites, harvest was performed at seed maturity. At harvest, edge plants were removed in each plot in order to weight the biomass within 16 m^2 (4 x 4 m). Dry biomass yield was calculated by weighing sub-samples of fresh biomass and after oven drying it at 65 °C until constant weight. The seed samples were air dried, cleaned and weighed for seed yield determination.

Results and Discussion

At the experimental farm of the Catania University where 4 varieties were evaluated, plant height ranged between 122 cm in Uso 31 and 192 cm in Futura 75. Observing the height of Futura 75 in the four sites, the highest height value was observed in Catania while the lowest in Caltagirone and Sclafani Bagni (153 and 154 cm, respectively). Both in Catania and Caltagirone, Uso 31 showed the lowest height values (122 and 103 cm, respectively).

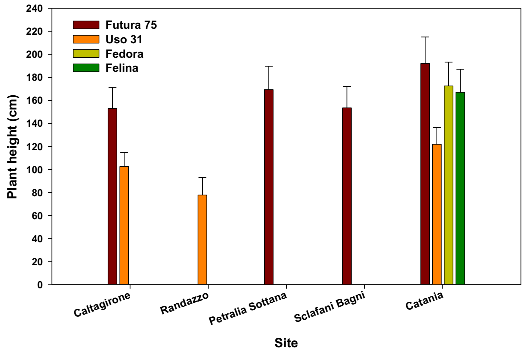


Fig. 1. Plant height (cm) in relation to the different sites and varieties.
Fig. 1. Altezza della pianta in relazione alle differenti località e varietà.

In the average of experimental sites and varieties, the stem dry biomass was equal to 4.21 t ha^{-1}. In Catania in the average of the four varieties the stem dry biomass was equal to 4.86 t ha^{-1} (Figure 2). The highest value was observed in Futura 75 (6.98 t ha^{-1}) followed by Felina (5.82 t ha^{-1}), Fedora (4.24 t ha^{-1}) and Uso 31 (2.27 t ha^{-1}). These results are in accordance to Cosentino et al. 2013 who reported, in the same environment, for Futura 75 a stem yield ranging from 6 to 10 t ha^{-1} in relation to water availability. The same authors (Cosentino et al., 2012) reported in relation to sowing time, yields ranging from 1.8 to 8.7 t ha^{-1}.

Also in Caltagirone where Futura 75 and Uso 31 were studied, Futura 75 was the most productive (4.58 t ha^{-1} against 3.30 t ha^{-1} of Uso 31). A very low stem dry yield was observed with Uso 31 in Randazzo, due to shallow soil caused by a heavy clay compacted layer at 30 cm depth.

Among the hemp genotypes, mean seed yield was 0.70 t ha^{-1} in all treatments. In Catania the highest value of seed yield was obtained in Futura 75 (1,00 t ha^{-1}) followed by Felina (0.89 t ha^{-1}), Fedora (0.83 t ha^{-1}) and Uso 31 (0.67 t ha^{-1}). In Caltagirone as well as for dry stem yield, Futura 75 yielded the most (0.71 t ha^{-1}) compared to Uso 31 (0.64 t ha^{-1}). A very low value of seed yield was obtained in Randazzo (0.19 t ha^{-1}). Among Futura 75, the most productive site was Catania (1 t ha^{-1} of seeds), followed by Sclafani Bagni (0.74 t ha^{-1}), Caltagirone (0.71 t ha^{-1}) and Petralia Sottana (0.49 t ha^{-1}).

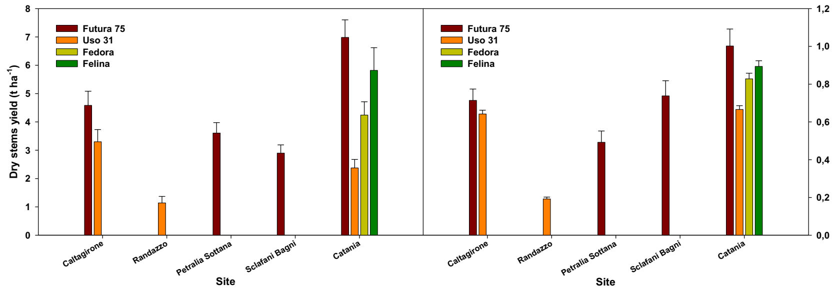


Fig. 2. Stem dry biomass (t ha-1) (left) and seed yield (t ha-1) (right) in relation to the different sites and varieties.
Fig. 2. Resa secca in culmi (t ha-1) (a sinistra) e resa in seme (t ha-1) (a destra) in relazione alle differenti località e varietà.

Conclusions

The hemp varieties evaluated in this study highlighted a good adaptability to Sicilian environment even under rainfed conditions. The obtained results suggest the possibility that hemp, in this environment, could be cultivated both for seed and fiber productions. The difference in seeds and stems yields observed in the studied varieties suggest to carry out further studies in order to identify the more suitable genotypes. However additional studies should focus on the evaluation of the best sowing density in order to increase seeds yield.

References

Amaducci S., Scordia D., Liu F.H., Zhang Q. Guo H., Testa G., Cosentino S.L., 2015. Key cultivation techniques for hemp in Europe and China. Industrial Crops and Products 68, 2–16.

Carus, M., Karst, S., Kauffmann, A., 2013. The European Hemp Industry: cultivation,processing and applications for fibres, shivs and seeds. EIHA 2003, 1–9.

Cosentino S.L., Testa G., Scordia D., Copani V., 2012. Sowing time and prediction of flowering of different hemp (Cannabis sativa L.) genotypes in southern Europe. Industrial Crops and Products 37, 20-33.

Cosentino S.L., Riggi E., Testa G., Scordia D., Copani V., 2013. Evaluation of European developed fibre hemp genotypes (Cannabis sativa L.) in semi-arid Mediterranean environment. Industrial Crops and Products 50, 312-324.

SOIL DNA METABARCODING: EVALUATING THE EFFICIENCY OF MULTIPLEX PRIMER SETS IN RECOVERING THE SOIL INVERTEBRATE'S COMMUNITY AS SOIL QUALITY INDICATORS

DNA METABARCODING DEL SUOLO: VALUTAZIONE DELL'EFFICIENZA DI ALCUNI SET DI PRIMER NELL'INVESTIGARE LA COMUNITÀ INVERTEBRATA DEL SUOLO COME INDICATORI DELLA QUALITÀ DEI SUOLI

Sumer Alali[1*], Paola Cremonesi[2], Bessem Chouaia[1], Valeria Mereghetti[1], Flavia Pizzi[2], Matteo Montagna[1], Stefano Bocchi[1]

[1] Università degli Studi di Milano, Dipatimento di Scienze Agraria e Ambiente-Produzione, Territorio, Agroenergia, via Celoria 2, 20133 Milano, Italy
[2] Istituto di Biologia e Biotecnologia Agraria, Consiglio Nazionale delle Ricerche, via Einstein, 26900 Lodi, Italy
[*] sumer.alali@unimi.it

Abstract

DNA Metabarcoding was used to investigate the efficiency of two sets of primers (combinations *A* and *B*) for characterizing the soil invertebrate's communities in different farming management systems. Soil samples were taken from three different sites in the South-West of Milan and DNA was extracted directly. PCR was applied by using 4 pairs of previously published primers targeting invertebrate's *cox1*, followed by Illumina Miseq sequencing. The results showed that the presence of the most popular primer pair used in barcoding studies (LCOI490-HCO2198) has affected negatively the taxonomic assignment of OTUs, since about 67.88 % of the obtained sequences where not identified. Our analysis showed that a higher percentage of Arthropoda, Annelida, Nematoda and Rotifera &Tardigrada (41.6, 5.9, 0.8 and 1% of total reads, respectively) was obtained with primer combination *B*; thus this primers set can be considered a promising method to evaluate the soil arthropods community.

Keywords: mitochondrial *cox1*, biodiversity, Illumina MiSeq.
Parole chiave: citocromo ossidasi subunità I, biodiversità, Illumina MiSeq.

Introduction:

Biodiversity assessment is the key factor in understanding the relationships between biodiversity and ecosystem functioning/services. The effects of major anthropogenic stressors on global ecosystems, including elevated CO_2, pollution, habitat loss and fragmentation, add urgency to this field, demanding an increasing focus on mechanistic and predictive studies. So far, there is a well-acknowledged biodiversity identification gap related to eukaryotic meiofaunal organisms (Creer et al., 2010). The most abundant micro- and mesofauna in soil include nematodes, microarthropods (i.e., Collembola, Acari, Insecta), Anellidae as Enchytraeids, and to a lesser extent, Tardigrades, Rotifers, and Proturans. Therefore, the accurate assessment of the taxonomic structure of these communities is both time-consuming and requires a high level of taxonomic expertise (Hamilton et al., 2009). The limitations inherent in morphology-based identification systems and the dwindling pool of taxonomists prompt the need for a new approach to taxon recognition (Hebert et al., 2003a,b).

DNA metabarcoding, a promising new technology, involves the direct extraction of DNA from soil samples, PCR amplification of the extracted DNA with specific primers, followed by libraries preparation with sample-specific tags and sequencing through Next Generation Sequencing technologies (Hamilton et al., 2009). Although presence–absence measures can provide useful indicators of biological diversity, they are often insufficient to link biological diversity to ecosystem functioning (Faust and Raes, 2012).

The Cytochrome Oxidase I (*cox1*) gene is typically used for DNA metabarcoding technique and extensive reference sequences are already available in online databases (Ratnasingham and Hebert, 2007, 2013), but, as previously evaluated, the utility of DNA metabarcoding remains limited due to severe primer bias, which prevents the detection of all taxa present in a sample (Piñol et al., 2014; Elbrecht and Leese, 2015). Therefore, the selectionof primers is the most critical component to assess macroinvertebrate bulk samples with DNA metabarcoding. Several *cox1* barcoding primers with different levels of degenerates base have been developed of which many are now used or could be suitable for

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Metabarcoding studies (e.g., Folmer et al., 1994; Hebert et al., 2004; Meusnier et al., 2008; Leray et al., 2013). One of the first primers pair designed on the 5' region of the mitochondrial *cox1* gene is the LCOI490-HCO2198 from Folmer et al. (1994), which has been successfully used in a plethora of DNA barcoding studies targeting a wide taxonomic range (e.g., Hebert et al., 2003a,b; Sheffied et al., 2009; García-Morales and Elías-Gutiérrez 2013; Magoga et al., 2016; Montagna et al., 2016). However, Metabarcoding primers typically recover approximately 80–90% or less of the taxa present in a sample (Leray et al., 2013; Brandon-Mong et al., 2015; Elbrecht and Leese, 2015). Furthermore, many primers have not been thoroughly evaluated for primer bias and the proportion of undetected taxa, making development and testing of universal primers a pressing issue.
In the present study, two combinations of primers sets targeting the mitochondrial *cox1* were tested in order to evaluate their efficiency in characterizing meso- and meio-faunal soil communities.

Material and methods:
Three sites under different farming management were chosen in the South-West area near Milan. The farms are located in the municipalities of Albairate (MI) and Cisliano (MI).
Three different types of soil samples (organic farm, conventional farm and forest), representing three main types of land-use in the study area, were collected in replicate in two farms from stable meadows and barley, during three different seasons (*i.e*., spring, summer and autumn),.
Soil samples were homogenized in laboratory, grounded with liquid nitrogen and the DNA was extracted from each replicate by Nucleospin® soil kit (Macherey-Nagel, Düren - Germany) following the procedure described by Capra and co-workers (2016).
Fragments of the *cox1* gene ranging from ~300 to 650 bp were amplified using the primers reported in the table (Tab. 1), and the two combinations of tested primers were: *A* = primers 1+2+3+4, *B* = primers 1+3+4. Samples were randomly selected for applying the primers combination resulting in 29 samples for *A* and 26 samples for *B* combination, respectively.

Tab.1: Primers used for the amplification of COI gene.
Tab.1: Primer usati per l'amplificazione del gene COI.

PCR_ID	Primers	Sequence 5' – 3'	References
1	COIF2 COIR2	TCTACYAATCATAAAGATATTGGTAC ACTTCTGGATGACCAAAGAATCA	Arribas et al, 2016
2	LCOI490 HCO2198	GGTCAACAAATCATAAAGATATTGG TAAACTTCAGGGTGACCAAAAAATCA	Folmer et al, 1994
3	mlCOIintf JgHCO2198	GGWACWGGWTGAACWGTWTAYCCYCC TAIACYTCIGGRTGICCRAARAAYCA	Leray et al, 2013; Geller et al, 2013
4	Foldf-foldr	GTGTATCTACGGTTGG CAATCCAGCAAGTCAGG	Yu et al. 2012

Libraries were assembled pooling PCR products, according with the primers combinations (*A* and *B*), in equimolar concentrations and sequenced on a paired 2X250 bp run on Miseq platform (Illumina, San Diego, CA, USA). Raw sequences were processed rebuilding full amplicon fragments via pair overlapping and analyzed using QIIme platform. In order to identify the obtained Operational Taxonomic Units (OTUs), a *cox1*-based reference database was built. The *cox1* dataset contains our target taxa (*i.e*., phyla belonging to Animalia) with the inclusion of Archea, Bacteria and Fungi representatives in order to detect cross-amplifications between the used primers with non-target taxa. A descriptive statistic was performed to determine the frequencies and percentages of OTUs in samples and sites.

Results and discussions:
A total of 13,506,930 raw reads were obtained by the adopted sequencing strategy, 79.9% of the reads were lost after filtering due to their low quality resulting in a total number of 2,713,429 high-quality reads to be assigned to OTUs and analyzed (mean = 50,247 ± 3,477 sequences/sample).
The 2,713,429 reads were assigned to 194,668 OTUs, 67% of them were unspecific in the set *A* and only 21% were unspecific in the set *B* (Fig. 1, a). Regarding the OTUs assignment, ~63% of the reads obtained from the set *B* and ~22%

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

of those from set *A* were assigned to the Animal kingdom. Focusing on our target groups, the invertebrates inhabiting soil (Fig. 1, b), the set *B* had a higher percentage of sequences assigned to Arthropods (41.6 %), Annelida (5.9 %), while in the case of set *A* the percentage of Arthropoda was 10.9 % and Annelida 5.4 % of the sequences.

Despite the assignment of 22.6% of sequences to non Animalia phyla (Fungi, Bacteria, etc…) in the set *B* (which was only 10.9% in the set *A*), the set *B* could recover a percentage of Arthopods four times higher than set *A* (41.6% and 10.9% in set *B* and set *A* respectively). Also higher percentages of sequences in the set *B* were assigned to Nematodes and other Metazoans like Rotifera and Tardigrades comparing with the set *A* (0.8% and 1% in set *B*; 0.01% and 0.3% in set *A*, respectively).

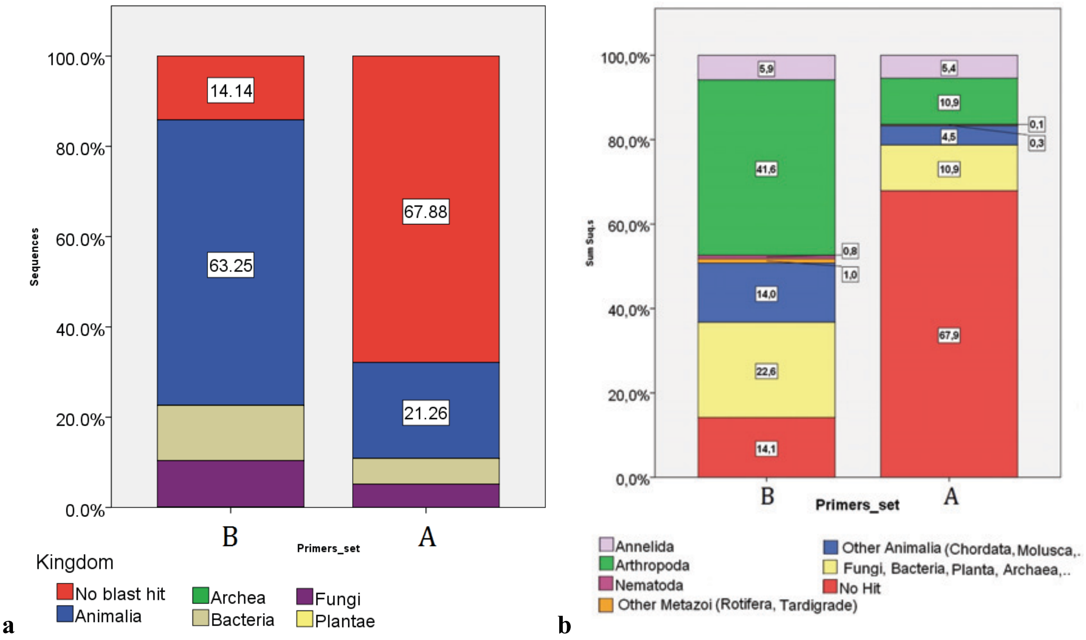


Fig.1: Percentage of the sequences assigned at the level of Kingdom (a) and at the level of Phyla for Animalia (b).
Fig.1: Percentuale delle sequenze assegnate a livello di Regno (a) e per i phyla animali (b).

Separating the obtained data according to the sampling site, the results confirmed that the primer set is a main factor affecting the recovered data, since the percentages of assigned OTUs to Arthropodes and Other groups of interest of Animalia were higher in the set *B* regardless the sites (Tab. 2). For example, the percentage of sequences assigned to Arthropodes in set *B* was four times higher than that of the set *A* in the Organic and Conventional sites.

Tab. 2: OTUs and percentages of sequences according to the primer set and the sampling sites.
Tab. 2: OTUs e percentuali di sequenze ottenute con i due set di primer nei tre siti di campionamento.

Primers_set	*A*			*B*		
Farm	Organic	Forest	Conventional	Organic	Forest	Conventional
Annelida	5,4%	7,9%	4,3%	4,0%	0,3%	7,2%
Arthropoda	9,2%	9,9%	14,5%	39,5%	3,7%	43,8%
Nematoda	0,1%	0,1%	0,1%	0,9%	0,0%	0,8%
Other Metazoi (Rotifera, Tardigrade)	0,2%	0,1%	0,4%	1,1%	0,0%	1,0%
Other Animalia (Chordata, Molusca)	4,1%	3,2%	5,9%	15,8%	2,0%	13,2%
Fungi, Bacteria, Plantae, Archaea	9,6%	15,6%	10,8%	22,5%	48,6%	22,0%
No Hit	71,4%	63,1%	64,1%	16,3%	45,3%	12,0%

DOI 10.6092/unibo/amsacta/5692

Conclusions:

The major result of this preliminary study is that the set of primers, used to assembly PCRs, is a crucial factor affecting the capability to analyze efficiently the desired group of interest. The primer combination *B* could represent a promising method to evaluate the soil invertebrate's communities.

Acknowledgments:

We would like to thank the owners of the three farms in Cisliano - Albairate (MILANO) for their collaboration and facilitating the collection of soil samples.

References:

Arribas, P., Andujar, C., Hopkins, K., Shepherd, M., Vogler, A. P., & Yu, D. (2016). Metabarcoding and mitochondrial metagenomics of endogean arthropods to unveil the mesofauna of the soil. Methods in Ecology and Evolution, 7(9), 1071–1081.

Brandon-Mong, G. J., Gan, H.M., Sing, K.W., Lee, P. S., Lim, P. E., andWilson, J. J., 2015. DNA metabarcoding of insects and allies: an evaluation of primers and pipelines. Bull. Entomol. Res. 105, 717–727.

Capra, E., Giannico, R., Montagna, M., Turri, F., Cremonesi, P., Strozzi, F., Leone, P., Gandini, G., Pizzi, F. 2016. A new primer set for DNA metabarcoding of soil Metazoa. European Journal of Soil Biology, 77: 53-59. Creer, S., Fonseca, V. G., Porazinska, D. L., Giblin-Davis, R. M., Sung, W., Power, D. M., Thomas, W. K., 2010. Ultrasequencing of the meiofaunal biosphere: Practice, pitfalls and promises. Molecular Ecology, 19(SUPPL. 1), 4–20.

Elbrecht, V., and Leese, F., 2015. Can DNA-based ecosystemassessments quantify species abundance? Testing primer bias and biomass—sequence relationships with an innovative metabarcoding protocol. PLoS ONE 10:e0130324

Faust K., Raes J., 2012. Microbial interactions: from networks to models. Nat. Rev. Microbiol. 10, 538–550.

Folmer, O., Black, M., Hoeh, W., Lutz, R., and Vrijenhoek, R., 1994. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Mol. Mar. Biol. Biotechnol. 3, 294–299.

García-Morales, A.E., Elías-Gutiérrez, M. 2013. DNA barcoding of freshwater rotifera in Mexico: evidence of cryptic speciation in common rotifers. Mol. Ecol. Resour. 13,1097-1107.

Geller J, Meyer C, Parker M, Hawk H. 2013 Redesign of PCR primers for mitochondrial cytochrome c oxidase subunit I for marine invertebrates and application in all-taxa biotic surveys. Mol. Ecol. Resour. 13, 851–861.Hamilton, H. C., Strickland, M. S., Wickings, K., Bradford, M. A., & Fierer, N., 2009. Surveying soil faunal communities using a direct molecular approach. Soil Biology and Biochemistry, 41(6), 1311–1314.

Hebert P. D. N., Cywinska, A., Ball, S. L., deWaard, J. R. 2003a. Biological identifications through DNA barcodes. Proceedings of the Royal Society of London, Series B 270, 313–321.

Hebert, P. D. N., Ratnasingham, S., & Waard, J., 2003b. Barcoding animal life : cytochrome c oxidase subunit 1 divergences among closely related species Barcoding animal life : cytochrome c oxidase subunit 1 divergences among closely related species. Proc. R. Soc. Lond. B, 270, S96–S99.

Hebert, P. D. N., Penton, E. H., Burns, J. M., Janzen, D. H., and Hallwachs, W., 2004. Ten species in one: DNA barcoding reveals cryptic species in the neotropical skipper butterfly Astraptes fulgerator. Proc. Natl. Acad. Sci. U.S.A.

Leray, M., Yang, J. Y., Meyer, C. P., Mills, S. C., Agudelo, N., Ranwez, V., et al., 2013. A new versatile primer set targeting a short fragment of the mitochondrial COI region for metabarcoding metazoan diversity: application for characterizing coral reef fish gut contents. Front. Zool. 10:34.

Meusnier, I., Singer, G. A., Landry, J.-F., Hickey, D. A., Hebert, P. D., and Hajibabaei,M., 2008. A universal DNA mini-barcode for biodiversity analysis. BMC Genomics 9:214.

Magoga G., Sassi, D., Daccordi, M., Leonardi, C., Mirzaei, M., Regalin, R., Lozzia, G., Montagna, M. 2016. Barcoding Chrysomelidae: a resource for taxonomy and biodiversity conservation in the Mediterranean Region. Zookeys 597, 27-38.

Montagna, M., Mereghetti, V., Lencioni, V. & Rossaro, B., 2016 Integrated Taxonomy and DNA Barcoding of Alpine Midges (Diptera: Chironomidae). PLoS ONE, 11 (3), e0149673.

Piñol, J., Mir, G., Gomez-Polo, P., and Agustí N., 2014. Universal and blocking primer mismatches limit the use of high-throughput DNA sequencing for the quantitative metabarcoding of arthropods. Mol. Ecol. Resour. 15, 1–12.

Ratnasingham, S., and Hebert, P., 2013. A DNA-based registry for all animal species: the Barcode Index Number (BIN) system. PLoS ONE 8:e66213.101, 14812–14817.

Ratnasingham, S., and Hebert, P., 2007. BOLD: the Barcode of Life Data System (http://www.barcodinglife.org). Mol. Ecol. Notes 7, 355–364.

Sheffield, C. S., Hebert, P. D. N., Kevan, P. G., Packer L. 2009. DNA barcoding a regional bee (Hymenoptera: Apoidea) fauna and its potential for ecological studies. Mol. Ecol. Res. 9, 196–207.

Yu, D. W., Ji, Y., Emerson, B. C., Wang, X., Ye, C., Yang, C., & Ding, Z. (2012). Biodiversity soup: Metabarcoding of arthropods for rapid biodiversity assessment and biomonitoring. Methods in Ecology and Evolution, 3(4), 613–623.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

DOES SALT STRESS INCREASE WEEDS INVASIVENESS?

LO STRESS SALINO AUMENTA L'INVASIVITA' DELLE SPECIE INFESTANTI?

Valerio Cirillo[1], Emilio Di Stasio[1], Giuseppe Zanin[2], Albino Maggio[1]*

[1] Dipartimento di Agraria, Università degli Studi di Napoli Federico II, Via Università 100, 80055 Portici (NA);
[2] Dipartimento Agronomia Ambientale e produzioni vegetali, Università degli Studi di Padova, Via dell'Università 16, 35020 Legnaro (PD);
* almaggio@unina.it

Abstract
Weed management is critical in agricultural productions. However, the link between environmental changes, weeds growth and their invasiveness has been not sufficiently addressed. Weeds are known for their ability to survive and spread in unfavorable environments including soils affected by high salinity. Salinization of agricultural lands is increasing due to reduced rainfall and inadequate irrigation management. Therefore, if weeds are less affected by salinity than crops expanding salinization could increase weeds invasiveness, enhancing their competition vs. crops.
In this context, we started to elaborate a meta-analysis study based on original research papers in which we associated the relative tolerance of weeds and crops to salt stress and we highlighted possible implications for weed management. Our findings, at this stage, showed that weeds generally exhibit halophytic behavior when subjected to salt levels that are unacceptable for most agricultural crops. These results may anticipate increasing weeds invasiveness in future agricultural systems.

Key words: weeds, competition, salinity, plant growth, environmental changes.
Parole chiave: erbe infestanti, competizione, salinità, crescita della pianta, cambiamenti ambientali.

Introduction
Weeds are responsible for significant crop yield losses in agricultural productions (Oerke, 2006). High competition with crops occurs when the availability of a resource is not adequate (Patterson, 1995). Yield loss depends on the infesting weed species, their population density and duration of infestation, as well as the soil conditions including high salinity levels (Azmi et al., 2007).
The progressive salinization of cultivated lands is a major abiotic stress responsible for reduced crop production in many of the world's regions (Rengasamy, 2006). Plants may have different growth responses to salinity and therefore different tolerance levels (Munns and Tester, 2008).
With increasing soil salinization weed control methods could benefit of a better understanding of the physiological mechanisms associated to crops and weeds response to salinity (Radosevich et al., 2007; Gurevitch et al., 2009). The field composition of weed species is strongly influenced by environmental heterogeneity, which is related in part to crop type and management practices and in part to specific environmental conditions and availability of environmental resources (Patterson, 1995; Petit et al., 2011).
Soil salinity can influence the germination and growth of weed species (Chauhan and Johnson 2010). Based on these findings, we started to investigate the response of several weeds and associated affected crops to salinity. Our purpose is to develop a database that could provide a range of information aimed at better understanding future invasiveness of weeds with the increasing salinization of cultivated lands.

Materials and methods
A meta-analysis was started based on original research papers in which the tolerance of over 70 weed species to different levels of salinity was evaluated. For assessment of crop salinity tolerance, we referred to the Maas and Hoffman model (1977) and Tanji and Kielen (2002). We used tolerance threshold and percentage slope per increase of electric conductivity (EC) to make a linear regression of the dry weight reduction caused by increasing levels of salinity. The threshold (a) represents the level of salinity at which the dry weight does not decrease compared to unstressed conditions. After this point, each unit increase in electrical conductivity (ECe in dS/m*)* causes a dry weight reduction equal to slope (b) expressed in percent per dS/m. The equation below allowed us to estimate the dry weight reduction (DWr) at each electrical conductivity level.

$$DWr = 100 - b(ECe - a)$$

The same linear regression has been calculated for weeds, using the data found in the original research papers. Thus, we compared the linear regression of four major crops worldwide (corn, soybean, wheat and rice) and their most detrimental weeds (Zimdahl, 2004). In addition, we calculated and listed thresholds and slopes for the weeds discussed in these papers.

Results and discussion
The increasing salinity of the root zone strongly affects the dynamics of crop/weeds competitions (Patterson, 1995). Figure 1 shows the trend of the dry weight reduction in crops and their associated weeds exposed to increasing salinity. Among the crops under assessment, wheat has shown the highest salinity tolerance compared to its related weeds. On the other hand, corn, soybean (Essa, 2002) and rice (Aslam et al., 1993) resulted more sensitive than their most common weeds.

DOI 10.6092/unibo/amsacta/5692

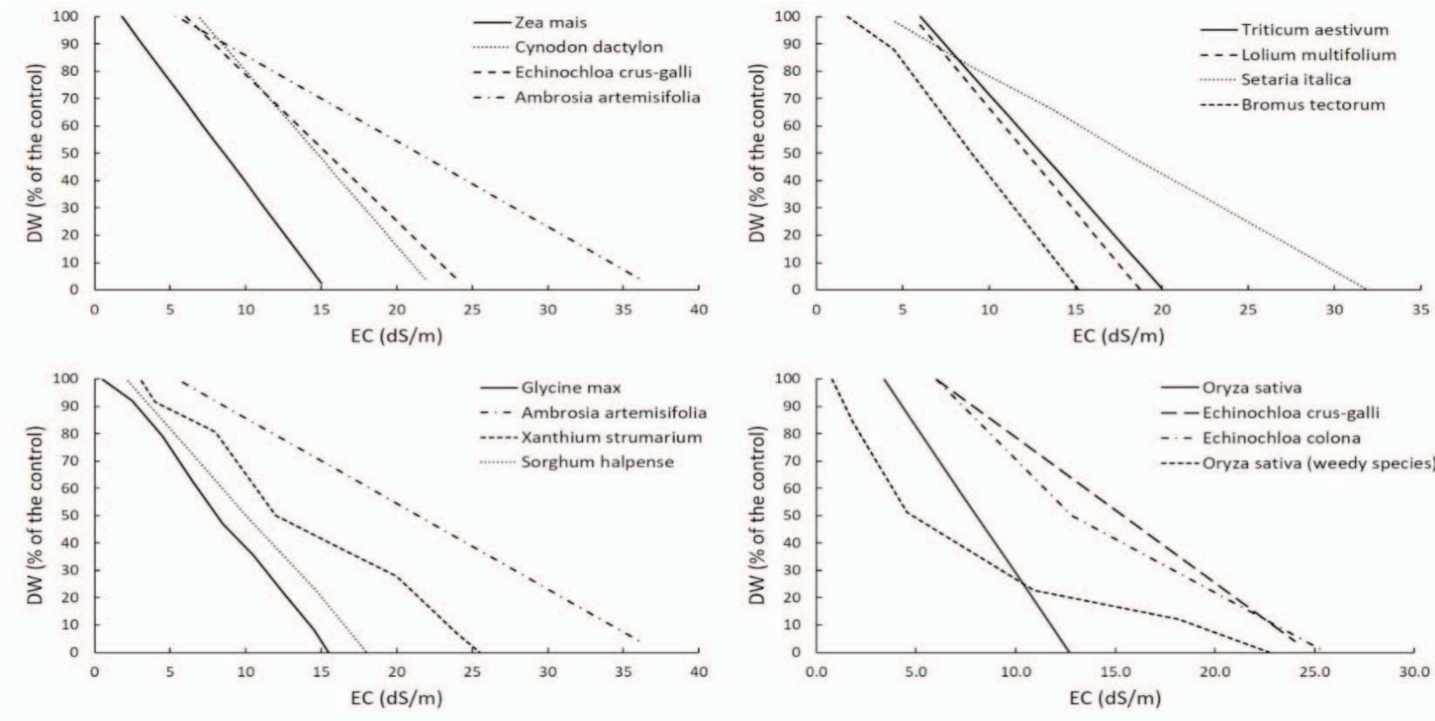


Figure 1. *Comparisons between linear regression of four of the most important crops worldwide with their most detrimental weeds.*
Figura 1. *Confronto tra le curve di regressione lineari di quattro tra le colture più rappresentative e le loro maggiori infestanti.*

An interesting aspect of this comparison is that weeds generally exhibit a lower slope than crops, i.e. smaller dry weight reduction at increasing salinity (dS/m) of the root zone after the specific tolerance threshold has been reached. This would indicate higher tolerance of weeds to salinity relative to crops. In addition to higher salt stress tolerance, weeds are characterized by remarkable adaptation to extreme environments. In water limited environments, various weeds are less sensitive to reduced soil water than crops with which they compete; this aspect, combined with more expanded root systems that weeds may have, may cause a rapid depletion of the water available for the crop (Patterson, 1995 and references cited therein). The combined drought and salinity tolerance of weeds may further amplify their competitiveness/invasiveness. Based on the Maas and Hoffman relationship (1977) we started to categorize most common weeds based on available literature data (Tab. 1). These data could be used as initial source to begin a systematic assessment of the relative and evolving tolerance of weeds respect to cultivated crops.

Table 1.: *Tolerance of some of the most critical weeds worldwide with their relative rating. Ratings (from sensitive to extremely tolerant) are defined following Tanji and Kielen (2002). Ratings have been calculated considering the relative threshold and slope at which the tolerance parameter showed a reduction of 50%.*
Tabella 1.: *Livello di tolleranza di alcune tra le più importanti infestanti. La classificazione delle infestanti (da sensibile a estremamente tollerante) è stata ricavata a partire dai limiti definiti n Tanji and Kielen (2002). I diversi livelli di tolleranza sono stati calcolati rispetto alle soglie e alle pendenze specifiche delle curve di ciascun livello, in cui il parametro considerato ha subito una riduzione del 50%.*

Common name	Botanical name	Tolerance based on	Threshold (EC_e in ds/m)	Slope (% per ds/m)	Rating*	References
Annual ragweed	Ambrosia artemisifolia	Shoot DW	6.55	1.38	ET	Eom*et al*., 2013
Cheatgrass	Bromus tectorum	Leaf DW	3.05	8.26	S	Kaylie *et al*.,2002
Lambsquarters	Chenopodium album	Germination	2.65	1.17	ET	Yao *et al*., 2010
Feathertop	Chloris virgata	Germination	4.55	4.40	T	Li *et al*., 2011
Field bindweed	Convolvulus arvensis	Germination	1.09	4.43	T	Tanveer*et al*., 2013
Bermuda grass	Cynodon dactylon	Shoot DW	6.90	6.40	MS	Tanji and Kielen 2002
Nutsedge	Cyperus spp.	Shoot Length	0.53	4.17	S	Hakim *et al*., 2011
Barnyard grass	Echinochloa crus-galli	Shoot DW	6.00	5.33	MT	Chauhan *et al*., 2017
Indian goosegrass	Eleusine indica	Germination	0.70	5.72	MS	Chauhan and Johnson, 2008
Catchweed	Galium aparine	Germination	2.80	11.96	S	Wang, H *et al*., 2016
Cogongrass	Imperata cylindrica	Shoot DW	1.00	2.91	ET	Hameed *et al*., 2009
Purselane	Portulaca oleracea	Shoot DW	1.42	4.41	T	Kafi and Rahimi, 2011
Foxtail millet	Setaria italica	Seedling DW	3.85	3.58	ET	Veeranagamallaiah*et al*., 2008
Johnson grass	Sorghum halepense	Total DW	2.09	6.24	MS	Sinha *et al*., 1986

* S= sensitive; MS= moderately sensitive; MT= moderately tolerant; T= tolerant; ET= extremely tolerant

Conclusions

Salinized areas of the world are expanding rapidly for various reasons, including reduced rainfall, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices. As salinity of impacted soils is strongly limiting the production of crops, especially in environment with limited resources, competition with other species becomes an increasingly critical issue.

At this stage of our analysis, we predict that a population of weeds, regardless its specific composition throughout the cultivation cycle, could be more tolerant to a wide range of salinity levels and become highly competitive to cultivated crops. This could anticipate increasing weed invasiveness and deleterious effects in resource limited environment. Currently, the implications of climate change scenarios on weed invasiveness and competition effects is largely overlooked. Future findings will allow us to better understand the complex range of interactions between crops and weeds, also with respect to environmental heterogeneity and evolving dynamics of cultivated area.

References

Aslam, M., Qureshi, R.H., Ahmed, N. (1993). A rapid screening technique for salt tolerance in rice (Oryza sativa L.). Plant and Soil 150: 99-107.

Azmi, M., Juraimi, A.S., Najib, M.Y.M. (2007) Critical period for weedy rice control in direct seeded rice. J of Trop Agric and Food Sci 35: 319–332.

Chauhan, B.S. (2012). Weed ecology and weed management strategies for dry seeded rice in Asia. Weed Technol. 26:1–13.

Chauhan, B.S., Johnson, D.E. (2008). Germination Ecology of Goosegrass (Eleusine indica): An Important Grass Weed of Rainfed Rice. Weed Science 56:699–706.

Chauhan, B.S., Abugho, S.B., Amas, J.C., Gregorio, G.B. (2017). Effect of Salinity on Growth of Barnyardgrass (Echinochloa crus-galli), Horse Purslane (Trianthema portulacastrum), Junglerice (Echinochloa colona), and Rice. Soil Till. Res. 106:15–21.

Eom, S.H., Di Tommaso, A., Weston, L.A. (2013). Effects of soil salinity in the growth of Ambrosia artemisiifolia biotypes collected from roadside and agricultural field. Journal of Plant Nutrition, 36:14, 2191-2204.

Essa, T.A. (2002). Effect of Salinity Stress on Growth and Nutrient Composition of Three Soybean (Glycine max L. Merrill) Cultivars. J. Agronomy & Crop Science 188, 86-93.

Gurevitch, J., Scheiner, S.M., Fox, G.A. (2009). Ecologia Vegetal (2nd Ed.), Artmed, ISBN 978- 853-6319-18-6, Porto Alegre, Brazil.

Hakim, M.A., Juraimi, A.S., Hanafi, M.M., Selamat, A., Ismail, M.R., Rezaul Karim, S.M. (2011). Studies on seed germination and growth in weed species of rice field under salinity stress. J. Environ. Biol. 32, 529-536, ISSN: 0254-8704.

Hameed, M., Ashraf, M., Naz, N. (2009). Anatomical adaptations to salinity in cogon grass (Imperata cylindrica (L.) Raeuschel) from the Salt Range, Pakistan. Plant Soil 322:229–238.

Kafi, M. and Rahimi, Z. (2011). Effect of salinity and silicon on root characteristics, growth, water status, proline content and ion accumulation of purslane (Portulaca oleracea L.). Soil Science and Plant Nutrition, 57:2, 341-347.

Kaylie, E., Rasmuson, K.E., Anderson Salinity, J.E. (2002). Salinity affects development, growth, and photosynthesis in cheatgrass. Journal of Range Management, 55(1).

Li, X.U., Jiang, D.M., Li, X.I., Zhou, Q.L. (2011). Effects of salinity and desalination on seed germination of six annual weed species. Journal of Forestry Research, 22(3): 475−479.

Munns, R., Tester, M., (2008). Mechanisms of salinity tolerance. Annu Rev Plant Biol. 59:651-81.

Oerke, E.C. (2006). Crop losses to pests. The Journal of Agricultural Science, 144(1), 31-43.

Papiernik, S.K., Grieve, C.M., Yates, S.R., Lesch, S.M. (2003). Phytotoxic effects of salinity, imazethapyr, and chlorimuron on selected weed species. Weed Sci. 4: 610- 617.

Patterson, D.T., (1995). Effects of Environmental Stress on Weed/Crop Interactions. Weed Science, 43:483-490.

Petit, S., Boursault, A., Le Guilloux, M., Munier-Jolain, M., Reboud, X. (2011). Weeds in agricultural landscapes. A review. Agron. Sustain. Dev. 31:309–317.

Radosevich, S.R., Holt, J.S., Ghersa, C.M. (2007). Ecology of Weeds and Invasive Plants: Relationship to Agriculture and Natural Resource Management (3rd Ed.), John Wiley & Sons, ISBN 978-047-1767-79-4, Hoboken, USA.

Rengasamy, P. (2006). World salinization with emphasis on Australia. J. Exp. Bot. 57, 1017–1023.

Sinha, A., Gupta, S.R., Rana, R.S. (1986). Effect of soil salinity and soil water availability on growth and chemical composition of Sorghum halepense L..Plant and Soil 95, 411-418.

Tanji, K.T. and Kielen N.C. (2002). Agricultural Drainage Water Management in Arid and Semi-Arid Areas. Fao Irrigation and Drainage Paper, 61- Annex 1. ISBN 92-5-104839-8.

Maas, E.V. & Hoffman, G.J. (1977). Crop salt tolerance - current assessment. *J. Irrig. and Drainage Div., ASCE* 103 (IR2): 115-134.

Tanveer, A., Tasneem, M., Khaliq, A., Javaid, M.M., Chaudhry, M.N. (2013). Influence of seed size and ecological factors on the germination and emergence of field bindweed (Convolvulus arvensis). Planta Daninha, Viçosa-MG, v. 31, n. 1, p. 39-51.

Veeranagamallaiah, G., Jyothsnakumari, G., Thippeswamy, M., Chandra Obul Reddy, P., Surabhi, G.K., Sriranganayakulu, G., Mahesh, Y., Rajasekhar, B., Madhurarekha, C., Sudhakar, C. (2008). Proteomic analysis of salt stress responses in foxtail millet (Setaria italica L. cv. Prasad) seedlings. Plant Science 175:631–641.

Wang, H., Zhang, B., Dong, L., Lou, Y. (2016). Seed Germination Ecology of Catchweed Bedstraw (Galium aparine). Weed Science 2016 64:634–641.

Yao, S., Chen, S., Xu, D., Lan, H. (2010). Plant growth and responses of antioxidants of Chenopodium album to long-term NaCl and KCl stress. Plant Growth Regul, 60:115–125.

Zimdahl, R.L. (2004). Weed-Crop Competition: A Review, Second Edition. Blackwell Publishing Professional 2121 State Avenue, Ames, Iowa 50014, USA. ISBN 0-8138-0279-2

Zulkaliph, N.A., Juraimi, A.S., Uddin, N.K., Begum, M., Mustapha, M.S., Amrizal, S., Samsuddin, N.H. (2011). Use of saline water for weed control in seashore Paspalum (Paspalum vaginatum). Aust J Crop Sci. 5:523-530.

WATER STRESS DETECTION IN SITI4FARMER, THE AGRICULTURE NETWORK
INDIVIDUARE LO STRESS IDRICO CON SITI4FARMER, IL NETWORK PER L'AGRICOLTURA

Simone G. Parisi[1*]

[1] Abaco S.p.A, Corso Umberto I, 43, 46100 Mantova
*s.parisi@abacogroup.eu

Abstract

Agro-meteorological indexes are derived from weather data and they are an indispensable support to field activities. The study presented here has the aim to test the diagnostic and predictive capabilities of specific field alerts related to the calculation of agrometeorological indexes implemented in the SITI4farmer agriculture web portal. Study cases for herbaceous (Corn) and arboreal (Vine) crops are considered. In particular, the focus is on the calculation of the water balance and the NDVI index, in order to intercept in advance, the water stress situations in the field and to verify the diagnosis through NDVI data. The analysis of the results shows that the use of the NDVI index associated with the water balance is an excellent diagnostic tool for field problems, but the crucial elements for modeling performance are: availability of meteorological and soil data at field scale, correct attribution of the phenological phase in order to associate the most suitable coefficient for calculation of water requirements and, last but not least, the varietal physiology conditioned by the development environment of a particular culture.

Keywords: GIS; Agro-meteorological indexes; climatology; DSS
Parole chiave: GIS; indici agrometeo; climatologia; DSS.

Introduction
The study presented here aims to illustrate the performance of the alert system implemented in SITI4farmer on the basis of Water balance index. Specific case studies of herbaceous and arboreal crops, in particular grape and corn, will be considered. For the vine was taken into consideration the form of "veronese pergola" typical of Valpolicella present among the Masi vineyards. Regarding Mais, data from the Bertoletti company of the Consorzio Agrario di Cremona was taken into account.

Materials and Methods
Agro-meteorological indexes are calculated within SITI4farmer in function of the crop plan inserted. Specifically, the system is able to handle indexes of over 6000 cultivation codes corresponding to as many herbaceous and tree varieties. As regards herbaceous varieties, the database implements a further cataloging based on the commercial seed used. Agrometeorological indexes allow estimation of the following variables: Solar radiation, soil temperature, evapotranspiration and water balance. The meteorological data base indispensable for calculating the above indices is rasterized on 2 km cells on weather station inputs of the respective regional environmental agency. The IDW method is used for rasterize temperature and relative humidity, which reconstructs the value of the unknown point with an inversely proportional weight to the square of the reciprocal distance between known point (weather station) and unknown. In addition, the altitude of the weather observations is taken into account, obtaining a linear regression that effectively reassembles the relative temperature and humidity values even in more complex orography areas.
For the spatialization of rainfalls and wind speed, the technique of autoKriging is used, an algorithm that assumes a spatial correlation between the measured values implemented in R language. This correlation is estimated by constructing the variograms (semi-variograms) and from which the automatic semi-variance calculation of the values starts. The technique is particularly effective in the presence of very localized precipitation, allowing the reconstruction of the quantity of a rainfall event to the right spatial area.

Water Balance
Thanks to temperature and precipitation daily data it's possible to retrieve crop evapotranspiration values by means of the Hargreaves equation and appropriate crop coefficients Kc, changeable in fuction of plant variety and his phenological stage. From evapotranspiration , rainfall and soil data the water balance index can be computed. The index is based on water reservoir model framework , where the dimension of the reservoir is function of the soil texture and root depth of the plant. This last data, determine the level of easy usable water and the plant stress level and hence the value in which the evapotranspiration goes toward zero.

NDVI - Normalized Difference Vegetation Index

Green leaves of plants absorb solar radiation in the spectral region of the so-called photosynthesis-active radiation (PAR), to activate the photosynthesis process. Leaf cells re-emit solar radiation in the region near the infrared spectrum.

The NDVI value is retrieved from the ratio:

NDVI = (NIR-VIS) / (NIR + VIS)

Where

VIS: Is the reflection of visible value (red band)

NIR: Reflection in the near infrared

The NDVI value is between -1 and +1. Near-+1 values are linked to high photosynthetic activity,vigourous plants, therefore a biomass-related index of the plant itself.

Values at 0.3:0.4 are linked to a low vegetative vigor that can be caused by the presence of different stress or vegetative rest. A limit on the use of the NDVI index is given by the low reflection of water in the spectral range considered, which results in negative index values. The co-presence of vegetation and ground water can affect the reability of NDVI's value. For example, in the case of submersion rice, until the crop has created a uniform canopy that can hide the visible water layer from above, NDVI's value will be affected by error.

Another limitation of the NDVI index is due to the presence of highly biomassed vegetation. In such conditions the index tends to "saturate" by not allowing a temporal analysis of the values.

The NDVI index is suitable for low-biomass crops

NDVI values come from multispectral image processing from Landsat 8 and Sentinel 2 satellites associated with the Copernicus program.

Results and Discussion

Case studies regard the estimation of the water balance at field scale during the 2016 campaign. The assessment criterion is based on the correlation to the detection of stress conditions by using the NDVI satellite vegetation index and the water balance index. The water stress is detected by DSS when two coherent signals are verified: (i) the NDVI signal decrease, corresponding to a lowering of photosynthetic activity and therefore vegetative activity, (ii) the water balance goes down to stress level. The corn sample parcels are located in the province of Cremona, at San Giovanni in Croce. For the vine cultivation, some Valpolicella sample parcels were considered as pergola breeding, easily detectable by satellite thanks to their horizontally extended canopy.

The verification took into account the variability of agro-meteorological conditions during the entire vegetative season of both crops. July 2016 had a trend in the Cremona province, characterized by temperature in the climatic average with occasional thermal peaks over 35 ° C. May was characterized by precipitation above the standard, distributed throughout the period, with repercussions on temperatures that were lower than normal in both the maximum and the minimum daily values. In the Valpolicella area, the meteorological trends were similar to those found in the Cremona. July temperature shows peaks lower than 35 ° C.

The water balance in the reference periods clearly shows a full water reserve status in May in both sites. In July, however, there is a rapid and inexorable decline, which results in a situation of potential water stress for most of the month.

Below are the NDVI images of the MASI Veronese pergola in Valpolicella area. It can be notified that till the end of June there is no stress, derived from high vegetative vigor. In July, there is a slightly lowering, until it reaches low level at the start of August. Concerning Corn, despite irrigation, a major discomfort in the last week of July is detectable visible. The results presented here show that the integrated use of the water balance index and NDVI images available on the platform, helps locating problems in the field in advance.

Conclusions

From the analysis of the case study presented here, it can be highlighted that the synergic use of the Water Balance Index and NDVI images provide excellent diagnostic and predictive support for water stress detection in the field. However, for optimum compliance of water balance values with the field real status, it is necessary to: retrieve soil data at farm scale, as the size of the "water tank" from which the crops are drawn is heavily influenced by texture and skeleton of the soil in the layer explored by the roots. In addition to the pedological data it is very useful to have a meteorological from a farm weather station, allowing to get a very precise weather data. A correct estimate of the appropriate varietal coefficient and its phenological phase are indispensable for the correct calculation of evapotranspiration. Finally, where possible, it is necessary to examine the development environment of a particular crop, due to its varietal characteristics, as environmental adaptation strategies can alter "average" responses to environmental forcing. Regarding remote sensing, the only real obstacle to technology is the presence of clouds, so accurate image filtering needs to be done.

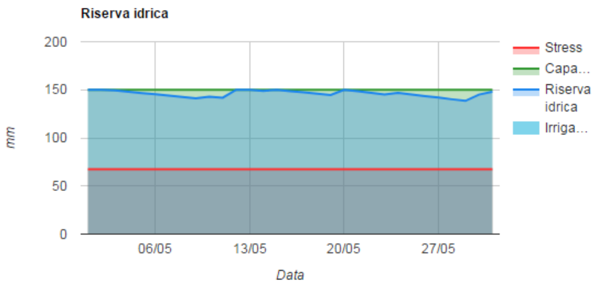


Fig. 1- Water Balance of San Giovanni in Croce Maize LOT during May 2016
Fig. 1 – Bilancio idrico di un appezzamento a Mais in San Giovanni in Croce a Maggio 2016

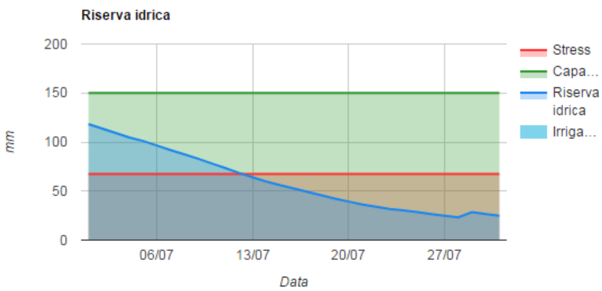


Fig. 2 - Water Balance of San Giovanni in Croce Maize LOT during July 2016
Fig. 2 – Bilancio idrico di un appezzamento a Mais in San Giovanni in Croce a Luglio 2016

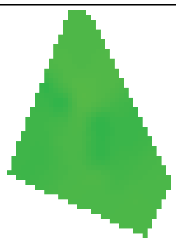
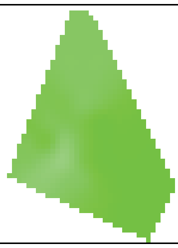
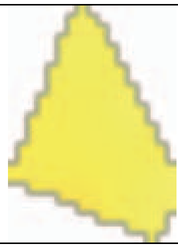
			
Date	**2016-06-28**	**2016-07-18**	**2016-08-02**
Avg	**0.7**	**0.6**	**0.4**
Min	**0.6**	**0.5**	**0.3**
Max	**0.6**	**0.6**	**0.4**

Fig. 3- NDVI images of a Pergola Veronese lot in S.Ambrogio di Valpolicella (VR). NDVI statistical values are shown
Fig. 3 – Immagini NDVI di una Pergola Veronese in S.Ambrogio di Valpolicella (VR). Vengono mostrati i relativi dati statistici.

References

Allen, R. G., 1997. A Self-Calibrating Method for Estimating Solar Radiation from Air Temperature. J. Hydrologic Engineering, ASCE 2 (2). 5, 6-67.

Allen, R. G., Pruitt, W. O.,1991. FAO-24 reference evapotranspiration factors. J. Irrig. and Drain. Engrg. 117(5), 758-773.

Anelli M., Lazzaroni G., 1998. Il bilancio idrico territoriale come supporto alle attività di pianificazione dei consorzi di bonifica. In: ATTI DEL WORKSHOP NAZIONALE DI AGROMETEOROLOGIA AIAM '98

Maina M.M., Amin M.S.M., and Yazid M.A., 2014. Web geographic information system decision support system for irrigation water management: a review. Acta Agriculturae Scandinavica, Section B — Soil & Plant Science, 64 (4)

WMO ,1981. Guide to Agricultural Meteorological Practices. WMO n° 134 (second edition), Geneva.

A NEW INTERACTIVE APPROACH AT TAILORED AGRO WEATHER NEWS
UN NUOVO APPROCCIO INTERATTIVO ALLE NOTIZIE :AGRO METEO NEWS

Ivano Valmori[1,], Gabriele Ghibaudo[2], Cristian Rendina[3] ,Stefania Roà[4]

[1] Direttore Image Line, Via Gallo Marcucci, 24, 48018 Faenza RA
[2] CEO LRC Servizi srl powering Datameteo.com, Via Piave 4/c 12022 Busca CN
[3,4] Meteorologo LRC Servizi srl powering Datameteo.com, Via Piave 4/c 12022 Busca CN

[1]info@agronotizie.it [2,3,4]info@datameteo.it

Abstract
The new multimedia communication frontiers, linked the modern numerical meteorology technologies, have allowed us to develop extremely accurate and tailored multifunctional meteorological services for agriculture. On one hand complicated forecasting numerical sequences become easy-understanding long-term weather trends, on the other hand a simple content on a social networks validated, by an innovative semantic algorithm, can become a useful info to create and hailstorm database. These cross-platform capabilities has been linked, and have been consolidated and strengthened, in a new scalable, innovative and tailored agro-weather delivery push-news service and content management, at the service of the whole agro community.
Le nuove frontiere della comunicazione, tecnologica, informatica e della meteorologia numerica, hanno permesso di far divenire servizi meteorologici estremamente accurati e multifunzionali degli strumenti innovativi, di facile accesso ed utilizzo anche per la community agrometeorologica. Ecco quindi complicate sequenze numeriche previsionali divenire comprensibili tendenze meteorologiche, mentre i contenuti dei social network, e non solo, diventano strumenti di validazione delle notifiche di eventi di grandine. In questo scenario trasversale mancava una nuova tipologia di approccio alla news di tipo agrometeorologico. L'innovazione della piattaforma Agro Meteo News sta proprio nell'intuitività, scalabilità, flessibilità ed accuratezza con cui alla redazione vengono resi disponibili contenuti meteo multimediali, altamente personalizzabili a livello di dati, formati, zoom.

Keywords: dati meteorologici, contenuti agro-meteo interattivi, agro meteo news
Parole chiave: weather data, interactive agro weather contents, agro weather news

Introduction

Per qualsiasi esperto di settore, giornalisti inclusi, l'avere a disposizione una piattaforma con fonti aggiornate di informazione è il segreto per essere sempre sulla "notizia". Quando la meteorologia di settore è la notizia, come lo è diventata l'agrometeorologia negli ultimi anni, il poter disporre di canali informativi che trattano il dato meteorologico numerico o il semplice report di un social network , facendoli diventare una news a forte target di settore, personalizzabile ed esportabile in formati ad alto impatto multimediale, crea un binomio di sicuro successo, in quanto si potrà disporre di contenuti interattivi che focalizzano eventi passati, presenti e futuri sui preminenti scenari di interesse agro meteorologico.
Continua quindi questa proficua collaborazione tra Image Line, leader nel settore della comunicazione nel campo agro media, e Datameteo, provider di servizi meteorologici interattivi che ha dato vita alla piattaforma Agro Meteo News.

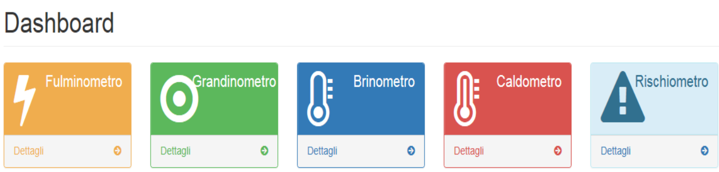


Fig. 1: The entry dashboard of the Agro Weather News platform with the selectable services activated
Fig. 1: Il pannello di controllo della piattaforma Agro Meteo News con i servizi attivabili

Materials and Methods

Attraverso l'intuitiva dashboard on line, mostrata in Fig.1, si accede a quello che è il vero e proprio motore di gestione e generazione dei contenuti e dei vari formati news esportabili, siano esse immagini o testi, facilmente includibili in qualsiasi struttura di portale. Lo sviluppo della piattaforma ha avuto 3 parole chiave cardine: ***qualità, aggiornamento, personalizzazione.***

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Qualità delle informazioni:
Analizziamo ora brevemente le informazioni disponibili, siano esse dati meteo o similari, attuali o passati, o previsioni meteorologiche.

- Le informazioni meteorologiche attuali e passate presenti come **fulminazione, report grandinate, dati meteorologici etc** sono validate con procedure sia automatiche, che manuali.
- Le **previsioni meteorologiche numeriche** sono aggiornate più volte al giorno, con controlli di qualità sulle emissioni.

Queste procedure di per se non indicano che il dato sia totalmente esente da errori o refusi, ma assicurano che le anomalie siano sporadiche e limitate, insomma si tende ad avere il miglior dato possibile, relativamente anche alla fonte.

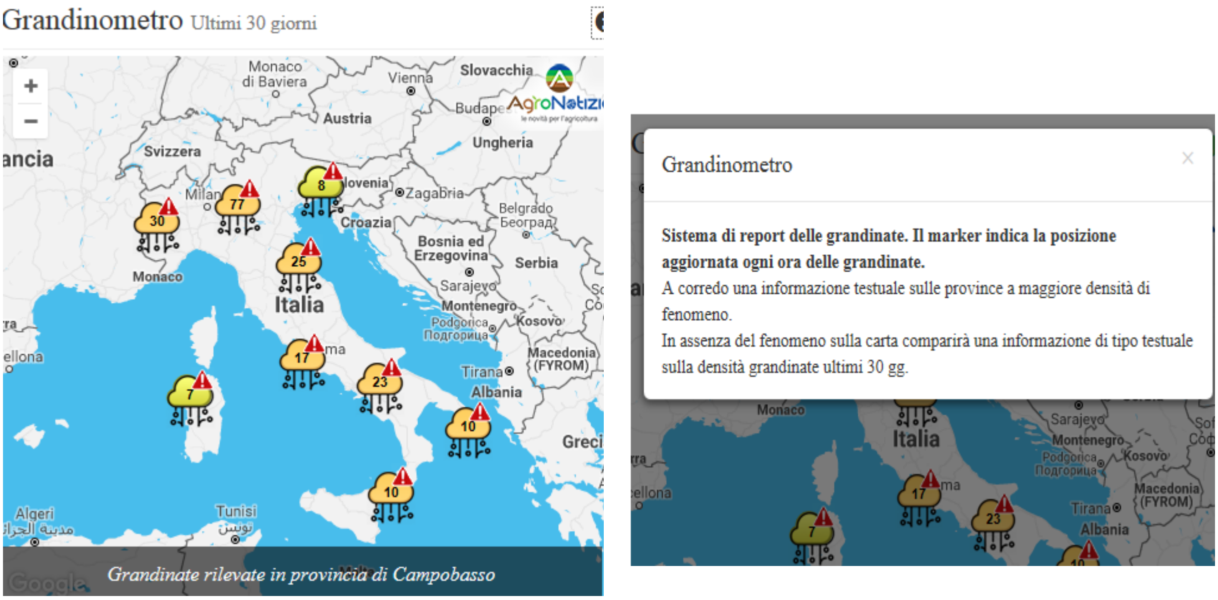


Fig. 2: a) Dettaglio zoomabile in modo interattivo nazionale dei riporti grandine occorsi con news testuale;
b) Box di dettaglio con le caratteristiche del servizio, approccio scientifico e aggiornamento.
Fig. 2: a) Zoomable Hail report for a certain day over Italy; b) Service detail textual box image

Aggiornamento delle informazioni:
il sistema è in grado di aggiornare le informazioni con cadenza **real-time** o **near-realtime,** dopo che le stesse hanno passato le verifiche di validazione e le stessa informazione è ritenuta valida.

Risults and Discussion
Inoltre si ha la possibilità di ***personalizzare l'informazione meteorologica generica in un contenuto agro-meteorologico.***

Oltre all'innovazione di tipo tecnologico ed interattivo che analizzeremo tra poco sono molto importanti le **caratteristiche** che permettono di post-processare l'informazione grezza, trasformandola in una news agro-meteo.
Infatti la piattaforma può **aggregare, mediare, filtrare** in modo attivo tutte le **variabili in entrata**, proponendo un contenuto a target che la redazione può trasformare in una news, interattiva.
Per ottenere questo risultato la redazione crea una news con un confronto tra precipitazioni passate e attese nei prossimi giorni, con focus su alcune regioni italiane. Questo viene ottenuto semplicemente scelti i giorni, il dettaglio di zoom, generando l'informazione in modo dinamico, per includerlo ad esempio in modo dinamico su di un articolo sul portale.
Nelle figure 2, e 3 vediamo alcuni esempi di mappe di eventi di grandine o precipitazione.
Allo stesso modo posso includere contenuti personalizzati come veri e propri canali tematici che lavorano ad aggiornamento continuo in modo intelligente. Vedasi ad esempio il servizio per evidenziare le brinate, che lavora confrontando il trend termometrico per i comuni sotto i 900 m , con un sistema "pesato", al fine di evidenziare il rischio di brinate o vere e proprie gelate estese.

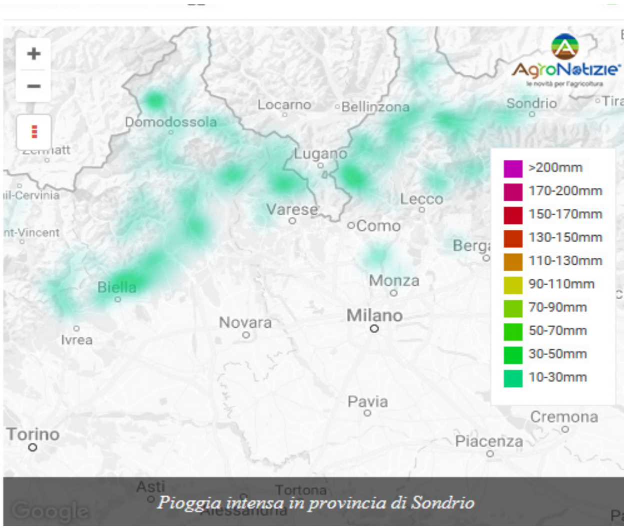


Fig. 3: Dettaglio dell'ammontare medio di precipitazione atteso oggi, zoomato su di una particolare regione italiana
Fig. 3: Averaged precipitation amount forecasted today, for selected Italian regions.

Oltre a formati grafici interattivi, sono impostabili messaggi testuali, a soglie differenziate, che possono divenire vere e proprie **push news realtime**.

Conclusions

Una recente indagine condotta da Nomisma ed Image Line (Fig. 4) ha evidenziato che il 33,6% degli agricoltori intervistati ricerca su internet previsioni meteo, mentre ben l'80,8% di quelli che usa web app, ricerca il meteo locale.
Qui entra in gioco l'importanza di avere informazioni meteorologiche e informazioni sul rischio **cross-platform**, cioè che provengono da fonti molto diverse (modelli meteo, social and community network etc..) erogate in tempo reale e con lo stesso approccio, cioè quello di avere la miglior immediatezza ed attendibilità possibile, unito ad un alto dettaglio territoriale (comune).
L'innovatività della piattaforma permette di erogare contenuti ai più diversi livelli:

- Canali tematici con contenuti agro-meto ad hoc
- Canali con sistemi di agro-meteo push news personalizzati
- Contenuti interattivi su variabili passate, attuale e future creabili in pochi clic e facilmente inseribili in ogni portale

Tutti i contenuti soni fruibili su ogni tipo di apparecchio mobile, ipad, notebook o pc. Benvenuta Agro Meteo News.

I RISULTATI DELL'INDAGINE DIRETTA: LE NUOVE TECNOLOGIE

Tra coloro che usano APP e/o web application (29,6% del totale) a supporto delle strategie aziendali i principali servizi di cui usufruiscono sono…

	%
Meteo personalizzato rispetto alla localizzazione dell'azienda	80,5%
Trattamenti da utilizzare sulle colture presenti in azienda	52,4%
Informazioni periodiche sui prezzi dei prodotti cui sono interessato	40,4%
Segnalazioni di news settoriali e/o di eventi dedicati (fiere, ecc.)	38,6%
Aggiornamenti normativi e di settore	37,0%
Aggiornamenti su bandi o altre opportunità di finanziamento pubblico sulla base del mio profilo	24,7%
Segnalazione delle principali scadenze da rispettare (domanda unica, bandi, comunicazioni, ecc.)	19,5%
Possibilità di fare pubblicità alla mia azienda (prodotti, servizi)	14,7%
Segnalazione relativa all'avvenuto pagamento della domanda unica **(pagamento diretto)**	10,3%
Gestione dell'allevamento (registrazione capi, produttività,..)	7,2%
Un elenco di professionisti cui rivolgermi per consulenze su domande di finanziamento	5,1%

Fig. 4: Ricerca Nomisma 2015 su Internet ed Agricoltura
Fig. 4: Nomisma 2015 Survey about Internet and Agriculture

References
Nomisma (2015) Ricerca Image Line - Nomisma su Internet e Agricoltura
Busacca S. (2013) Hail Forecasting in Italy: A validation to a model approach
Fierro (2012) A cloud-scale lightning data assimilation technique implemented within the WRF-ARW model.
Falco A, Rendina C, Gabriele G (2016) Meteobrowser 2 Interactive weather validated data platform user manual

ADAPTATION OF IRRIGATED AND RAIN-FED ITALIAN CROP SYSTEMS TO FUTURE CLIMATE: ASSESSING THE POTENTIAL OF INTRA-SPECIFIC BIODIVERSITY

ADATTAMENTO DI SISTEMI COLTURALI ITALIANI (IRRIGUI E NON) AL CLIMA FUTURO: IL POTENZIALE DELLA BIODIVERSITA' INTRA-SPECIFICA

Francesca De Lorenzi[1*], Eugenia Monaco[1], Maria Riccardi[1], Silvia Maria Alfieri[2], Michele Rinaldi[3], Antonello Bonfante[1], Angelo Basile[1], Ileana Mula[4], Massimo Menenti[2,5]

[1] Consiglio Nazionale delle Ricerche – Istituto per i Sistemi Agricoli e Forestali del Mediterraneo, Via Patacca 85, 80056, Ercolano (NA)
[2] Delft University of Technology, Department of Geoscience and Remote Sensing, Stevinweg 1, 2628 CN, Delft, The Netherlands
[3] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria – Centro di ricerca Cerealicoltura e Colture Industriali, S.S. 673 km 25.2, 71121 Foggia
[4] Ariespace s.r.l., Centro Direzionale, Isola A3, 80143 Napoli
[5] State Key Laboratory of Remote Sensing Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100101, China
[*] francesca.delorenzi@cnr.it

Abstract
The study illustrates and applies a framework to evaluate options for adaptation in relevant Italian crop systems. Adaptation assessment relies on the identification of cultivars optimally adapted to expected climatic conditions, building on existing crop intra-specific biodiversity. The approach uses a process-based simulation model of water flow in the soil-plant-atmosphere system to calculate expected hydrological indicators. Empirical functions of cultivars yield responses to water availability are used to determine cultivar-specific hydrological requirements. In a future climate (2021-2050) case studies are analyzed on rain-fed crops (olive, wine grapes, durum wheat) in a hilly area of southern Italy and on irrigated field and horticultural crops (maize and tomato) in a plain of southern Italy. We have identified cultivars adapted to the future climate; for irrigated crops options for adaptations have been identified as a combination of cultivars and irrigation schedules

Keywords: climate change; simulation models; potential cultivation area; irrigation; Climate Adaptation Information System
Parole chiave: cambiamento climatico; modelli di simulazione; areale di coltura potenziale; irrigazione; Sistema Informativo per l'Adattamento al Clima

Introduction

Food production is already being negatively affected by climate change and climate trends are determining water shortages in many parts of the world, including southern Europe. Agriculture is heavily dependent on irrigation and water resources which are, in turn, tightly coupled to climate variability. In Mediterranean environments a significant determinant of the sensitivity of a production system is crop response to water stress. Sensitivity can be reduced by interventions on crops, and intra-specific differences in yield response to water availability need to be investigated to identify options for adaptation to projected climatic conditions. The intra-specific biodiversity of agricultural crops, in fact, is very significant (Elia et al., 2013) and can provide a major opportunity to cope with the effects of the changing climate on crop systems. In irrigated agriculture sensitivity can be reduced through changes in irrigation management; however, in face of the predicted changes in water resources availability and in agricultural water demand, irrigation strategies need to be optimized. The study therefore addresses the biophysical dimension of crop adaptation. An approach (Menenti et al. 2008, 2015) is applied to evaluate options for adaptation by identifying cultivars optimally adapted to expected climatic conditions, building on existing crop intra-specific biodiversity. The aim is to remove or at least reduce the vulnerability of current production systems without altering the pattern of current species and cultivation systems.

Materials and Methods

Adaptability was assessed through a three-step approach (Menenti et al. 2008, 2015) that involves (Fig.1a): 1) calculation, through the mechanistic model SWAP, of indicators of expected hydrological conditions (*Relative EvapoTranspiration* $Deficit_{calc}$ and *Relative Soil Water* $Deficit_{calc}$) accounting for each species under study and for site-specific soil hydrological properties. For irrigated crops optimal and deficit irrigation schedules were simulated and irrigation effectiveness was calculated; 2) determination of hydrological requirements of each cultivar (*Relative EvapoTranspiration* $Deficit_{req}$ and *Relative Soil Water* $Deficit_{req}$) to attain a target yield. Requirements are determined through experimental yield response functions to water availability; 3) assessment of cultivars adaptability, i.e. of the probability of each cv. to attain a target yield, by matching indicators and requirements. Potential spatial distribution of cultivars was described. An information

system (Climate Adaptation Information System – CAIS) (Fig. 1b) was developed to run the model SWAP iteratively with different crops, soil data, and meteorological input data. Procedures and algorithms for data query and analysis on simulations are also performed by the information system, which is based on an automated web infrastructure.
Two climate cases were considered: a reference (1961-1990) and a future (2021-2050) climate; daily time series of precipitation and of maximum and minimum air temperature were produced, on a 35 × 35 km grid, by spatial statistics (1961-1990) and by statistical downscaling on predictions by general circulation models (AOGCM) under emission scenario A1B (2021-2050). Two areas of the Campania Region were studied: the Beneventano, a hilly area dominated by rain-fed crops (olive, wine grapes, durum wheat) and the Sele river plain, where irrigated field and horticultural crops (maize and tomato) are grown.

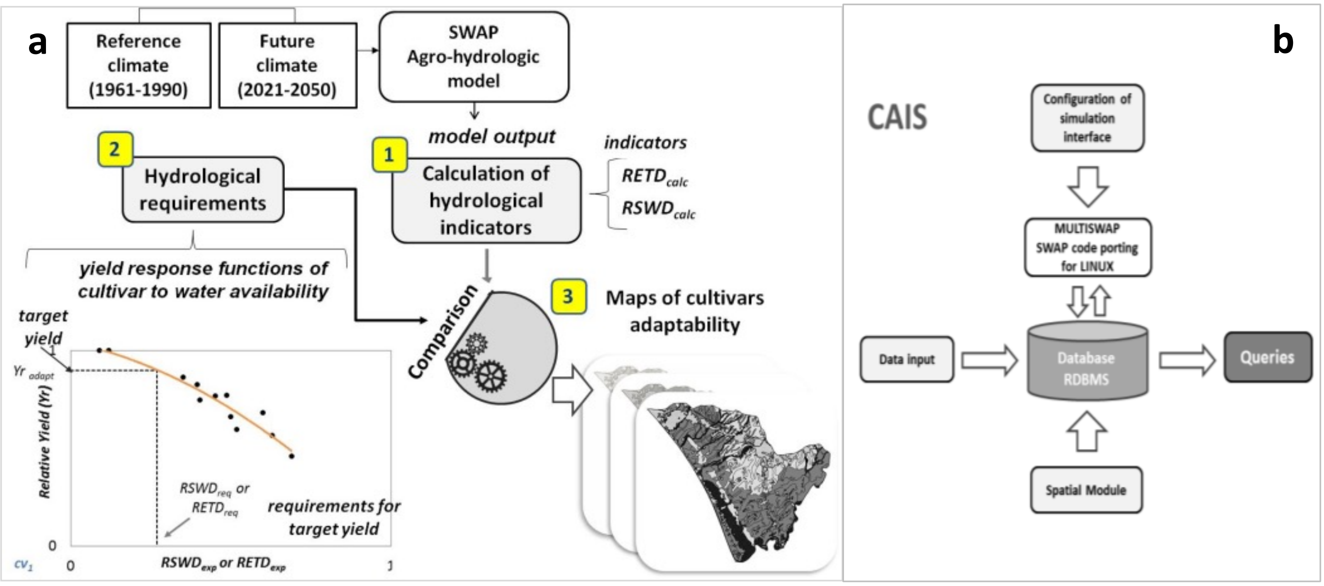


Fig.1 – Scheme of the approach to assess the adaptability of cultivars to climate evolution (a) and simplified scheme of the Climate Adaptation Information System (CAIS)(b).
Fig.1 – Schema dell'approccio per la determinazione dell'adattabilità delle cultivars al clima futuro (a) e del Sistema Informativo per l'Adattamento al Clima (CAIS) (b).

Results and Discussion
From reference to future climate, mean air temperature is expected to increase, on average, by 1.5 °C and yearly precipitation is predicted to decrease by 15% with strong spatial and inter-seasonal variability.
For the five species under study, hydrological requirements of 64 cultivars were determined. Values of hydrological requirements spanned quite different ranges between and within species (Table 1).

Crops	Cultivars examined	Requirements and ranges	
Olive	11	$RSWD_{req}$ and $RETD_{req}$	0.31–0.73
Wine grapes	4	$RSWD_{req}$	0.28–0.55
Durum wheat	23	$RSWD_{req}$	0.28–0.54
Maize	21	$RETD_{req}$	0.03–0.18
Tomato	5	$RSWD_{req}$	0.26–0.54

Tab.1- Hydrological requirements to attain the target yield: ranges of their values across cultivars. $RSWD_{req}$ *and* $RETD_{req}$ *are, respectively, the relative soil water deficit and the relative evapotranspiration deficit.*
Tab.1- Requisiti idrologici per una produzione ottimale: intervalli dei valori nel pool di cultivars studiato. $RSWD_{req}$ *e* $RETD_{req}$ *sono, rispettivamente, il deficit idrico relativo del suolo e l'evapotraspirazione relativa.*

ADAPTABILITY OF A RAIN-FED CROP – OLIVE CV. FRANTOIO
As an example the study on the adaptability of cv. Frantoio is shown. The adaptability of Frantoio (i.e. the probabilities that the cultivar attained the target relative yield) was determined in the Valle Telesina, within the Beneventano study area. The probabilities of adaptation were assessed in all soil types (47 soil mapping units) identified within the Valle Telesina. Figure 2 shows the potential extent of the cv., within each range of adaptability, in the two climate cases. The probabilities of adaptation in the future climate were lower than in the reference one since a higher soil water deficit occurred in the 2021–2050 period. In 1961-1990 the cv. could potentially extend, with probabilities of adaptation within the range 0.16-1, in the 90% of the area of the Valle Telesina, whereas in 2021-2050 the same range of probabilities was achieved in 38% of the area. The spatial variability of the probabilities of adaptation was determined by soil hydrological properties: the adaptability was higher in the soils located at lower elevations, because of their higher total water retention capacity.

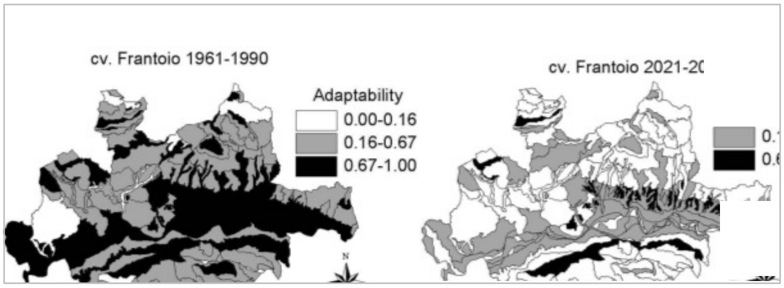


Fig.2 – Olive cv. Frantoio: spatial pattern of the adaptability in the two climate cases (1961-1990 e 2021-2050) in the 47 soil mapping units of the Valle Telesina.
Fig.2 – Olivo cv. Frantoio: distribuzione spaziale dell'adattabilità nei due casi climatici (1961-1990 e 2021-2050) nelle 47 unità di suolo della Valle Telesina.

ADAPTABILITY OF AN IRRIGATED CROP IN A WATER SCARCITY SCENARIO – MAIZE

The adaptability of 21 maize hybrids was assessed in the Sele river plain; probabilities of adaptation were determined at optimal and at reduced irrigation depth (90% of optimal one) in the 23 soil typological units (STU) that were identified in the plain. Figure 3 shows the probabilities of adaptation of the hybrids (indicated by letters A through U) under a specific combination of climate (2021-2050), irrigation depth (90%) and soils (soil typological units – STU). Combinations of hybrids and soils could be identified to attain the target yield at moderately reduced water availability: twelve hybrids were predicted to attain the target yield in at least 75% of the study area; no hybrid was assessed to be adaptable in one soil (STU 20) and in another one (STU 21) only two hybrids were adaptable. Therefore the differences in hydrological conditions across the soils, due to different soil physical properties, played an important role in determining adaptability.

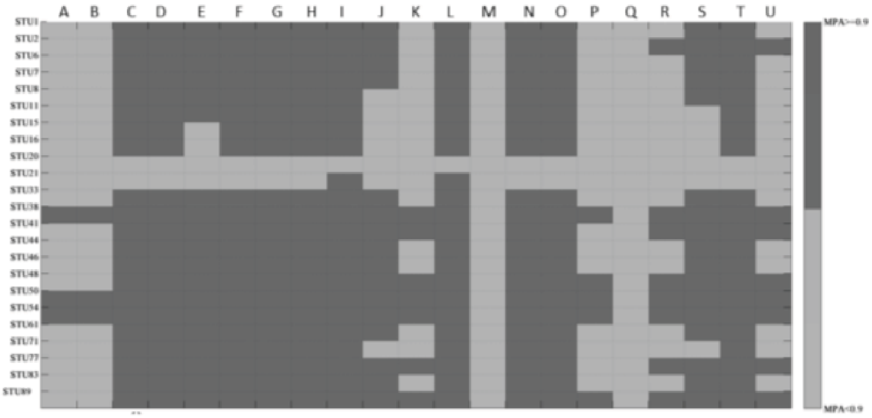


Fig.3 – Adaptability of 21 maize hybrids (letters A through U), at reduced irrigation, in the future climate (2021-2050) in the 23 soil typological units (STU) of the Sele river plain. Combinations of hybrids and soils where adaptability was attained are indicated by darker cells.
Fig.3 – Adattabilità di 21 ibridi di mais (lettere A-U), con irrigazione sub-ottimale, nel clima futuro (2021-2050) nelle 23 unità di suolo (STU) della Piana del Sele. Le celle più scure indicano le combinazioni di ibridi e suoli per le quali è stata individuata l'adattabilità al clima futuro.

Conclusions

In our study we propose as an option for adaptation the exploitation of the intra-specific biodiversity of crops, i.e. the possibility to choose, from a wide range of cultivars, the ones that are able to maintain the target yields at reduced water availability, as determined by climate trends. Cultivars adapted to the future climate have been identified for rain-fed crops (e.g. 5 olive cultivars). For irrigated crops we have evaluated adaptability for optimal and deficit irrigation schedules, accounting for site-specific soils hydrological properties. Options for adaptations have been identified as a combination of cultivars, soils and irrigation schedules (e.g. twelve maize hybrids had high probabilities of adaptation at moderately reduced water availability and two tomato cultivars have been identified as options for adaptation at severely reduced water availability). Adaptation cannot be dealt without accounting for the dependency of crop responses to climate change on soil type. In the future climate, with reduced water resources, a proper choice and combination of cultivars, soils and irrigation strategies would allow to maintain the current production system in a large part of the studied areas.

Acknowledgements

The work was carried out within the Italian national project AGROSCENARI funded by the Ministry for Agricultural, Food and Forest Policies (MIPAAF, D.M. 8608/7303/2008). The authors are grateful to Dr. Cristina Patanè for supplying data on tomato cultivars.

References

Elia, A., Santamaria, P. 2013. Biodiversity in vegetable crops, a heritage to save: The case of Puglia region. Italian Journal of Agronomy, 8. e4, 21e34.

Menenti M., De Lorenzi F., Bonfante A., Cavallaro V., Lavini A., Raccuia A., d'Andria R., Leone A., De Mascellis R., 2008. Biodiversity of most important mediterranean crops: A resource for the adaptation of agriculture to a changing climate. Italian Journal of Agrometeorology, 2: 22-37.

Menenti M., Alfieri S.M., Bonfante A., Riccardi M., Basile A., Monaco E., De Michele C., De Lorenzi F., 2015. Adaptation of irrigated and rain-fed agriculture to climate change: The vulnerability of production systems and the potential of intra-specific biodiversity. Case studies in Italy. In: Handbook of Climate Change Adaptation. Leal Filho W., Springer-Verlag Berlin Heidelberg, 41 pp.

MODELIZATION OF MICROMETEOROLOGICAL AND PHYSIOLOGICAL PARAMETERS IN THE PIEDMONTESE VINEYARD ECOSYSTEM

MODELLIZZAZIONE DI PARAMETRI MICROMETEOROLOGICI E FISIOLOGICI NEGLI ECOSISTEMI VITICOLI PIEMONTESI

Claudio Cassardo[1*], Valentina Andreoli[1], Federico Spanna[2]

[1] Dipartimento di Fisica, Università di Torino, Via Giuria 1,10125 Torino, Italy
[2] Settore Fitosanitario, Regione Piemonte, Via Livorno 60, 10144 Torino, Italy
*claudio.cassardo@unito.it

Abstract

Agricultural production is generally strongly dependent on environmental conditions: grapevine yield and quality, in particular, are extremely sensitive to microclimatic conditions. A precise knowledge of the plant responses (in terms of growth) to environmental forcing, in particular in the actual period of climate changes, would be considerably interesting from a point of view of knowledge and strategic even more for growers. Numerical models represent a promising tool to study a complex system as a vineyard: simulating physical and physiological processes occurring at the atmosphere-vegetation-soil interfaces and estimating plant responses to environment at the microscale.

Keywords: numerical models; grapevine; physiological processes; climate.
Parole chiave: modelli numerici; vite; processi fisiologici; clima.

Introduction

Grapevine productivity depends on several factors including soil fertility, management practices, climate and meteorology. In particular, concerning the latter, there is a need for a reliable assessment of the effects under a changing climate on its yield and quality. In this respect, it is essential to primarily understand how and how much climate and meteorology affect grape productivity and quality.
In this context, crop models are essential tools for investigating the effects of climate change on crop development and growth via the integration of existing knowledge of crop physiology relating to changing environmental conditions.
The focus of this paper is on vineyards because the wine is one of the most exported Italian products, in particular for Piemonte region, which produces several high-quality wines (DOCG and DOC).
Due to their great importance to the Italian and Piedmontese economy, the oenology and viticulture has been object of many studies aimed to developing tools to manage vineyards and improve wine quality. In particular, much interest has the monitoring of physical and physiological processes related to environmental conditions that have influence on vine growth, yield and grape quality and the characterization of the vineyard microclimate and its variability within the vineyard itself.
A tool of numerical models has been developed to study a complex system as a vineyard, simulating physical, physiological, and phenological processes and diagnosing plant responses to environment at the microscale.
In particular, two models have been used in this study: a land surface scheme, named UTOPIA (University of TOrino model of land Process Interaction with Atmosphere), has been run for evaluating all components of hydrological and energy budget, as well as soil and canopy parameters. Subsequently, the crop model IVINE (Italian Vineyard Integrated Numerical model for Estimating physiological values) has been applied, feeded by some UTOPIA outputs and other data, to the same locations, in order to obtain a list of physiological parameters, such as the phenological phases, the berry sugar content, the leaf water potential, and other characteristic variables. The simulations have been performed on a climatological basis, and the data needed by models as boundary conditions have been extracted by the freely available global database GLDAS (Global Land Data Assimilation System: https://disc.gsfc.nasa.gov/gesNews/gldas_2_data_release).
The preliminary results of the simulations will be presented during the conference.

Materials and Methods

The study here described aims to simulate micro-meteorological conditions within vineyards using a numerical model (the land surface SVAT scheme UTOPIA) and to simulate physiological and phenological vineyard conditions using another numerical model (the crop model IVINE). The data obtained will allow to infer micro-meteorological and physiological variables within the vineyards. If the boundary conditions will extend for a time period of climatological relevance, it may be possible to get a description of the behavior of model outputs on a climatic basis. In this way, it may be studied which micro-climatic conditions could improve grape quality. Since input data required by models are not always simple to be retrieved, in this work we have used data coming by worldwide distributed databases. The eventual success of this methodology can indicate that it is suitable to employ numerical models to evaluate agronomic variables trends by means of gridded databases.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The two models used in this study are here shorthly described. The University of Torino model of land Processes Interaction with Atmosphere (UTOPIA) is a diagnostic one-dimensional model [Cassardo, 2015], and was formerly named as the Land Surface Process Model [LSPM; Cassardo et al., 1995; Cassardo, 2006]. The UTOPIA can be used as a stand-alone basis. It can be also coupled with an atmospheric circulation model or a regional climate model, serving as the lower boundary condition. All specific details about its use and features are fully described in Cassardo [2015].
The land surface processes in UTOPIA are described in terms of physical fluxes and hydrologic states of the land. The former includes radiation fluxes, momentum fluxes, sensible and latent energy fluxes and heat transfer in multi-layer soil, while the latter includes snow accumulation and melt, rainfall, interception, infiltration, runo□ , and soil hydrology.
The UTOPIA routines evaluate the balance between the incoming and reflected short-wave solar radiation and both incoming and outgoing long-wave radiation. Other energy exchanges between the soil and the atmosphere above that are parameterized by UTOPIA are: turbulent sensible and latent heat fluxes, and the turbulent transports of momentum and water vapor. All fluxes are computed using an electric analogue formulation, in which a flux is directly proportional to the gradients of the related scalars and inversely proportional to an adequate resistance. Since the UTOPIA is a diagnostic model, thus some observations in the atmospheric layer are required as boundary conditions, including air temperature, humidity, pressure, wind speed, cloud cover, long-wave and short-wave incoming radiation, and precipitation rate. Usually these observations are measured values, eventually with the reconstruction of some missing data using adequate interpolation techniques.
The Italian Vineyard Integrated Numerical model for Estimating physiological values (IVINE) is a crop model created in 2016 by two of the authors (Andreoli V., Cassardo C.) to simulate physiological and phenological vineyard conditions. The required boundary conditions, to be provided during the simulation, data are: temperature, relative humidity, solar global radiation, photosynthetically active radiation, soil temperature, soil water content, wind speed and direction, rainfall, and leaf wetness. Other data are required as input: vineyard and soil characteristics, geographic informations (latitude, longitude, slope, height), plant density, variety characteristics (clusters/plants, berries/cluster,..), and vineyard management (trimming, severity of trimming). Some of those input data are also required by UTOPIA. The main model outputs are: the predawn leaf water potential, the timing of the main phenological phases (dormancy break, budburst, …), the leaf development, the yield, and the sugar concentration. The model requires to set some experimental parameters depending on the cultivar. At present, considering that, in Piemonte region, the most famous wine is derived by Nebbiolo vineyards, the model has been optimized with Nebbiolo parameters.
The numerical experiments were performed by running UTOPIA first, and then IVINE. The latter used as input data the following UTOPIA output: soil temperature, soil water content, and leaf wetness. The other required input, e.g. relative humidity, air temperature, solar global radiation, photosyntetically active radiation, wind speed and direction, rainfall, and atmospheric pressure, were taken from the gridded database GLDAS2.0.
Three preliminary simulations were carried out using the data extracted by GLDAS2.0 into the three grid points closer to the vineyards of three Piedmontese wine factories, located in Cocconato, Fubine and Castiglione Falletto. Simulations were performed for a time span of 40 years, from 1970 to 2010 (the latter year is the latest year contained in the GLDAS2.0 database).
A subsequent set of simulations is actually in phase of execution and will regard fifteen grid points, chosen as representative of the most popular wine regions of Piemonte: Langhe, Roero and Monferrato. In this case, the time span of the simulations has been selected considering the total temporal extension of the database, e.g. the sixty years from 1951 to 2010.

Results and Discussion

This section contains only a summary of the main findings of this study, relatively to the first set of simulations. During the conference, also the results relative to the second set of simulations will be presented.

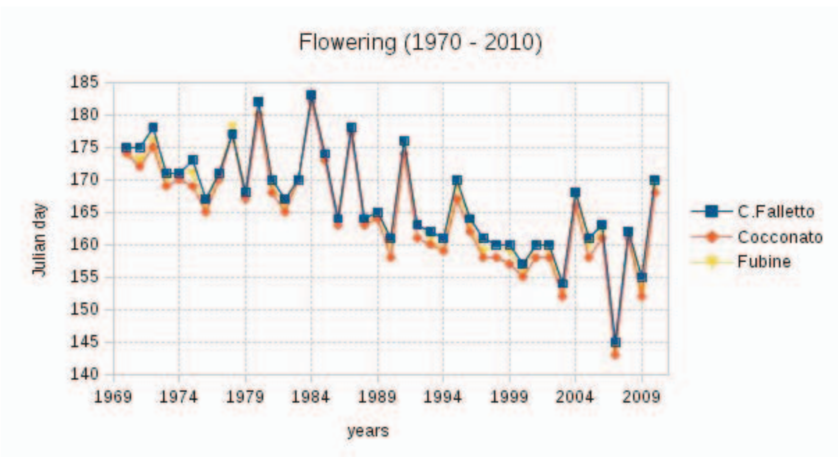


Fig. 1: time trend of the Julian day corresponding to the phenological phase "flowering", evaluated by IVINE model in the three Piedmontese sites.
Fig. 1: andamento del Giorno Giuliano corrispondente alla fase fenologica "fioritura", valutata dal modello IVINE nei tre siti piemontesi.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The time trend of flowering in the three sites (Fig. 1) appears quite similar, with a systematic advance of a few days at Cocconato and an equally systematic delay at Castiglion Falletto. However, the distinctive characteristic of the curve is the decreasing trend, which – even if statistically not significant - indicates an anticipation of almost twenty days for the flowering in the forty year period analyzed.

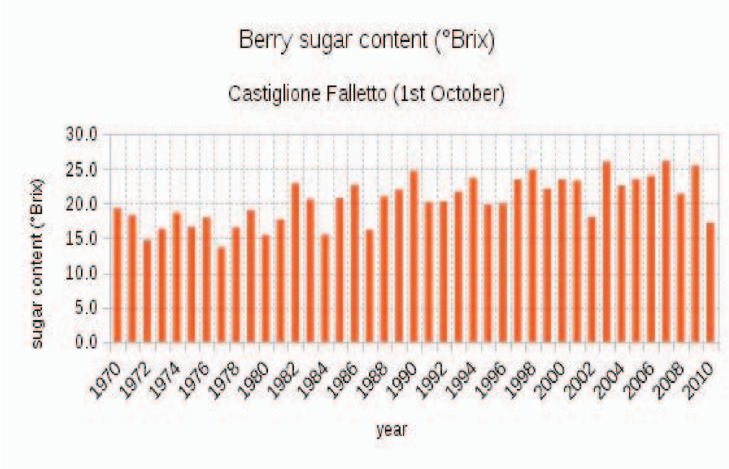


Fig. 2: time trend of the berry sugar content evaluated at the day October 1st of each year in the site of Castiglione Falletto by IVINE model.
Fig. 2: andamento del contenuto zuccherino dell'acino valutato al giorno 1° ottobre di ogni anno nel sito di Castiglion Falletto dal modello IVINE.

The berry sugar content (Fig. 2) shows similar behaviors but different values in the three sites, with the minimum values in Cocconato (not shown). Also in this case, there is an evident trend of increment, statistically not significant, quantifiable in about 5 ° in the forty years period.

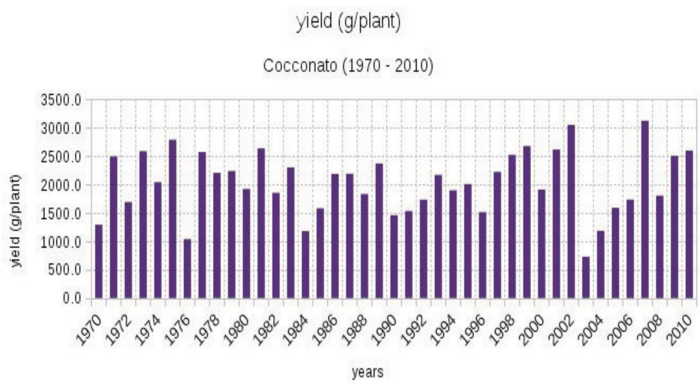


Fig. 3: time trend of the yield per vine evaluated in the site of Cocconato by IVINE model.
Fig. 3: andamento della produzione per pianta di vite valutato nel sito di Cocconato dal modello IVINE.

The yield shows significant variations in the three sites, with the largest values in Cocconato (Fig. 3). This variable do not shows a clear trend, but is positively correlated with the values of soil moisture in the root zone and LAI, larger in Cocconato than in other sites. In the sequence of the years, it is well evident the absolute minimum in 2003 (present also in the other sites).

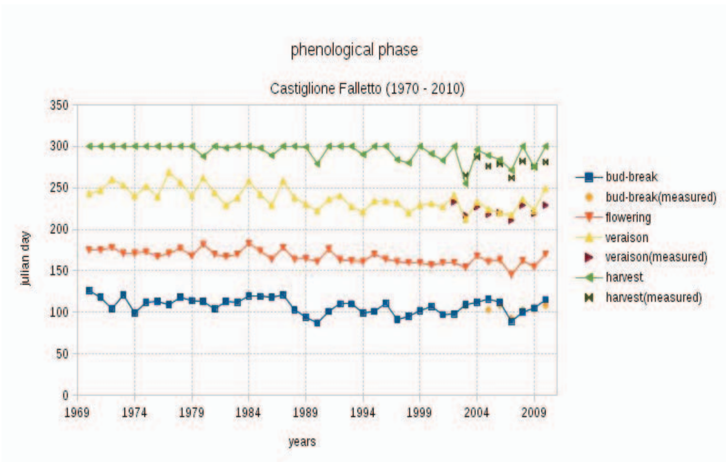


Fig. 4: time trend of the main phenological phases (bud break, flowering, veraison, and harvest) evaluated in the site of Castiglion Falletto by IVINE model.
Fig. 4: andamento delle principali fasi fenologiche (apertura del germoglio, fioritura, invaiatura e vendemmia) valutato nel sito di Castiglion Falletto dal modello IVINE.

For the phenological phases, each phase shows a decreasing trend, quantifiable in about twenty days during the forty-year period of the simulation. The only exception is the harvest date, whose calculation need further optimizations. The values

fixed at the Julian day 300 (27 October) for the first two thirds of the simulation are a threshold imposed when, at that date, the thermal sum used to evaluate harvest date has not yet reached its threshold.
For three phases, experimental data collected in one wine factory at Castiglion Falletto were available during the last 6-8 years, and are plotted in Fig. 4. Despite their number is too low to allow sone statistical conclusions, however these values allow the validation of model output in this site.

Conclusions
Two numerical experiments have been planned in order to derive a climatology for some vineyard's variables. In the first one, 40 years of data (1970-2010) were simulated into three locations in Piemonte region using UTOPIA and IVINE models, both driven by the data gathered by GLDAS2.0 dataset. These results have been discussed here. The second experiment will regard a larger time span (sixty years, from 1951 to 2010) and more locations (fifteen sites selected among the most famous wine regions in Piemonte). This experiment is ongoing and its results will be presented during the conference. The results available in this moment reveal that the model chain seems able to evaluate the most characteristic variables related to the vine, which may be used in order to guess the quality of the grape. A close look on the time trend during the 40-years period reveal clear trends for many variables, although statistically not significant, due to the large interannual variability.
The future perspective of this work is a deepening of the analysis, with more quantitative conclusions about data and variations. Also simulations for different cultivars will be performed with IVINE, that must be optimized for such cultivars. Finally, other parametes may be evaluated. Among these, we may mention: acids, alcohol content, etc.

Aknowledgements
The author acknowledges a grant jointly supportedby the Lagrange Project – CRT Foundation/ISI Foundation (Torino, ITALY) and IWAYs.r.l. (Cernusco sul Naviglio (MI), ITALY)

References
C. Cassardo, 2015: The University of TOrino model of land Process Interaction with Atmosphere (UTOPIA) Version 2015. Tech. Rep., CCCPR/SSRC-TR-2015-1, CCCPR/SSRC, Ewha Womans University, Seoul, Republic of Korea, 80 pp.
S. Prino, F. Spanna, C. Cassardo, 2009: Verification of the stomatal conductance of Nebbiolo grapevine. Journal of Chongqing University (English Edition), No. 8(1), pp. 17~24.
C. Francone, C. Cassardo, F. Spanna, L. Alemanno, D. Bertoni, R. Richiardone and I. Vercellino (2010): Preliminary Results on the Evaluation of Factors Influencing Evapotranspiration Processes in Vineyards, Water, No. 2(4), pp. 916-937; doi:10.3390/w2040916
C. Cassardo, C. Francone, R. Richiardone, D. Bertoni, L. Alemanno, F. Spanna (2011) Experimental and modeling analysis of micro-meteorological factors involved in the development of piedmontese vineyards, Proceedings of "Incontri Fitoiatrici 2011", Cuneo, 4 Marzo 2011
I.Cortazar Atauri et al., Asynchromous dynamics of grapevine (VITIS VINIFERA) maturation: experimental study for a modelling approach. J. Int. Sci. Vigne Vin, 2009, 43, n.2, 83-97
G.Cola et al.,Description and testing of a weather-based model for predicting phenology, canopy development and source-sink balance in Vitis Vinifera L. cv. Barbera. Agricultural and Forest Meteorology 184 (2014) 117-136
A.Singels et al.,Refinement and validation of the PUTU wheat crop growth model 2.leaf area expansion. S.Afr.J.Plant

EFFECTS OF PGPR INOCULATION ON ROOT GROWTH AND NITROGEN ACCUMULATION OF COMMON WHEAT IN CONTROLLED CONDITIONS AND IN OPEN FIELDS

EFFETTI DELL'INOCULAZIONE DI PGPR SULL'ACCRESCIMENTO RADICALE E L'ACCUMULO DI AZOTO IN FRUMENTO TENERO IN CONDIZIONI CONTROLLATE ED IN PIENO CAMPO

Cristian Dal Cortivo[1*], Barion Giuseppe[1], Giovanna Visioli[2], Giuliano Mosca[1], Teofilo Vamerali[1]

[1] Department of Agronomy, Food, Natural Resources, Animals and the Environment, University of Padova, viale dell'Università 16, 35020 Legnaro-Padova, Italy
[2] Department of Life Sciences, University of Parma, Parco Area delle Scienze 11/A, 43124 Parma, Italy
*cristian.dalcortivo@phd.unipd.it

Abstract
This study investigated whether a commercial bio-fertiliser containing a consortium of PGPB affects root and shoot growth and N accumulation in common wheat. Trials were conducted firstly in rhizoboxes, applying bacteria either as a seed-coating inoculum or foliar+soil spraying, and then in the field by spraying bacteria to the canopy at tillering stage with decreasing N fertilisation (160, 120, 80 kg ha^{-1}).
Environmental scanning electron microscope (ESEM) imaging revealed their excellent ability to colonise plant surface and both leaf mesophyll and root vascular tissues. Bacteria increased the number of root tips and ramifications (+65% vs. non-inoculated) in sterilised pot soil and the root length density in the open field with medium (+29%) and high (+11%) N supply, resulting in greater N accumulation (about +25 kg ha^{-1}). Although without yield benefits, the rooting power of these bacteria can help to reduce N losses from agro ecosystems and to save chemical fertilisers.

Keywords: Bio-fertilisers; common wheat; nitrogen accumulation; endophytic bacteria; root growth.
Parole chiave: biofertilizzanti; frumento tenero; contenuto azotato; batteri endofiti; crescita radicale.

Introduction
Chemical fertilisers are commonly used to supply essential nutrients to soil-plant systems in a wide range of cultivated crops. However, the use of high amounts of chemical fertilisers, especially nitrogen, has raised environmental concerns in the current agricultural systems of industrialised countries. There is an urgent need to find safe, alternative fertilisation strategies in order to improve the sustainability of agro-ecosystems, especially in cereal cultivation, while at the same time retaining competitive crop yields. One potential method of attenuating the negative environmental impact of chemical fertilisers and pesticides is to apply plant growth promoting rhizobacteria (PGPR) as bio-fertilisers (Pérez-Montaño *et al*., 2014).
These bacteria play a role in plant nutrition by exerting non-symbiotic N fixation, enhancing the availability of nutrients in the rhizosphere, such as phosphorus and iron, and increasing the root surface area through the production of hormones (Kumar *et al*., 2014). There is growing interest in the use of PGPR with cereals and various studies are demonstrating their beneficial role in the growth and yields of several crop species. However, several factors, such as plant genotype, bacteria species and strain, and agricultural practices may affect plant responses and the success of inoculation (Tahir *et al*., 2015).
Against this background, the aim of this work was to study the effects on common wheat (*Triticum aestivum* L.) of a mixture of PGP-rhizobacteria and free-living N-fixing bacteria, i.e., *Azospirillum* spp., *Azoarcus* spp. and *Azorhizobium* spp., provided as a commercial formulation (TripleN®, Mapleton Agri Biotec, Australia) suitable for use on a wide variety of field and tree crops. Effects on the root characteristics of young and mature plants, N accumulation, and yield were examined in controlled and open field experiments at the experimental farm of the University of Padua (NE Italy).

Materials and Methods
Seeds of common wheat *Triticum aestivum* L. cv. Bologna (S.I.S, Bologna, I) were coated in aseptic conditions with a bacterial inoculum (TripleN®) from the commercial formula. Seven-day-old fresh roots and 14-day-old fresh leaves of seedlings from inoculated and non-inoculated wheat seeds were collected for Environmental Scanning Electron Microscope (ESEM) imaging using a Quanta™ 250 FEG ESEM to assess bacteria-root and -leaf interactions.
To assess whether the bacterial inoculum had direct effects on early root growth of wheat, an experiment was set-up in controlled conditions (rhizoboxes with transparent walls) inside a greenhouse. Three seeds per rhizobox were sown at a depth of 3 cm and plants were grown for 50 days during February and March. Two methods of bacteria application were examined, a seed-coating treatment before sowing (a widespread inoculation option) and foliar+soil spraying after

emergence (suggested by the biofertiliser manufacturer), in comparison with non-inoculated controls. Root parameters were analysed with WinRhizo (Reagent Instruments, Quebec - CA) software after image acquisition with a flatbed scanner.
In order to assess the effects of the biofertiliser in real cultivation conditions, an open field trial was carried out during the growing seasons 2013-14 and 2014-15. The experimental design was a completely randomised block with 3 replicates. The wheat variety Africa (APSOV, Voghera – Pavia, I) was cultivated in the first year and Bologna (SIS, Bologna, I) in the second year. Plants treated with the TripleN bio-fertiliser and non-inoculated controls were factorially combined with nitrogen fertilisation (applied as ammonium nitrate, 34% N) at three levels: 80, 120 and 160 kg ha^{-1}. After pre-sowing fertilisation (with 32 kg of N for each level), half of the remaining N dose was supplied at the tillering stage and half at the onset of stem elongation.
The bacterial inoculum was applied following the manufacturer's instructions at a label dose of 4 g of commercial product (bacterial concentration of 1×10^{10} CFU g^{-1}) per hectare at the tillering stage. Leaf chlorophyll content (SPAD) was monitored during the growing cycle of each year. Yield, straw and grain weights were also assessed in a check area of 1 m^2 in each plot at harvest time. N concentrations were determined from the sample materials according to the Kjeldahl method.
The root system was investigated down to a depth of 1 m at full flowering in each year using the coring method. The soil cores were split into 0.1-m sub-samples and roots, after separation from soil particles, were acquired as 1-bit 400-DPI TIFF format images using a flatbed scanner and processed by KS 300 Rel. 3.0 software (Zeiss, Milan, I) to obtain main parameters. ANOVA was carried out on the data, separation of means was set up at $P \leq 0.05$ with the Newman-Keuls test.

Results

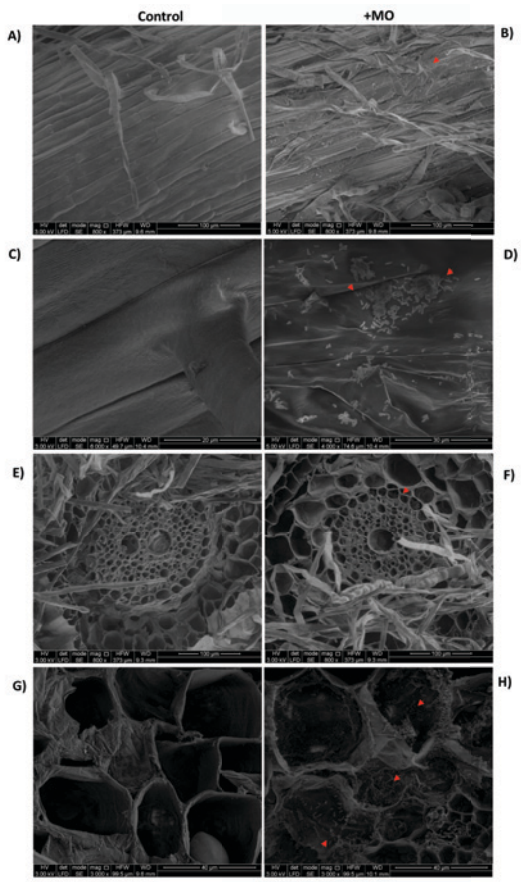


Fig. 1: ESEM micrographs of root surfaces (A-D) and transversal sections (E-H) in non-inoculated (control, left) and inoculated (+MO, right) 7-day-old wheat seedlings. Red arrows indicate the points magnified to observe bacterial colonisation.
Fig. 1: Immagini ESEM di superficie radicale (A-D) e sezioni trasversali (E-H) di piante di frumento non inoculate (control, sinistra) e inoculate (+MO, destra) a 7 giorni dalla germinazione. Le frecce rosse indicano i punti ingranditi per l'osservazione della colonizzazione batterica.

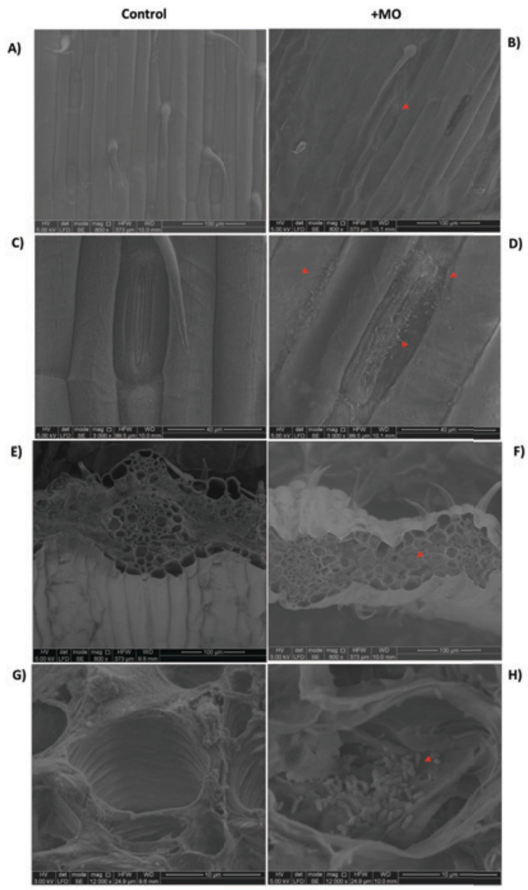


Fig. 2: ESEM micrographs of leaf surfaces (A-D) and transversal sections (E-H) of non-inoculated (control, left) and inoculated (+MO, right) 14-day-old wheat seedlings. Red arrows indicate the points of the leaf tissues magnified to observe bacterial colonisation.
Fig. 2: Immagini ESEM di superficie fogliare (A-D) e sezione trasversale (E-H) di piante di frumento non inoculate (control, sinistra) e inoculate (+MO, destra) a 14 giorni dalla germinazione. Le frecce rosse indicano i punti ingranditi per l'osservazione della colonizzazione batterica.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

With ESEM, it was found good physical association of bacteria in plant tissues, with excellent colonisation of root cavities and deep bacterial biofilm formation (Fig. 1 B, D), as well as abundant colonisation of inner root tissues (Fig. 1 F, H). Applied bacteria penetrated also in the intercellular spaces of leaf epidermis and crowding, in particular, around the stomata complexes (Fig. 2 D). There was also considerable internal mesophyll colonisation (Fig. 2 H), while no bacteria were found on the shoots and roots of non-inoculated control seedlings, either externally or internally.
In the rhizoboxes, all analysed root parameters were positively affected by the application of bacteria, whether as seed coating or foliar+soil spraying (Table 1). The most affected parameters were diameter (+26% average of the two treatments) and those related to root architecture, such as the number of root tips (+60% and +69%, respectively) and branches (+68% and +54%, respectively) ($P \geq 0.05$).

Tab. 1: Root parameters (mean; n=3) in bacteria-inoculated wheat plants (two methods of application) vs. non-inoculated controls at 50 days after sowing in sterilised soil in rhizoboxes. Letters: significant differences among treatments (Newman-Keuls test, P≤0.05). In brackets: % variation in bacteria-treated plants vs. non-inoculated controls.
Tab.1: Parametri radicali (media; n=3) in piante di frumento inoculate con batteri (due metodi di applicazione) vs. controlli non inoculati a 50 giorni dalla semina in rhizobox con terreno sterilizzato. Lettere: differenze significative tra i trattamenti (test di Newman-Keuls, P≤0.05). Tra parentesi: variazione % delle piante trattate vs. piante di controllo.

Treatment	Length ($m\ plant^{-1}$)		Surface area ($m^2\ plant^{-1}$)		Diameter (µm)		Root tips (no. $plant^{-1}$)		Ramification index (no. forks m^{-1})	
Untreated	35.6	a	0.37	a	344	b	7559	b	555	b
Seed application	29.7	a (-17)	0.41	a (+10)	443	a (+29)	12102	a (+60)	933	a (+68)
Soil + foliar spraying	36.2	a (+2)	0.47	a (+25)	422	a (+23)	12758	a (+69)	856	a (+54)

In the more complex field conditions, in the first year, at medium (120 kg ha^{-1}) and high (160 kg ha^{-1}) nitrogen fertilisation rates, mainly in the top 0.4 m of soil depth (Fig. 3), root length density (RLD) was +29% and +11%, respectively, *vs*. non-inoculated controls. At these two N levels, the average RLD increase due to bacteria over the whole 0-1 m profile was still appreciable (+8% and +18%, respectively). With respect to the effects of N fertilisation, as expected, RLD progressively decreased with N supply (3.9, 3.8 and 3.6 cm cm^{-3} at 80, 120 and 160 kg N ha^{-1}, respectively). Unfortunately, many of these effects were not found in the second trial, where the mean RLDs of the root profile in bacteria-treated plots was even slightly lower than those of the non-inoculated controls: -8%, -2% and -11% (not significant, $P \geq 0.05$) at 80, 120 and 160 kg N ha^{-1} of chemical fertilisation, respectively (Fig. 3).

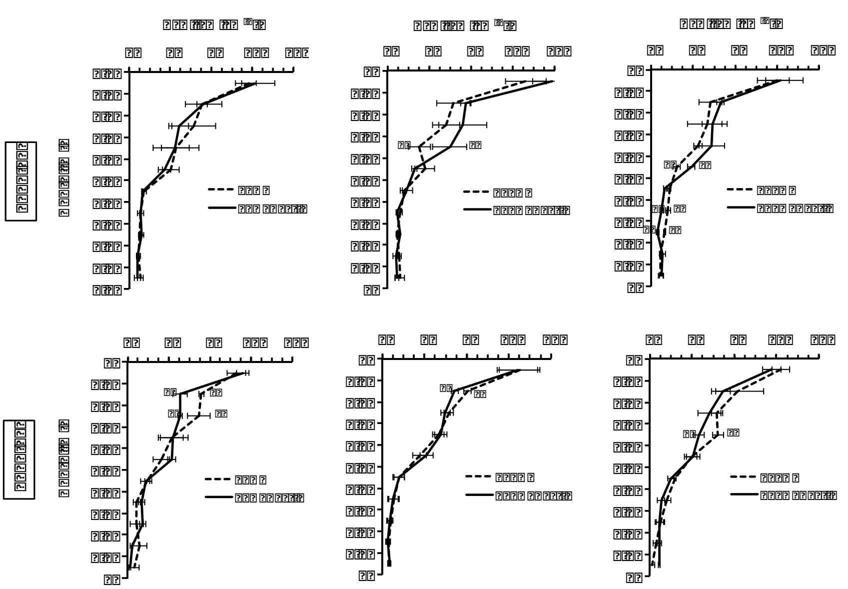


Fig. 3: Patterns of root length density (RLD) in bacteria-inoculated wheat plants (continuous line) vs. non-inoculated controls (dashed line) with decreasing N fertilisation levels (160, 120 and 80 kg ha^{-1}) at the flowering stage in a two-year field trial. Letters: significant differences among treatments at each soil depth (Newman-Keuls test, P≤0.05).
Fig. 3: Profilo di densità di lunghezza radicale (Root length density, RLD) delle piante di frumento inoculate con batteri (linea continua) vs. controllo non inoculato (linea tratteggiata) a livelli di fertilizzazione azotata decrescenti (160, 120 e 80 kg ha^{-1}) in stadio di fioritura nei due anni di sperimentazione. Lettere: differenze significative tra i trattamenti ad ogni livello di profondità (test Newman-Keuls, P≤0.05).

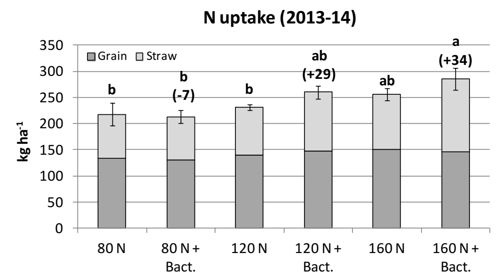
F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

In both years, plants showed improved growth and leaf chlorophyll contents as a result of the greater N supply and bacterial inoculation. Nitrogen concentration in the grain slightly benefited from bacterial treatment (range of increase: 1-4%) (Tab. 2). A similar trend was also observed with grain N concentration, with a more general improvement.
Bacterial treatment improved N uptake at medium-high N fertilisation levels compared with non-inoculated controls, 25 kg ha^{-1} (+12%) on average in both years (Fig. 4). Wheat yield was also very stable across treatments, with non-significant 1-3% increases due to bacteria inoculation (Tab. 2).

Tab. 2: Chlorophyll content (SPAD), grain nitrogen concentration and yield (mean; n=3) in bacteria-inoculated wheat plants vs. non-inoculated controls at decreasing N fertilisation levels (160, 120 and 80 kg ha^{-1}) in a two-year field trial. Letters: significant differences among treatments (Newman-Keuls test, P≤0.05). In brackets: % variation in bacteria-treated plants vs. non-inoculated controls at each N fertilisation level.
Tab. 2: Contenuto di clorofilla (SPAD), concentrazione di azoto nella granella e resa (media; n=3) nelle piante di frumento inoculate con i batteri vs. controlli non inoculati, a livelli di fertilizzazione azotata decrescenti (160, 120 e 80 kg ha^{-1}) nei due anni di sperimentazione in campo. Lettere: differenze significative tra i trattamenti (test di Newman-Keuls, P≤0.05). Tra parentesi: variazione % delle piante inoculate vs. piante di controllo ad ogni livello di fertilizzazione azotata.

Treatment	SPAD		Grain [N] (% d.w.)		Yield (kg ha^{-1})	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
80 N	45.8 c	39.7 d	2.06 c	1.83 b	6507 a	5158 b
80 N + Bact.	48.0 bc (+5)	40.2 d (+1)	2.13 bc (+3)	1.85 b (+1)	6356 a (-2)	5252 b (+2)
120 N	49.4 ab	41.5 c	2.17 bc	1.84 b	6469 a	5604 ab
120 N + Bact.	49.5 ab (+1)	42.9 b (+3)	2.21 abc (+2)	1.90 b (+3)	6688 a (+3)	5745 a (+3)
160 N	50.8 a	44.2 a	2.39 a	1.95 ab	6294 a	5982 a
160 N + Bact.	49.7 ab (-2)	43.7 ab (-1)	2.30 ab (-4)	2.03 a (+4)	6353 a (+1)	6057 a (+1)
Fertilisation	**	***	**	**	ns	***
Bact. app.	Ns	ns	ns	ns	ns	ns
Fert × Bact. app.	Ns	ns	ns	ns	ns	ns

n.s. = not significant; *, ** and *** = significance at *P*≤0.05, P≤0.01 and P≤0.001, respectively.



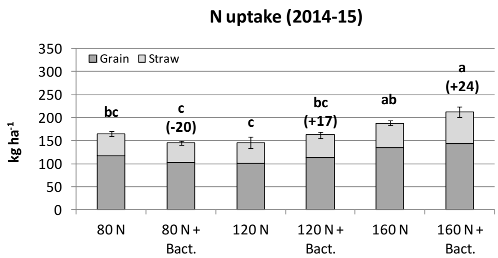


Fig. 4: Overall (grain + straw) nitrogen uptake on a per hectare basis by bacteria-inoculated wheat plants vs. non-inoculated controls with decreasing N fertilisation levels (160, 120 and 80 kg ha^{-1}) at plant harvest in a two-year field trial. Letters: statistically significant differences among treatments for multiple comparisons (Newman-Keuls test, P≤0.05). In brackets: variation (kg ha^{-1}) in bacteria-treated plants vs. non-inoculated controls at each N fertilisation level.
Fig. 4: Asportazione complessiva (granella + paglia) di azoto (kg ha^{-1}) di frumento inoculato con batteri vs. controlli non inoculati, a livelli di fertilizzazione azotata decrescenti (160, 120 e 80 kg ha^{-1}) alla raccolta nei due anni di sperimentazione. Lettere: differenze significative tra i trattamenti (test di Newman-Keuls, P≤0.05). Tra parentesi: variazione (kg ha^{-1}) nelle piante trattate vs. piante di controllo ad ogni livello di fertilizzazione azotata.

Discussion and Conclusions
In aseptic conditions, ESEM analysis revealed considerable survival rates and colonisation of external and internal leaf and root tissues by *Azospirillum* spp., *Azoarcus* spp. and *Azorhizobium* spp. bacterial species after artificial application, evidencing the vitality of the biofertiliser product that is a premise for its successful application in open fields. About this, it is still to be considered that physical, chemical and biological activities that take place in open field can affect, even totally, microbial growth and distribution on crop plants.

The most appreciable effect of bacteria inoculation in controlled conditions was root stimulation; variations in root architecture were related to a marked increase in the number of root tips and ramifications. In this way, faster root establishment would allow the plant to explore greater soil volumes and have access to greater amounts of nutrients. Some authors showed that seed inoculation with various PGPR have positive effects on shoot development and yield of wheat (Piccinin *et al*., 2011; Mahanta *et al*., 2014) and other crops, but only little information is available on root growth.

In the more complex situation of open fields, appreciable root enhancements were found in the arable layer at medium-high N fertilisation levels in the first year, but not in the second year. Similarly, unstable effects due to PGPR were found with seed inoculation of sorghum with various strains of *Azospirillum brasilense* in open fields by Basaglia *et al*. (2003), who reported considerable root enhancement in one year, but no effect/colonisation in the second year of the trial, ascribing the failure to abundant rainfall after sowing in clay soil. The interactions between PGPR and the resident soil microbioma, soil fertility, plant age and phenotype, soil and climatic conditions and agronomic management should all be considered to gain a better understanding of their true role (Roesti *et al*., 2006).

The maximum N dose tested (160 kg ha^{-1}) is the recommended rate for yield productivity in north Italy for a yield target of 6-7 t ha^{-1} and seems to be compatible with the positive role of bacteria; even a reduction to the medium dose (120 kg N ha^{-1}) still preserves the effects of these bacteria.

Improved N accumulation in inoculated plants due to biological N-fixation of PGPR is well documented (Dalla Santa *et al*., 2004), but in our temperate climate it is assumed that root growth enhancement has probably played a major role in nutrient acquisition (Steenhoudt and Vanderleyden, 2000). *Azoarcus* and *Azospirillum* have been found to colonise plant leaves, where they apparently find a favourable environment for N fixation and for obtaining nutritional resources from the host in the absence of strong competition from the natural rhizospheric microbioma (Pedraza et al., 2009).

The use of mixed PGPR and N-fixing bacteria in conventional common wheat cultivation presents an opportunity for improving root growth and potentially to have some positive physiological benefits and possibly yield improvements. Integration of the mechanisms of rooting power and N-fixation of a consortium of bacteria can help to reduce N losses from agricultural ecosystems and accordingly to save on chemical fertilisers, although external N fertilisers are still essential to maintain crop yield and grain quality standards.

References

Basaglia, M., Casella, S., Peruch, U., Poggiolini, S., Vamerali, T., Mosca, G., Vanderleyden, J., De Troch, P., Nuti, M.P., 2003. Field release of genetically marked *Azospirillum brasilense* in association with *Sorghum bicolor* L. Plant Soil 256, 281-290.

Dalla Santa, O.R., Hernández, R.F., Alvarez, G.L.M., Ronzelli, Junior P., Soccol, C.R., 2004. *Azospirillum* sp. inoculation in wheat, barley and oats seeds greenhouse experiments. Braz. Arch. Biol. Technol. 47, 843-850.

Kumar, A., Maurya, B.R., Raghuwanshi, R., 2014. Isolation and characterization of PGPR and their effect on growth, yield and nutrient content in wheat (*Triticum aestivum* L.). Biocatal. Agric. Biotechnol. 3, 121-128.

Mahanta, D., Rai, R.K., Mishra, S.D., Raja, A., Purakayastha, T.J., Varghese, E., 2014. Influence of phosphorus and biofertilizers on soybean and wheat root growth and properties. Field Crops Res. 166, 1-9

Pedraza, R.O., Bellone, C.H., Carrizo de Bellone, S., Boa Sorte, P.M.F., dos Santos Teixeira, K.R., 2009. *Azospirillum* inoculation and nitrogen fertilization effect on grain yield and on the diversity of endophytic bacteria in the phyllosphere of rice rainfed crop. Eur. J. Soil Biol. 45, 36-43.

Pérez-Montaño, F., Alías-Villegas, C., Bellogín, R.A., del Cerro, P., Espuny, M.R., Jiménez-Guerrero, I., López-Baena, F.J., Ollero, F.J., Cubo, T., 2014. Plant growth promotion in cereal and leguminous agricultural important plants: From microorganism capacities to crop production. Microbiol. Res. 169, 325-336.

Piccinin, G.G., Dan, L.G.M., Braccini, A.L., Mariano, D.C., Okumura, R.S., Bazo, G.L., Ricci, T.T., 2011. Agronomic efficiency of *Azospirillum brasilense* in physiological parameters and yield components in wheat crop. J. Agron. 10, 132-135.

Roesti, D., Gaur, R., Johri, B.N., Imfeld, G., Sharma, S., Kawaljeet, K., Aragno, M., 2006. Plant growth stage, fertiliser management and bio-inoculation of arbuscular mycorrhizal fungi and plant growth promoting rhizobacteria affect the rhizobacterial community structure in rain-fed wheat fields. Soil Biol. Biochem. 38, 1111-1120.

Steenhoudt, O., Vanderleyden J., 2000. *Azospirillum*, a free living nitrogen-fixing bacterium closely associated with grasses: genetic, biochemical and ecological aspects. FEMS Microbiol. Rev. 24, 487-506.

Tahir, M., Mirza, M.S., Hameed, S., Dimitrov, M.R., Smidt, H., 2015. Cultivation-based and molecular assessment of bacterial diversity in the rhizosheath of wheat under different crop rotations. PLoS ONE 10(6):e0130030.

WHEAT SPATIAL VARIATION BASED ON SPECTRAL VEGETATION INDICES AND SOIL ANALYSIS

VARIABILITÀ SPAZIALE DEL FRUMENTO SULLA BASE DI INDICI DI VEGETAZIONE SPETTRALI E SULLE ANALISI DEL TERRENO

Lorenzo Barbanti[1*], Josep Adroher[1,2], Júnior Melo Damian[1,3], Nicola Di Virgilio[4], Gloria Falsone[1], Matteo Zucchelli[5], Roberta Martelli[6]

[1] Dept. of Agricultural Sciences, University of Bologna, Italy
[2] Dept. of Chemical and Agricultural Engineering and Agrifood Technology, University of Girona, Spain
[3] Dept. of Soil Science, ESALQ, University of São Paulo, SP, Brazil
[4] Institute of Biometeorology, National Research Council, Bologna, Italy
[5] Trimble Geospatial, Vimercate, MB, Italy
[6] Dept. of Agricultural and Food Sciences, University of Bologna, Italy
*lorenzo.barbanti@unibo.it

Abstract
Soil characteristics, proximal and remote spectral vegetation indices were geo-referentially assessed in a 4.15 ha wheat field in northern Italy. Data obtained in the three separate domains were submitted to principal component analysis (PCA), and the retained PCs were clustered to delineate homogeneous areas at low (L), intermediate (I) and high (H) potential, based on soil parameters (CLU_{sp}), proximal (CLU_{pi}) and remote spectral vegetation indices (CLU_{ri}). Spatial distribution of soil and crop data showed a low performing area (GY < 3 Mg ha^{-1}) and a high performing one (GY > 8 Mg ha^{-1}). CLU_{sp} staged a lower GY difference between L and H area (60%) than CLU_{pi} and CLU_{ri} (ca. 100%). Area levels (L, I, H) based on vegetation indices outlined a better degree of agreement with GY, compared to area levels based on soil parameters. In exchange for this, the above referred soil parameters are quite consistent in time, allowing soil data to be used for more crop seasons.
Keywords: homogeneous areas; soil properties; remote vegetation indices; wheat; yield mapping.
Parole chiave: aree omogenee; caratteristiche terreno; indici di vegetazione remoti; frumento; mappatura produttiva.

Introduction
The sustainable improvement of wheat production in a frame of precision agriculture (PA) relies on the appraisal of spatial and temporal variability of soil and crop properties (Diacono *et al*., 2013). This variability is still largely unexplored even in cereals that, owing to their large surface, are best suited for site specific management (SSM). SSM allows a field to be split into areas that express a relatively homogeneous combination of yield limiting factors, for which a single rate of a specific crop input is appropriate (Fridgen *et al*., 2004). The cost and time needed to obtain the information to set up homogeneous areas represent a constraint that is largely responsible for the slow progress in SSM (Pierce and Novak, 1999). Thus, alternative methods are sought to replace crop yield records and soil characteristics that are commonly used at present. The optical sensing of crop properties includes many potentially useful methods. Among them, the normalized difference vegetation index (NDVI) addressing general growth status is the reference spectral index, although limits have been evidenced compared to other indices operating in the same wavebands (Erdle *et al*., 2011). One of the drawbacks associated with NDVI assessed through active optical sensors is the need to operate at, or near, ground level. Owing to this, remote sensing from satellite is gaining interest over proximal sensing from ground or low altitude platforms. However, also remote sensing has weak points: the influence of weather conditions, spatial and temporal scale, and difficulties in processing and evaluating spectral images (Zhang and Kovacs, 2012).
Given the pending problems undermining the adoption of PA practices, in light of the uncertainties surrounding wheat spectral indices, this work addressed the study of proximal *vs* remote vegetation indices, and soil properties, in the interpretation of wheat yield spatial variation. The study was intended as a showcase for SSM adoption in the wheat crop.

Materials and Methods
STUDY AREA
The study was conducted in 2014 in the coastal plain near Ravenna, Italy. A 4.15 ha experimental area was chosen in a lager field cultivated with winter wheat (*Triticum aestivum* L.) in the Agrisfera Cooperative. Wheat management (tillage, seeding, fertilization, weed, pest and disease control) reflected good crop practices for this area.

SOIL AND CROP ASSESSMENTS
On March 12, soil samples (0-0.3 m layer) were taken in a 24-cell grid established in the experimental area (cell size, 1728 m^2), to assess particle size distribution, pH, total carbonates ($CaCO_3$), organic carbon (C), total nitrogen (N), available P (Olsen), exchangeable cations (K, Ca, Mg, Na) and cation exchange capacity (CEC).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Proximal spectral vegetation indices were assessed in a 36-cell grid established in the experimental area (cell size, 1152 m²) in three times during stem elongation (from March 25 to April 24), using the chlorophyll meter N-Tester (NT), and the active radiometer GreenSeeker (GS) that determines NDVI.
Remote indices were based on the Landsat 8 satellite, OLI multispectral sensor, 15 × 15 m spatial resolution. Raw images acquired in three dates from March 15 to April 16 were processed by Trimble Agriculture Division to remove interferences. Multiple bands in the visible to near-infrared range were used to obtain the PurePixel™ Chlorophyll Index (PPCI) indicating chlorophyll content, and the PurePixel™ Vegetation Index (PPVI) that is related to general growth status.
Crop traits included: plant height, the number of spikes m^{-2} (S/m²), the number of grains per spike (G/S), mean grain weight (MGW), test weight (TW), grain protein content (GPC), and harvest index (HI).
Combine harvesting was carried out on July 7 using a machine equipped with a yield mapping system. A total of 4160 grain yield (GY) data filtered and adjusted at 13% moisture was archived in the experimental area.

DATA ANALYSIS AND MANAGEMENT ZONE DELINEATION

Descriptive statistics of soil parameters, proximal and remote indices, and plant traits was carried out. Pearson's correlation was used to assess the relationship of soil traits, proximal and remote indices, with GY and related traits. Continuous maps of all traits were created by interpolating data points using inverse distance weighting, i.e. assuming that each point value exerts an influence decreasing with distance.
Sub-division of the experimental field into homogeneous areas was based on three different criteria: soil parameters, proximal and remote vegetation indices. In each case, a maximum of three levels was set as the number fostering sufficient differentiation while avoiding excessive patchiness of the experimental area. In the soil data set composed of 14 parameters, a principal component analysis (PCA) was run to reduce the number of variables (Fraisse *et al.*, 2001). Thereafter, fuzzy c-means clustering was performed on data of the PCs retained from the analysis, using the Management Zone Analyst software (Fridgen *et al.*, 2004).
PCA was also run on proximal and remote vegetation indices, resulting in two indices per three dates submitted to PCA in both proximal and remote indices. Fuzzy c-means clustering was performed on the PCs retained, as in soil parameters.
To assess the ability of the three criteria to delineate areas at different crop behaviour, data of plant morphology, yield and quality associated with the homogeneous areas established with the three criteria were submitted to a one-way ANOVA.
Lastly, a cell-by-cell comparison was conducted between the GY level associated with each cell, obtained through independent clustering, and the level determined for that cell by clustering with the three criteria. Of the three levels assigned, low (L), intermediate (I) and high (H), the percentage of cells belonging to the same level in the two scales was used to indicate the degree of agreement between between clusters based on either criteria, and GY (Tagarakis *et al.*, 2013).

Results and Discussion

DESCRIPTIVE STATISTICS AND CORRELATIONS

Soil texture ranged from loamy to sandy-loamy, showing a noticeable spatial variation (CV of sand, silt and clay between 26 and 32%). The pH was from moderately to strongly alkaline, in association with high $CaCO_3$ content. Organic carbon was always low, as no sample attained 10 g C kg^{-1}. C and N varied concurrently, resulting in a low C/N ratio. P and K were in the low range of the respective scales of evaluation.

Table 1 – Descriptive statistics of the five soil and plant traits best correlated with GY, and GY. The last column reports values of the correlations with GY.
Tab. 1 – Statistica descrittiva dei cinque parametri suolo/pianta meglio correlati con la resa produttiva (GY), e GY. L'ultima colonna riporta i valori delle correlazioni con GY.

Variable	Mean	Median	Min.	Max.	SD	CV (%)	r with GY
Sand (g kg^{-1})	513	510	314	773	134	26.1	-0.91
pH	8.4	8.4	8.3	8.7	0.1	1.2	-0.87
Org. C (g kg^{-1})	6.5	6.7	3.4	9.1	1.5	22.4	0.85
GS 3/25	0.66	0.68	0.47	0.78	0.09	13.8	0.96
PPVI 3/31	74.6	76.0	55.0	82.0	5.2	7.0	0.92
GY (Mg ha^{-1})	6.25	6.66	2.42	8.57	1.70	27.3	

Proximal vegetation indices NT and GS increased during stem elongation, in accordance with the wheat plant attaining peak growth. Remote vegetation index PPVI also increased, whereas PPCI remained quite steady during this period.
Plant height varied between ca. 0.5 and 1 m. The mean value (0.83 m) was closer to the highest value and the variation was quite low (CV, 13%), suggesting that only a small fraction of the experimental area was affected by poor growth conditions. GY exhibited a normal mean value for wheat grown in the region (6.25 Mg ha^{-1}), and a sizeable variation (CV,

27%) due to changes in the three yield components (S/m², G/S and MGW). Lastly, the two traits of grain quality, TW and GPC, exhibited a respective high (83.7 dg L^{-1}) and low mean level (101 g kg^{-1}), in both cases with limited variation.
GY, plant height and HI were significantly correlated with many soil parameters and vegetation indices (r values not shown): negative relationships were shown with sand and pH, whereas positive relationships were evidenced with silt, clay, C, N, and with all proximal and remote indices. Concerning the three yield components, S/m² was poorly correlated with all soil and vegetation data, whereas G/S and MGW were correlated with many soil parameters and all vegetation indices.
Descriptive statistics of the five soil and crop traits best correlated with GY, and GY, are reported in Table 1. Correlations with GY (r values always significant at $P \leq 0.01$) are also indicated.

SPATIAL DISTRIBUTION OF SOIL AND CROP TRAITS

Continuous maps of the three soil parameters and the two vegetation indices featuring the highest correlations with GY (Table 1), and GY map are shown in Figure 1.

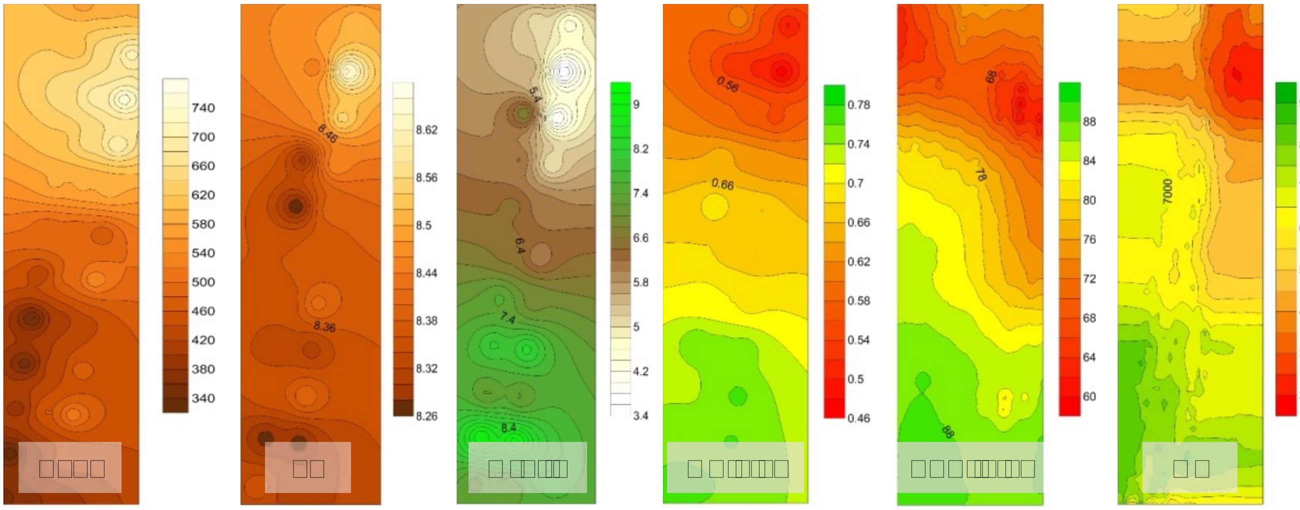


Fig. 1 – Continuous maps of sand, pH and soil organic C, vegetation indices GS and PPVI at stem elongation, and GY.
Fig. 1 – Mappe continue di sabbia, pH e C organico nel suolo, indici vegetazionali GS e PPVI in levata, e resa prod. (GY).

Sand displayed the highest values (>700 g kg^{-1}) in the north-eastern part of the experimental field, in contrast to the lowest values (<400 g kg^{-1}) in the south-western part. The pH outlined a similar pattern, despite a sharper shift from very high values in the north-eastern tip, to lower values in the rest of the field. Organic C exhibited a pattern opposed to sand: very low values (<4 g kg^{-1}) in the north-eastern area where sand was abundant, in exchange for quite higher values (>8 g kg^{-1}) in the southern part where sand was counter-balanced by silt and clay. GS and PPVI at early stem elongation (March 25 and 31, respectively) exhibited values indicating stunted growth in the north-eastern part of the field, compared to normal growth in the southern part. Finally, very low GY (<3 Mg ha^{-1}) was recorded in the north-eastern area of the field, whence values gradually increased attaining top wheat yields (>8 Mg ha^{-1}) in the south-western area.

HOMOGENEOUS AREAS

Homogeneous areas set with the three criteria consistently placed the L and H area in the respective north and south part of the field (maps not shown). However, differences in shape and, especially, size were shown among the three areas (Table 2). Clustering based on soil parameters (CLU_{sp}) partitioned the highest share of the experimental field to the I area (46%), in exchange for lower shares to the H (29%) and L area (25%). Compared to this, clustering based on remote indices (CLU_{ri}) apportioned the highest share to the H area (46%) and the lowest to the L area (16%). Lastly, clustering based on proximal indices (CLU_{pi}) displayed a more even distribution among the three areas (25, 42 and 33% for the respective L, I and H area).
Submitting spectral vegetation indices to PCA was aimed at delineating homogeneous areas based on data covering a more extended wheat stage, during which time practices as nitrogen topdress fertilization could be carried out in a frame of SSM. More to this, it was a straightforward option to join PPCI and PPVI that are determined simultaneously, despite the intrinsic difference of a chlorophyll (PPCI) vs. growth (PPVI) index. Thus, it appeared sensible to do the same with NT and GS that are the two equivalent proximal traits.
Submitting soil parameters and vegetation indices to PCA and subsequent clustering of the PCs retained led to the delineation of homogeneous areas whose robustness was proved by their ability to indicate field areas consistently matching potential (L, I, H zone) with analogous differentiation of morphological and yield traits.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Table 2 – Plant morphology, yield and quality traits in field field areas clustered on the basis of soil parameters (CLU_{sp}), proximal (CLU_{pi}) and remote spectral vegetation indices (CLU_{ri}).
Tab. 2 – Morfologia della pianta e produzione quanti-qualitativa in aree di campo raggruppate sulla base di parametri suolo (CLU_{sp}), e di indici di vegetazione spettrali prossimali (CLU_{pi}) e remoti (CLU_{ri}).

	Level	% area	Height (m)	HI (w/w)	GY (Mg ha^{-1})	S/m² (no. m^{-2})	G/S (no. $spike^{-1}$)	MGW (mg)	TW (dg L^{-1})	GPC (g kg^{-1})
CLU_{sp}	L	25	0.64 b	0.47 b	4.28 b	571	16.1 b	37.6 b	83.4	107.6
	I	46	0.82 a	0.51 a	6.72 a	574	28.2 a	40.0 a	83.8	100.9
	H	29	0.83 a	0.49 ab	6.84 a	586	27.2 a	39.3 ab	83.7	97.7
CLU_{pi}	L	25	0.69 c	0.47 b	4.09 c	563	14.9 c	37.4 b	83.7 ab	110.0 a
	I	42	0.84 b	0.50 a	6.11 b	592	25.5 b	39.7 a	84.1 a	101.3 ab
	H	33	0.93 a	0.52 a	8.05 a	560	32.8 a	40.4 a	83.1 b	93.6 b
CLU_{ri}	L	16	0.67 c	0.48 b	3.83 c	583	16.6 c	38.1 c	84.0 a	108.6 a
	I	38	0.75 b	0.49 b	5.51 b	572	22.1 b	38.9 b	83.9 a	104.4 b
	H	46	0.86 a	0.51 a	7.70 a	588	30.2 a	40.1 a	83.3 b	94.9 c

Within each clustering, different letters indicate significantly different data at $P \leq 0.05$ (LSD test).

The comparison between cell levels determined by clustering with the three criteria and GY in the three respective grids, showed a better degree of agreement for proximal (89%) and, to a lesser extent, remote indices (72%), than soil parameters (50%). It is therefore evidenced that spectral vegetation indices supplied a more reliable indication of yield potential, beside providing a stronger differentiation of GY (Table 1). In exchange for this, the soil parameters used in this study are rather consistent in time, whereas spectral vegetation indices are intrinsically variable between years, depending on growth conditions affecting canopy reflectance properties (Diacono *et al*., 2013). Thus, soil analysis supplies data that can be used for more years, whereas spectral vegetation indices need to be assessed at each crop season. In exchange for this, canopy sensing involves less burden and cost than soil analysis, especially in the case of remote sensing.
Finally, the similar good performance of proximal and remote vegetation indices demonstrates the quality of remote data acquisition and processing achieved by commercial systems, compared to a recent work where proximal sensing was still used only for calibration of satellite images (Basso *et al*., 2016).

Conclusions

Advantages and disadvantages of homogeneous area delineation using soil parameters *vs* proximal and remote spectral vegetation indices appear non univocal, in light of the above results. This work based on one year of wheat cropping in a region where wheat rotation with other crops is the standard good practice, represents a showcase of the three systems' potential. Nevertheless, the approach used in data processing has resulted in a robust delineation of filed homogeneous areas, as proved by the substantial consistency with final yield and related attributes.

References

Basso B., Fiorentino C., Cammarano D., Schulthess U., 2016. Variable rate nitrogen fertilizer response in wheat using remote sensing. Precis. Agric., 17: 168-182.

Diacono M., Rubino P., Montemurro F., 2013. Precision nitrogen management of wheat. A review. Agron. Sustain. Dev., 33: 219-241.

Erdle K., Mistele B., Schmidhalter U., 2011. Comparison of active and passive spectral sensors in discriminating biomass parameters and nitrogen status in wheat cultivars. Field Crop. Res., 124: 74-84.

Fraisse C.W., Sudduth K.A., Kitchen N.R., 2001. Delineation of site-specific management zones by unsupervised classification of topographic attributes and soil electrical conductivity. T. ASAE, 44: 155-166.

Fridgen J.J., Kitchen N.R., Sudduth K.A., Drummond S.T., Wiebold W.J., Fraisse C.W., 2004. Management zone analyst (MZA). Agron. J., 96: 100-108.

Pierce F.J., Nowak P., 1999. Aspects of precision agriculture. Adv. Agron., 67: 1-85.

Tagarakis A., Liakos V., Fountas S., Koundouras S., Gemtos T.A., 2013. Management zones delineation using fuzzy clustering techniques in grapevines. Precis. Agric., 14: 18-39.

Zhang C., Kovacs J., 2012. The application of small unmanned aerial systems for precision agriculture: a review. Precis. Agric., 13: 693-712.

ASSESSMENT OF CROP RESIDUES MANAGEMENT AS STRATEGY OF ADAPTATION AND MITIGATION TO CLIMATE CHANGE

VALUTAZIONE DELLA GESTIONE DEI RESIDUI COLTURALI COME STRATEGIA DI ADATTAMENTO E MITIGAZIONE AI CAMBIAMENTI CLIMATICI

Domenico Ventrella[1], Luisa Giglio[1], Marco Bindi[2], Bruno Basso[3], Umberto Bonciarelli[4], Anna Dallamarta[2], Francesco Danuso[5], Luca Doro[6], Roberto Ferrise[2], Francesco Fornaro[1], Pasquale Garofalo[1], Fabrizio Ginaldi[7], Ileana Iocola[6], Paolo Merante[2], Laura Mula[6], Andrea Onofri[4], Simone Orlandini[2], Massimiliano Pasqui[8], Rodica Tomozeiu[9], Giulia Villani[9], Alessandro Vittorio Vonella[1], Pier Paolo Roggero[6]

[1]CREA-AA, Sede di Bari, [2]DISPAA, Univ. Firenze; [3]Dep. Geolog. Sc., Michigan State Univ., USA; [4]Dsa3, Univ. Perugia; [5]Di4a, Univ. Udine; [6]Dip. di Agraria e NRD, Univ. Sassari; [7]CREA-AA, Bologna; [8]CNR-IBIMET, Roma; [9]Arpae-SIMC-Emilia-Romagna
*domenico.ventrella@crea.gov.it

Abstract
This paper reports main results of a research developed in the three-years (2013-16) project "IC-FAR - Linking long term observatories with crop system modeling for better understanding of climate change impact and adaptation strategies for Italian cropping systems" (www.icfar.it). The goals are: i) to parameterize crop models considering two Long Term Agro-Ecosystem experiments (LTAE) located in experimental farms of Foggia (FG) and Papiano, Perugia (PG), in Southern and Central Italy, respectively and ii) to evaluate the crop residue (CR) management as a strategy of adaptation and/or mitigation to climate change forecasted for the reference areas of the LTAEs in study. Climate scenarios were generated by setting up a statistical model using predictors from ERA40 reanalysis and seasonal indices of temperature and precipitation from E-OBS gridded data for the period 1958-2010. The statistical downscaling model was applied to CMCC-CM predictors to obtain climate projections at local scale over the period 1971-2000 and 2021-2050 (RCP45 and RCP85 emission scenarios).

Keywords
Wheat, maize, DSSAT, crop residues, soil organic carbon
Parole chiave
Frumento, mais, DSSAT, residui colturali, carbonio organico del suolo

Introduction
Farming practices as crop residues (CR) management can affect the level and dynamics of Organic Carbon (OC) in the soil, influencing its fertility, obtainable crop yields and the rate of carbon sequestration or release. Since, the dynamic of OC processes take place very slowly, at local level is fundamental to use datasets collected of long-term experimental trials.
This paper reports results of soil OC and crop yield simulation developed within the project "IC-FAR - Linking long term observatories with crop system modeling for better understanding of climate change impact and adaptation strategies for Italian cropping systems (www.icifar.it). In particular, dataset collected during two Long term Agro-Ecosystem research (LTAE), located in Foggia (FG) and Papiano Perugia (PG), respectively in Southern and Central Italy, were utilized in crop simulation approaches. After appropriate calibration process, the crop model capacity were exploited to explore the impact of different CR management options, possibly proposed as a strategy of adaptation and/or mitigation to climate change forecasted for the reference areas of the LTAEs in study. For this purpose, crop yield and soil OC dynamic were compared under different climatic change scenarios.

Materials and Methods
LTAE of FG consist of monoculture of winter durum wheat submitted, since 1977, to nine treatments based on burning and soil incorporation of CR with and without N fertilization or irrigation applied on crop residues before ploughing. The experimental design was a randomized complete block design with five replications**.**
The soil has a clay-loam texture of alluvial origin and the climate is classified as "accentuated thermomediterranean", with rainfall concentrated in the winter months and an annual average of 550 mm (Ventrella et al., 2016).
LTAE of PG, started on 1971, on a loamy soil, compare different cropping system obtained from a factorial combination of two different types of management of CR (removal at harvest and incorporation at ploughing) and several type of rotations. Among these, we considered a biennial maize-wheat rotation based on removal of CR and N fertilization at a rate of 150 e 100 kg ha^{-1}, respectively for wheat and maize. This LTAE area present a climate warm-temperate, with mild winters and no dry season with mean annual rainfall of 831mm (Bonciarelli et al, 2016).
Performance of several crop models are comparing during the study, but this paper reports only the results obtained using DSSAT 4.6, that includes CENTURY algorithm as soil organic matter component. To initialize soil OC, both

calibration/validation process, and climatic scenarios simulation were running in continuous with the same pre-run period, based on the previous history of the experimental sites.

Tab. 1 Agronomical treatments.
Tab.1 Trattamenti agronomici.

Agronomical treatment for Adaptation/Mitigation Analysis	
ID	*Description*
RE	CR REmoved at arvest
ON	CR left ON soil - No tillage
IN	CR INcorporate by ploughing
INN	CR INcorporated by ploughing + 50 kg ha^{-1} (wheat)

Table 1 shows a range of CR management options applied to both LTAEs and examined in this study.
Climate change impact were explored running DSSAT under Baseline scenario e two future scenarios (RCP45 and RCP85) generated by a statistical downscaling approach based on Canonical Correlation Analysis using ERA-40 and ERA-interim reanalysis (www.ecmwf.int/en/research/climate-reanalysis/era-interim). The generated scenarios refer to LTAE sites and are computed respect seasonal temperature and precipitation of the reference period 1971-2000 and 2021-2050, respectively for Baseline scenario and future scenarios. 360, 460 e 490 ppm were the CO_2 concentration considered under Baseline, RCP45 and RCP85 scenarios, respectively.

Results and Discussion

At site of FG, OC measurements highlighted no particular trend, according to DSSAT simulation, despite significant discrepancies during an intermediate period. However, at PG the model was able to describe in an efficient way the effect of CR removal and incorporation (Fig. 1).

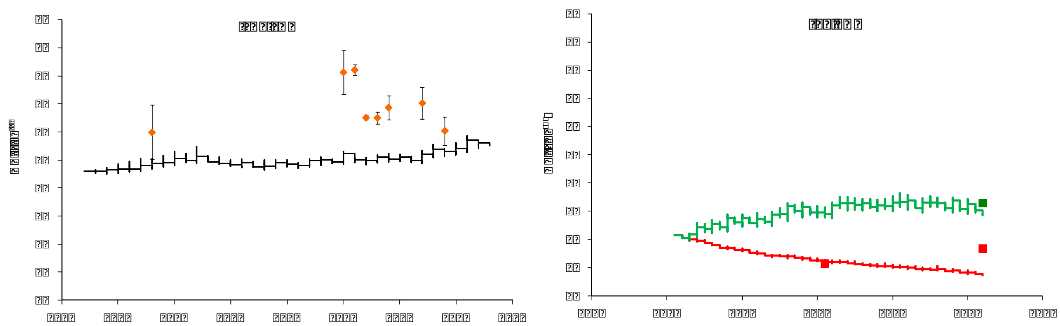


Fig.1: Trend of soil OC, at 0-40 cm, simulated by DSSAT and compared with measurements collected during LTAE of FG and PG with incorporation (green line) and removal (red line) of CR.
Fig. 1: Andamento del CO del suolo, a 0-40 cm, simulato dal DSSAT e confrontato con le misure raccolte durante prove sperimentali di lungo termine: di FG e PG con interramento (linea verde) e rimozione (linea rossa) dei RC.

In figure 2 results of scenarios application under different treatments were reported. They show that CR removal determined a progressive reduction in OC with a steady state level reached about of 40 years. Such equilibrium level was about 75% of OC initial value without difference between climatic scenarios.
The CR incorporation showed maximum levels of OC with a slightly higher values under INN. At FG, ON treatment allowed OC levels very close to IN and INN, while at PG the steady state values were about 90% of IN (Fig. 2).
ON treatment could be a useful strategy of mitigation reducing CO_2 emission (due to no tillage) and ensuring a good level of CO_2 sequestration. However, the impact of different CR management options on soil OC dynamic is highly site-specific because affected by climate and type of soil.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

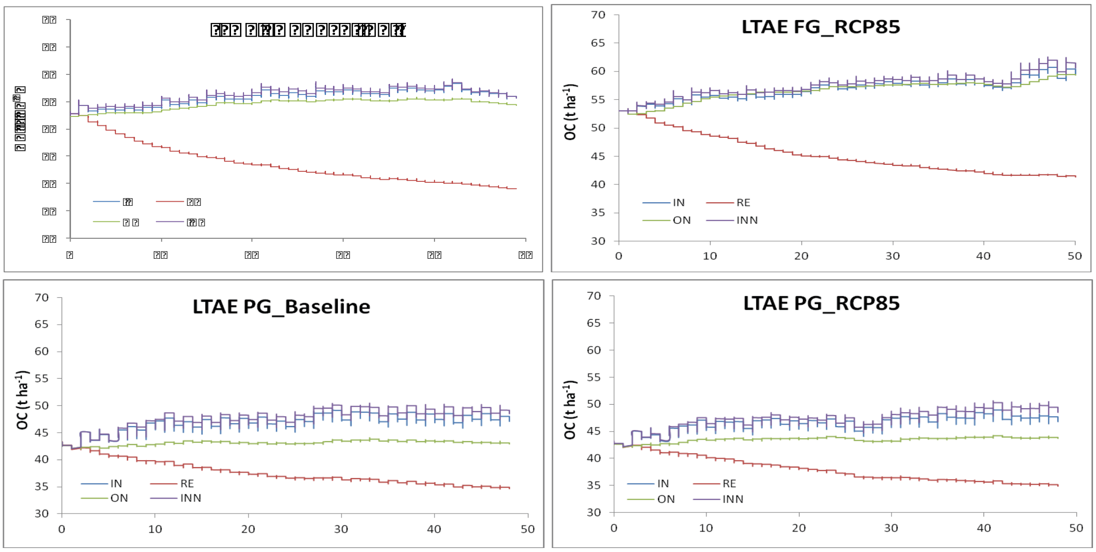


Fig.2: Impact of Baseline and RCP85 scenarios with alternative CR management on trend of soil OC, at 0-40 cm.
Fig.2: Impatto degli scenari Baseline e RCP85 con alternative gestioni dei RC sul trend del carbonio organico del suolo, 0-40 cm.

Results on yield and adaptation

For winter wheat under RCP85, CR incorporation with N (INN) and CR leaving on soil surface counterbalanced the yield reduction, about 10% in average, due to CC better than the others two treatments.

Such effect of CR management was not evident for maize that was more penalized by climate change with a yield reduction of about 27% (Fig. 3).

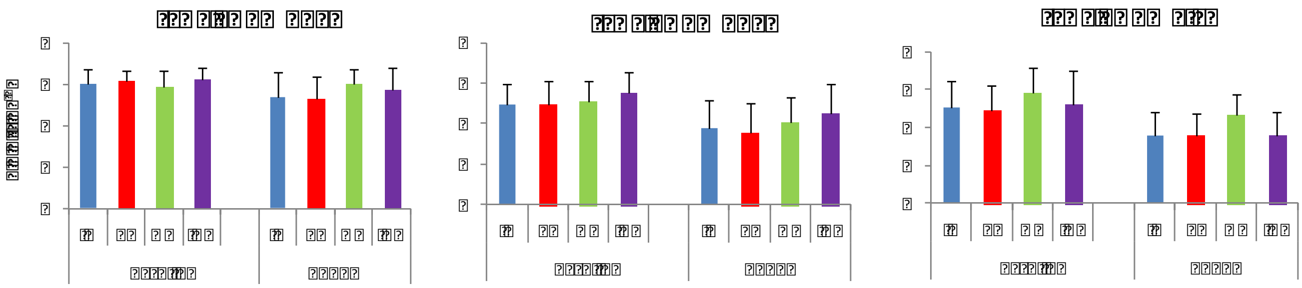


Fig.3: Simulated yield of wheat monoculture at FG site and of wheat-maize rotation at PG site, under climate scenarios and all treatment of CR management.
Fig.3: Resa simulata della monocoltura di frumento nel sito di FG e resa della rotazione frumento-mais nel sito di PG, negli scenari climatici e in tutti di gestione RC.

Conclusions

In conclusion, as emerged from this analysis, the interaction between forecasted climate scenarios and alternative management of CR, highlighted that crop residue removal after harvest can reduce markedly soil OC content reaching a steady-state value after 25-30 years. On the contrary, under a context of climate change, leaving on soil surface or incorporating crop residues, with low supply of N, could be a simple way to maintain or increase soil OC levels and to contribute to stabilize the productive performance to levels of Baseline scenario.

References

Bonciarelli U. et al., 2016. Long-term evaluation of productivity, stability and sustainability for cropping systems of in Mediterranean rainfed conditions. Eur. J. Agron., 77: 146-155.
Ventrella D. et al., 2016. Effects of crop residue management on winter durum wheat productivity in a long term experiment in Southern Italy. Eur. J. Agron.,77: 188-198.

SENTINEL-2 AS NEW TOOL FOR WATER AND NITROGEN MANAGEMENT: THE MAIZE AND TOMATO CASE STUDY

SENTINEL-2 COME STRUMENTO PER LA GESTIONE DI ACQUA E AZOTO: I CASI STUDIO DI MAIS E POMODORO

Alessandra Fracasso[1*], Karolina Sakowska[1], Michele Colauzzi[1], Massimo Vincini[2], Stefano Amaducci[1]

[1] Dipartimento di Produzioni Vegetali Sostenibili, Università Cattolica del Sacro Cuore, via Emilia Parmense 84, 29122, Piacenza
[2] CRAST, Università Cattolica del Sacro Cuore, via Emilia Parmense 84, 29122, Piacenza
*alessandra.fracasso@unicatt.it

Abstract
Plant nitrogen (N) and water status assessment is important for a range of applications including precision agriculture and the global carbon cycle studies. On the one hand, both parameters are growth limiting factors, affecting leaf area index (LAI), biomass production, and photosynthetic rates. On the other hand, the excessive use of fertilizers and irrigation should be avoided to minimize environmental impacts. Site-specific optimization of nitrogen and water input is nowadays the main solution to meet the challenge of supplying food for a growing population reducing at the same time the environmental impact of agriculture. Given the above, the accurate detection of N and water deficient areas requiring specific inputs in specific quantities is needed in order to implement the precision agriculture strategies. In this context, remote sensing, and in particular, the Sentinel-2 satellite mission, providing high spatial, spectral and temporal resolution images, is an unique tool presenting advantages of repeatability, accuracy, and cost-effectiveness over the ground-based surveys for nutrient and water stress detection. In this study we evaluated the impact of water and N fertilization on seasonal dynamics of spectral signature, LAI and chlorophyll content of irrigated maize (*Zea mays* L.) and tomato (*Solanum lycopersicum* L.) fertilized at different nitrogen rates. The above mentioned ground data collected with Cropscan MSR16R system (CROPSCAN Inc., Rochester, USA), ASD FieldSpec, AccuPAR LP-80 Ceptometer (Decagon Devices Inc., Pullman Washington, USA) and SPAD 502 Plus Chlorophyll Meter (Specialty Products Agricultural Division, Minolta Corporation), respectively, were compared with the available Sentinel-2 optical data acquired over the investigated experimental plots located in Emiglia-Romagna region (Italy). In addition, the crop productivity and yield was also assessed in order to determine the optimal N and water fertilization doses.

Keywords: precision agriculture, water and nitrogen management, Sentinel-2, run time calibration model,
Parole chiave: agricoltura di precisione, gestione dell'acqua e dell'azoto, Sentinel-2, calibrazione run time

Introduction
Il monitoraggio aziendale e territoriale è attualmente affidato al soggettivismo di un tecnico. Essendo presupposto fondamentale per la gestione efficace e sostenibile dell'agroecosistema, è auspicabile che tale monitoraggio venga effettuato attraverso l'impiego di tecnologie innovative e di precisione a servizio del coltivatore. L'utilizzo di sensoristica remota o a terra potrebbe rappresentare in questo senso un salto qualitativo in termini di accuratezza, tempestività ed estensione del dato rilevato. In questo quadro di costante e continua innovazione, il telerilevamento si inserisce come strumento essenziale per l'identificazione in campo di zone che richiedono una gestione differenziata degli input colturali.
Il presente lavoro si inserisce all'interno del progetto POR-FESR della Regione Emilia Romagna "MoRe Farming".
Scopo ultimo del progetto è quello di fornire all'utente finale uno strumento integrato di raccolta e gestione di dati in grado di supportare le decisioni in merito a concimazione azotata e gestione degli interventi irrigui, promuovendo tecniche di coltivazione più sostenibili.
Una piattaforma software sviluppata nell'ambiente Scilab è stata utilizzata per simulare la crescita e la produzione delle colture utilizzate nei campi sperimentali (mais e pomodoro). Tale piattaforma avrà accesso ai dati telerilevati da satellite e utilizzerà gli stessi per operare un processo di *run-tme calibration* (Jongschaap 2006), ovvero la calibrazione in tempo reale di parametri precedentemente simulati. A partire dell'autunno 2015, infatti, l'Agenzia Spaziale Europea (ESA) rende disponibili i dati multispettrali del visibile (VIS), infrarosso vicino (NIR) e medio (SWIR) raccolti dal satellite Sentinel-2. Un secondo satellite, Sentinel-2b, è stato lanciato in orbita nella primavera 2017 per garantire una copertura globale delle immagini telerilevate sia in termini spaziali che temporali. I dati multispettrali di Sentinel sono alla base del calcolo di indici di vegetazione, alcuni dei quali sensibili al contenuto in azoto di una coltura e al suo stato idrico (Clevers et al., 2013). Gli indici di vegetazione calcolati in campo attraverso misure di proximate sensing saranno confrontati con quelli calcolati a partire da immagine telerilevate e saranno utilizzati per la calibrazione iniziale del modello.

Materials and Methods

SVILUPPO DEL MODELLO

Per simulare la crescita e la produzione delle colture utilizzate nei campi sperimentali è stata utilizzata una piattaforma software sviluppata nell'ambiente Scilab. Questo è un ambiente di programmazione associato a una ricca raccolta di algoritmi numerici che coprono molti aspetti di calcolo scientifico e la gestione di grossi dataset. La piattaforma, denominata AgriSERV, è stata progettata per mantenere e gestire ampie serie storiche di dati climatici e diverse situazioni ambientali caricate su database MySQL (free software relational database). Attualmente, le tabelle del database includono informazioni sui suoli (servizi ambientali regionali) e le serie meteorologiche. AgriSERV comprende diversi modelli di simulazione colturale che possono essere utilizzati per diverse finalità. Nel caso specifico di Mo.Re.Farming, viste le numerose implicazioni di tipo fisiologico previste nella sperimentazione, è stato utilizzato il simulatore di crescita delle colture Gecros (Yin e van Laar, 2005) che affronta i più importanti processi fisiologici delle colture attraverso una solida base meccanicistica.

Al contrario di molti simulatori generici (es CropSyst), Gecros, attraverso una oculata parametrizzazione, permette di catturare alcuni caratteri specifici delle risposte genotipiche all'ambiente. Il meccanismo è basato su descrizioni quantitative di tratti complessi legati alla fenologia, allo sviluppo del sistema radicale, alla fotosintesi, alla conduttività stomatica ed allo 'stay green' della coltura. Il modello può generare osservazioni fisiologiche, come ad esempio l'acclimatazione fotosintetica a CO_2 elevata (Xu et al., 1994).

ATTIVITA' DI CAMPO

Per la calibrazione del modello sono state condotte delle prove sperimentali in campo presso l'azienda agricola Losi di Ivaccari di Piacenza (44°59'N, 9°44'E) e presso l'azienda agricola V. Tadini di Gariga di Podenzano (44°58'N, 9°41'E). Per entrambe le colture, mais e pomodoro, sono state eseguite due epoche si semina, o trapianto, al fine di creare una variabilità intra-appezzamento. La variabilità intra-appezzamento è stata ulteriormente esacerbata dall'impiego di tre differenti dosi di azoto (N0, N1 = 100 kg N ha^{-1} e N2= 300 kg N ha^{-1}).

Fenologia, altezza, concentrazione della clorofilla (SPAD e lettura spettrofotometrica), LAI, misure spettroradiometriche sono state eseguite ogni settimana in mais e pomodoro e delle raccolte distruttive per la determinazione della biomassa, LAI e concentrazione di clorofilla e azoto, sono state previste durante la stagione colturale.

Results and Discussion

I dati meteo reali e previsionali, insieme a dati fisio-fenologici a disposizione sui genotipi di mais e pomodoro utilizzati per la sperimentazione, sono stati utilizzati per la calibrazione del modello e per generare le prime simulazioni (Fig.1). In Fig.1 è riportato l'andamento del LAI di mais per la prima (linee continue) e la seconda semina (linee tratteggiate). Risulta evidente come la concimazione azotata sia decisiva per il raggiungimento di un determinato valore di LAI. I dati collezionati durante i primi rilievi sembrano confermare le simulazioni ottenute. La simulazione ottenuta per N0 sembra sottostimare il valore reale di LAI. Così come sembra sottostimato il valore di LAI relativo alla seconda semina.

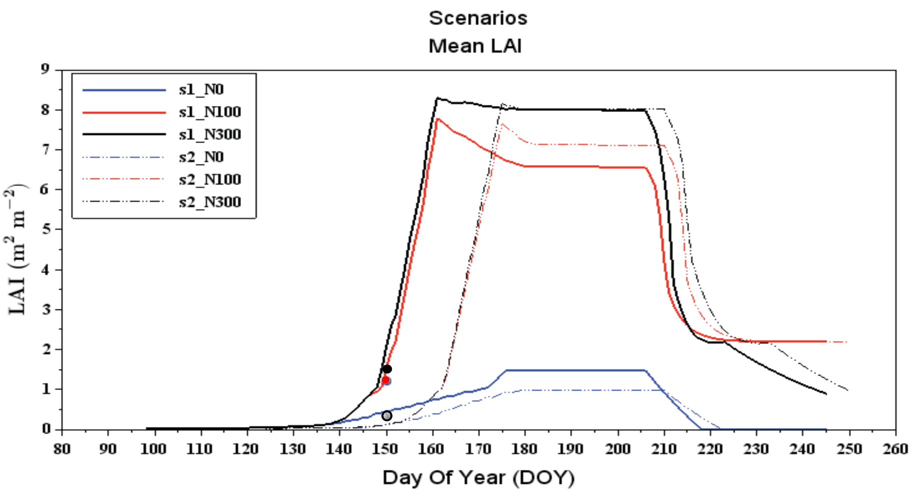


Fig. 1: Simulated mean LAI of 6 different scenarios. Continuous lines represent first sowing date whilst dotted lines represent the second one. Different colours stand for different nitrogen inputs: blu=0 kg N ha^{-1}, red= 100 kg N ha^{-1}, black= 300 kg N ha^{-1}. Points represent observed data. In the second sowing date all points are still overlapped.

Fig. 1: Simulazione di LAI medio per 6 differenti scenari. Le linee continue rappresentano la prima data di semina, mentre quelle tratteggiate la seconda. I differenti colori indicano differenti dosi azotate: blu= 0 kg N ha^{-1}, rosso = 100 kg N ha^{-1}, nero = 300 kg N ha^{-1}. I punti rappresentano i dati osservati. Nella seconda data di semina sono ancora tutti sovrapposti.

Attraverso l'impiego delle immagini multispettrali fornite da Sentinel-2 e quelle rilevate a terra, sarà possibile calibrare il modello per una lettura ed interpretazione automatizzata del dato multispettrale, riuscendo ad ottenere in tempo reale risposte circa lo stato nutrizionale della coltura, e quindi attuare un intervento tempestivo e mirato ad una specifica zona dell'appezzamento.

Conclusions

Senza dubbio ulteriori misurazioni, più accurate simulazioni e l'integrazione nel modello dei dati telerilevati e dei dati meteo previsionali, potranno portare allo sviluppo di una piattaforma integrata interrogabile dall'utente finale, in grado di supportare le decisioni aziendali e favorire un utilizzo sostenibile delle risorse.

References

Jongschaap E, 2006. Run-time calibration of simulation models by integrating remote sensing estimates of leaf area index and canopy nitrogen, European Journal of Agronomy, 24: 316-324.

Clevers JGPW and Gitelson AA, 2013. Remote estimation of crop and grass chlorophyll and nitrogen content using red-edge bands on Sentinel-2 and -3, International Journal of Applied Earth Observation and Geoinformation, 23:344-351.

Yin X, Van Laar HH, 2005. Crop system dynamics an ecophysiological simulation model for genotype-by-environment interactions, Wageningen Academic Pubblishers, The Netherlands.

Xu DQ, Gifford RM, Chow WS, 1994. Photosynthetic acclimation in pea and soybean to high atmospheric CO, partial pressure. Plant Physiology, 106:661-671

COUPLING REMOTE SENSING AND MODELING APPROACH FOR OPTIMIZING INPUT MANAGEMENT IN A TYPICAL MEDITERRANEAN CROPPING SYSTEM

REMOTE SENSING E MODELLISTICA PER OTTIMIZZARE LA GESTIONE DEGLI INPUT IN UN TIPICO SISTEMA COLTURALE MEDITERRANEO

Claudia Di Bene[1*], Silvia Vanino[2], Pasquale Nino[2], Enrico Anzano[3], Melania Migliore[1], Roberta Farina[1], Bruno Pennelli[1], Stefano Fabiani[2], Guido D'Urso[3], Alessandro Marchetti[1], Chiara Piccini[1], Carlo De Michele[3], Stefano Canali[1], Fabio Tittarelli[1], Rosario Napoli[1]

[1] Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Centro Agricoltura e Ambiente (CREA-AA), via della Navicella 2-4, 00184 Roma
[2] Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Centro Politiche e Bioeconomia (CREA-PB), via Po 14, 00198 Roma
[3] ARIESPACE s.r.l., Centro Direzionale IS A3, 80143 Napoli
[*]claudia.dibene@crea.gov.it

Abstract
The efficient use of resources is a priority for sustainable agriculture. FATIMA-H2020 project aims at developing innovative farming tools for nutrients and water management, in intensive farming systems. In an Italian farm trial, it was carried out a 2-yr durum wheat (*Triticum durum* Desf. var. Iride) - tomato (*Solanum lycopersicum* L. var. Vulcano) rotation, with the following issues: providing remote sensing derived products for monitoring crop status, using EPIC model to simulate plant growth, and proposing fertilizer management to improve the N use efficiency. The spectral indexes assessed by remote sensing were validated with proximal sensing measure, showing to describe accurately nitrogen status of the crop in the field. Moreover, EPIC model, validated in the area, was used to fill the gap between successive remote sensing measures. Our findings indicate that coupling EPIC model with remote sensing results in a valid decision support tool to address wheat nitrogen demand, while further investigation are needed to applied it on tomato nitrogen management.

Keywords: sustainable agriculture; remote sensing; EPIC model; nitrogen leaching; water use efficiency; compost; cover crops.
Parole chiave: agricoltura sostenibile; remote sensing; modello EPIC; lisciviazione dell'azoto; efficienza d'uso dell'acqua; compost; colture da sovescio.

Introduction

The efficient use of resources is a key priority for sustainable agriculture. EU policies are encouraging farm practices and adoption of new technologies that increase productivity, sustainability and resilience of agricultural systems. Precision farming is a management practice based on the development of information technologies, ground sensors and remote sensing. Its aim is to optimize yields through systematic gathering and handling of data about crops and fields and to tailor input use according to effective needs. Usually, intensive agriculture depends on high fertilization and irrigation input, and N supply often exceeds crop requirements. The N surplus gives rise to NO_3^- leaching and consequent groundwater pollution, particularly serious in Mediterranean semi-arid countries (Daudén et al., 2004; Trindade et al., 2009) where substantial N loss occurs during the rainy period in winter and after irrigation practice in summer.
In this framework, FATIMA-HORIZON 2020 project (http://fatima-h2020.eu/), financed by the EU Commission, aims at developing innovative farming tools for external nutrient input and water management, in intensive farming systems. FATIMA project integrates agri-environmental, socio-economic, and political issues with the objective to bridge sustainable crop production and fair economic competitiveness. In this paper, preliminary results from the Italian pilot case study carried out in the Nitrate Vulnerable Zone (NVZ) of Tarquinia irrigation district (Lazio Region) are presented. An experimental trial was carried out in a farm cultivated with a 2-yr durum wheat (*Triticum durum* Desf. var. Iride) - processing tomato (*Solanum lycopersicum* L. var. Vulcano) rotation, addressing the following issues: (1) provide remote sensing derived products for monitoring crop status, (2) assessment of EPIC model prediction performance in improving the cropping system sustainability in the short- and long-term, and (3) proposal of alternative fertilizing management to improve the N use efficiency in the Mediterranean conditions.

Materials and Methods

<u>*Site description and experimental set-up*</u>: The Italian pilot case study was set-up in a private farm (20 ha) located in the Viterbo Province coastal plain, 7 km Northwest part of the Tarquinia town, and almost 3 km from seashore (western Central Italy; 42° 69' N lat and 11° 69' E long; 25 m a.s.l.; 3% mean slope) (Figure 1). Intensive agriculture is the prevalent land use, characterized by rainfed winter cereals and irrigated summer horticultural crops. The management is characterized by an excess of synthetic N fertilizer application, coupled with high water consumption in summer crops, directly contributing to the groundwater pollution. The climate was typically Mediterranean with warm and dry summers,

and the rainy seasons are autumn (October-December) and spring (March-April). The soil, classified as *Typic Haploxeroll* by FAO system (WRB, 2014), has a loamy texture.
The field experiment started in autumn 2015 and was carried out in a total area of about 3 ha, conventionally cultivated with a durum wheat (*Triticum durum* Desf. var. Iride) - processing tomato (*Solanum lycopersicum* L. var. Vulcano) rotation. The field was splitted in two different plots (A and B) to test the effects, across space and time, of alternative N fertilization methods (synthetic and organic) on crop yield and agri-environmental quality – e.g. the reduction of nitrate leaching. A comparison with the conventional management used as control was performed (Tables 1a,b).

Figure 1. Localization of the Pilot area (left) and the experimental Farm (right with yellow border).
Figura 1. Localizzazione dell'area pilota (sinistra) e confini aziendali (destra, linea gialla).

Table 1a. Nitrogen fertilization management in Durum wheat trials.
Tabella 1a. Fertilizzazione azotata nei campi di Frumento duro.

Treatment	**Time**	**Type**	**N%** *(w/w)*	**N** *(Kg/ha)*
SYN	Sowing	NP	18	40
	Top dressing 1	$NH_4^+ NO^{3-}$	26	52
	Top dressing 2	$NH_4^+ NO^{3-}$	26	39
	Total			**131**
ORG	Sowing	Poultry manure	3	**131**

Table 1b. Nitrogen fertilization management in processing tomato trials.
Tabella 1b. Fertilizzazione azotata nei campi di Pomodoro.

Treatment	**Time**	**Type**	**N%** *(w/w)*	**Quantity** *kg/ha (ss)*	**N** *(Kg/ha)*
SYN	Transplanting	Fertilizer	15.0	200	30
	Top dressing 1	Fertilizer	12.0	600	72
	Top dressing 2	Fertigation	-	-	30
	Total				**132**
ORG	Transplanting 1	Horse bean green manure	3.1	7260	226
	Transplanting 2	Green residues compost	1.6	6380	102
	Top 1	Fertilizer	12.0	600	72
	Top 2	Fertigation	-	-	30
	Total				**430**

Data collection: During the growing season the following data were collected in both experimental plots:

- canopy chlorophyll, indirectly determined with the use of the MC-100 Apogee Chlorophyll Concentration meter (Apogee Instruments, 2016);
- total soil and crop N concentration, analysed by automated combustion method (Nitrogen/protein FP628-LECO; LECO Corporation, St. Joseph, MI, USA);
- canopy reflectance, measured by a FIELD SPEC instrument - hand-held hyperspectral radiometer - then used to calibrate Sentinel-2 satellite imagery;
- Leaf Area Index (LAI), measured by a portable LICOR LAI 2000 Plant Canopy Analyser;
- crop water information, obtained by Sentinel-2 satellite images and water meter in the field;
- soil temperature and moisture, measured continuously using field sensors up to 90 cm depth;

- water soil characteristichs, measured by Richards apparatus in the top layer;
- soil mineral N (NO_3^- and NH_4^+) and total organic carbon (TOC). Nitrogen forms were determined colorimetrically in the eluate by continuous flux analyser (Autoanalyser Technicon II, AxFlow S.p.A., Milan, Italy), while TOC was measured using Carbon RC612-LECO (LECO Corporation, St. Joseph, MI, USA);
- Crop biomass component (yield and residues), measured at harvest.

The methodology applied to monitor the N status of wheat is based on calculation of different chlorophyll satellite-based spectral indexes and the correlation between canopy chlorophyll and leaf N content field measurements. The methodology used to calculate Crop Water Requirement (CWR) for processing tomatoes, adapted to remote sensing data, is based on the approach proposed by FAO (http://www.fao.org/docrep/X0490E/X0490E00.htm). Crop parameters (mainly albedo and LAI) were derived from Sentinel-2 images collected during the growing season.

Model simulation: EPIC model v.0810 (Williams, 1995) was used to simulate crop yield of the tested crop rotation. The model was calibrated using site soil and weather data, and management information. Daily weather data were derived from a 20 km x 20 km cell grid-based climate dataset available from the Joint Research Centre (http://mars.jrc.ec.europa.eu/mars/About-us/AGRI4CAST), for the interval 2000–2016 and validated with locally observed data. The actual soil physical and chemical characteristic (including the hydraulic properties) were used as inputs in the EPIC model. The model was calibrated for the crops yield and ground water table dynamics. For each crop and treatment, a total of 10 yield observations were available yearly.

Nitrogen use efficiency and nutrition index: Nitrogen use efficiency (NUE) was calculated according to Dobermann et al. (2007). Nitrogen Nutrition Index (NNI) was calculated according to Lemaire et al. (2008) by the ratio between actual crop N uptake and critical N uptake. NNI is based on the combined use of: (i) EPIC model to derive the relationship between the Leaf Area Index (LAI) and the total crop biomass, and (ii) Sentinel-2 spectral indices in the red-edge region to estimate canopy chlorophyll content and LAI.

Results and discussion

WHEAT YIELD AND N STATUS: In 2016, wheat yield under SYN (control) and ORG (alternative) treatment was 6.79 and 4.34 Mg ha^{-1}, respectively with a NUE of 1.1 and 0.6, respectively. The worse performance of ORG is probably due to the scarce availability of N from organic fertilizer. The comparison between measured and simulated wheat yield data showed that EPIC model accurately discriminates between SYN and ORG treatment (6.09 and 4.13 Mg ha^{-1}, respectively). The results of N status confirmed the presence of significant correlation ($p<0.01$) between spectral indexes derived from Sentinel-2 and the canopy chlorophyll content, and consequently N content, as confirmed by comparison between MC-100 readings and LECO data, and were good predictors of yields. As regards NNI value, a N deficiency and an over-fertilization were detected in February and March respectively, while a substantial balance was observed in May.

TOMATO YIELD, N STATUS AND CROP WATER REQUIREMENT: In 2016, tomato yield under SYN (control) and ORG (alternative) treatment was 104.94 and 69.96 Mg ha^{-1}, respectively with a NUE of 2 and 0.4, respectively. Also for tomato, there was a lower availability of N in ORG treatment as accurately predicted by EPIC model (99.42 and 63.43 Mg ha^{-1}, in SYN and ORG, respectively). Instead NNI value showed a consistently excessive fertilization both at the beginning and at the end of the growing season. Therefore, additional investigation is needed to infer from remote spectral data the N status of tomato. The potential evapotranspiration results obtained from the analysis of satellite data showed that the tomato in the field area was 2690 m^3 ha^{-1} during the period 12/6/2016 - 7/8/2016, when micro-irrigation was applied. Data from the water meter in the field showed that in the same period 2761 m^3 ha^{-1} of water were applied. Considering the whole tomato growing season, the ETp derived from remote sensing data is about 3150 m^3 ha^{-1}, while the total water supplied with sprinkler and micro-irrigation is about 3700 m^3 ha^{-1}. This data confirmed the goodness of remote sensing calculation of ETp and highlighted an inefficient water management at farm level.

Conclusions

Our findings indicate that coupling EPIC model with remote sensing ends-up is a valid decision support tool to address wheat nitrogen demand, while further investigation are needed to apply it on tomato nitrogen management.

References

Daudén, A., Quílez, D., Vera, M.V. 2009. Pig slurry application and irrigation effects on nitrate leaching in Mediterranean soil lysimeters. J. Environ. Qual. 2004, 33, 2290–2295.

Dobermann, A. 2007. Nutrient use efficiency-Measurement and management. In Fertilizer Best Management Practices; IFA International Workshop on Fertilizer Best Management Practices (FBMPs): Brussels, Belgium, 1-28 pp.

Trindade, H., Coutinho, J., Jarvis, S., Moreira, N. 2009. Effects of different rates and timing of application of nitrogen as slurry and mineral fertilizer on yield of herbage and nitrate-leaching potential of a maize/Italian ryegrass cropping system in north-west Portugal. Grass Forage Sci. 64, 2–11.

Williams, J.R., 1995. The EPIC model. In: Singh, V.P. (Ed.), Computer Models of Watershed Hydrology. Water Resources Publications, Highlands Ranch, pp. 909–1000

WRB, 2014. World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome, Italy.

BIOGAS AND SEQUENTIAL CROPPING: A SUSTAINABLE DEVELOPMENT IN AGRICULTURE

BIOGAS E SISTEMI COLTURALI SEQUENZIALI: UNO SVILUPPO AGRICOLO SOSTENIBILE

Guido Bezzi[1*], Paolo Mantovi[2], Lorella Rossi[1], Ernesto Folli[3]

[1] CIB – Consorzio Italiano Biogas e Gassificazione, via Albert Einstein, loc. C.na Codazza, 26900 Lodi (LO)
[2] CRPA s.p.a. – Centro Ricerche Produzioni Animali s.p.a., Viale Timavo 43/2, 42121 Reggio Emilia (RE)
[3] Az. Agr. Palazzetto, Via Pasquale Folli, 2, 26023 Zanengo (CR)
*agronomia@consorziobiogas.it

Abstract

In order to achieve safe environmental targets (COP21), each sector has to reduce its emissions. Agriculture can have a huge potential to contribute on safe environment if it will be able to introduce efficient and conservative agronomic systems based on circular integration of productions. In this way, it will be possible to improve productivity with a sustainable use of natural resources, recycling nutrients and valorise sub-products. Biogasdoneright® is an integrated circular production model based on the integration of biogas plant on farm, efficient use of digestate and introduction of sequential cropping. This model is already applied in some Italian farms and it contributes to improve productivity, maintain food, feed and bioenergy production and reduce their environmental impact. In this work it is analysed a real case study in Po Valley in order to demonstrate positive impacts of Biogasdoneright® on soil fertility, productivity, low ILUC risk biomass production, low carbon foot print of biomethane productions and economic feasibility of sequential cropping.

Keywords: biogas; ILUC; additional biomass; agronomic systems; sequential cropping; soil organic matter.
Parole chiave: biogas; ILUC; biomasse addizionali; sistemi agronomici; colture sequenziali; sostanza organica nel suolo.

Introduction

Efficienza e sostenibilità delle produzioni sono due temi di stretta attualità poiché correlati alla necessità di ridurre gli impatti ambientali antropici in accordo con i recenti accordi sul clima (COP21). Il settore agricolo, oggi responsabile del 12% delle emissioni globali, è chiamato a rispondere alla sfida di soddisfare la domanda crescente di produzione diminuendo, allo stesso tempo, il suo impatto ambientale. Il raggiungimento di questo obiettivo sarà funzione della capacità di introdurre sistemi di gestione agronomica efficienti, conservativi e basati sull'integrazione e circolarità dei cicli produttivi. In questa maniera sarà possibile preservare le risorse naturali ottimizzandone l'utilizzo.

Un esempio concreto di fattibilità dell'integrazione sostenibile di filiere produttive in agricoltura è quello offerto dallo sviluppo del biogas in Italia. In particolare, negli ultimi anni, diverse aziende agricole hanno saputo integrare l'impianto biogas con un sistema colturale avanzato e conservativo che permette di sostenere sia la produzione alimentare sia quella energetica aumentando la produttività aziendale in maniera sostenibile. Tale modello, denominato Biogasdoneright®, si basa su un sistema di produzione agricola circolare, in cui l'impianto biogas è il fulcro di valorizzazione di biomasse, scarti e sottoprodotti aziendali (Dale et. al, 2016). L'utilizzo efficiente del digestato da digestione anaerobica, quale importante vettore di riciclo della sostanza organica e nutrienti al terreno, e l'introduzione di avvicendamenti sequenziali (un raccolto per alimento e un raccolto per energia nello stesso anno) gestite con tecnologie avanzate (minime lavorazioni, strip-tillage, e semina su sodo accoppiate con la distribuzione del digestato) completano il sistema.

Il Biogasdoneright®, quindi, si differenzia dal modello produttivo del biogas tradizionale stimolando uno sviluppo concreto dei sistemi produttivi agricoli. In questo modo l'azienda agricola può produrre in maniera sostenibile nello stesso anno colture tradizionali e biomassa con un aumento sostanziale della capacità fotosintetica rispetto all'avvicendamento monocolturale. Inoltre, grazie all'adozione di tecniche conservative e al ritorno della sostanza organica nel suolo può migliorarne la fertilità (Bezzi et. al., 2016), ridurre le perdite per dilavamento ed erosione e ridurre l'apporto di fattori produttivi (es.: fertilizzanti) con un impatto positivo sia sulla biodiversità dell'agro-ecosistema che sulla riduzione delle emissioni complessive (Dale et. al, 2016, Valli et al. 2017).

In questo lavoro, basato sull'analisi di un caso studio reale in Pianura Padana, vengono quantificati gli effetti agronomici, ambientali ed economici dell'applicazione del modello Biogasdoneright® con sistema colturale sequenziale a confronto con la conduzione ordinaria dell'azienda agricola.

Materials and Methods

L'analisi è stata realizzata mediante l'elaborazione e analisi di dati storici e reali raccolti direttamente nell'azienda agricola Palazzetto di Zanengo (CR) (45°12'56" N; 9°50'58" E, 54 m s.l.m.) costituita da circa 250ha di terreno coltivabile, un allevamento di 650 vacche da latte (di cui 300 in lattazione) e un impianto biogas installato da 1MWe.

Nella fattispecie, tutte le rilevazioni dello studio sono state realizzate su 3 appezzamenti rappresentativi dell'azienda (Chiappa Grassa, C. Nuovo e Cornaletta) e più in generale della pianura Cremonese. Il periodo di riferimento dello studio è stato compreso fra il 2005 (rilevazioni storiche e precedenti l'introduzione del Biogasdoneright®) e il 2013 – 2016 (rilevazioni con Biogasdoneright® consolidato).
Ai fini dell'analisi, per ogni appezzamento e per ogni annata sono stati raccolti ed analizzati i seguenti parametri:

- VALUTAZIONE DEL RISCHIO ILUC: confronto fra le produzioni storiche delle colture tradizionali e la produttività attuale sia in termini di t/ha che in termini di Unità Foraggere (UF/ha);
- FERTILITA' DEL SUOLO: analisi ripetute del terreno negli anni per la valutazione dell'andamento dei principali fattori di fertilità con l'adozione della coltura sequenziale;
- IMPRONTA DEL CARBONIO DELLA PRODUZIONE BIOMETANO: elaborazione dei dati aziendali per l'analisi LCA con applicativo SimaPRO;
- SOSTENIBILITA' ECONOMICA: analisi e confronto dei costi produttivi sostenuti con il sistema tradizionale e dopo l'introduzione della coltura sequenziale.

Results and Discussion

VALUTAZIONE DEL RISCHIO ILUC

Gli andamenti relativi al confronto tra la produttività storica aziendale e la produttività aggiuntiva ottenuta applicando Biogasdoneright®, sono risultati sostanzialmente simili come si vede in Figura 1.

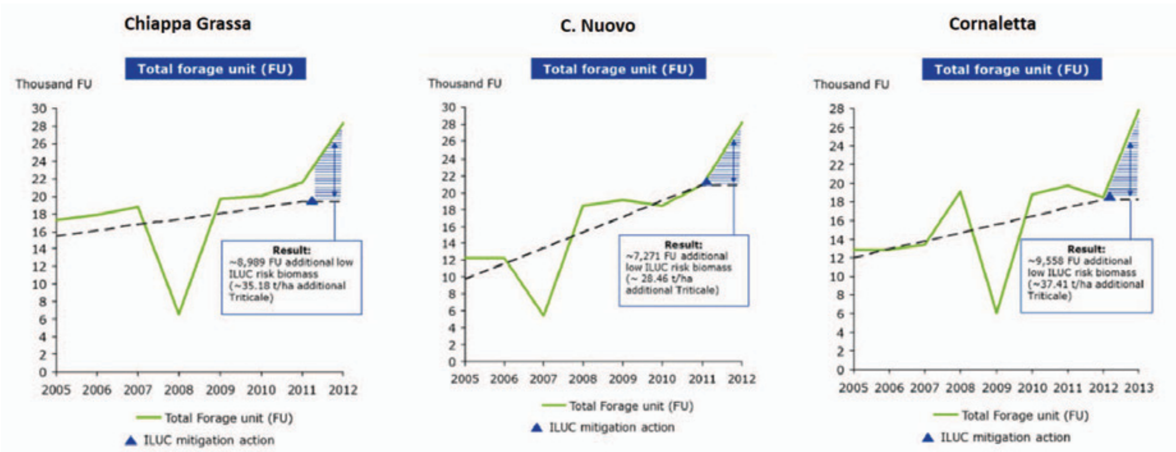


Fig. 1: Historical production trend and additional production with Biogasdoneright® in terms of Forage Unit (UF) in each study fields..
Fig. 1: Andamento produttivo storico e produzione addizionale con l'adozione di Biogasdoneright® in termini di Unità Foraggere (UF) in ognuno dei tre terreni studio.

Con l'adozione di Biogasdoneright® e l'applicazione di avvicendamenti sequenziali (doppia coltura), è stato possibile ottenere un incremento di produttività, rispetto alla conduzione tradizionale, compreso fra 28,46 t ha^{-1} ovvero 7,27 UF dell'appezzamento C.Nuovo e 37,41 t ha^{-1} ovvero 9.56 UF dell'appezzamento Cornaletto.
In tutti i casi analizzati, l'incremento produttivo è stato realizzato grazie all'introduzione di una coltura di triticale prima del mais tradizionale che ha permesso l'ottenimento di biomassa addizionale. Tali dati dimostrano come con l'avvicendamento sequenziale sia possibile aumentare la produttività aziendale ottenendo biomassa a basso rischio ILUC poiché ottenuta mantenendo la coltura principale sullo stesso terreno.

FERTILITÀ DEL SUOLO E AVVICENDAMENTO SEQUENZIALE

Tra i principali fattori di fertilità del suolo analizzati durante l'applicazione dell'avvicendamento sequenziale si riportano i risultati di contenuto di sostanza organica.
Grazie all'applicazione continua del digestato abbinato a tecniche di lavorazione conservativa (minime lavorazioni, strip-tillage e semina su sodo) e alla continua copertura del terreno offerta dalla doppia coltura, è stato possibile ottenere un incremento del contenuto di sostanza organica nel terreno. Nella fattispecie nel periodo compreso dal 2009 al 2016 gli appezzamenti C. Nuovo e Cornaletto hanno mostrato un incremento di 0,5% di sostanza organica (da 2,5% a 3%) mentre su Chiappa Grassa si è misurato un incremento di 0,1% di sostanza organica (da 2,9 a 3%). Tali dati dimostrano come, con l'apporto continuo di digestato, sia stato possibile migliorare un aspetto fondamentale della fertilità del suolo solo con un'azione mirata a migliorare l'efficienza dei processi dinamici di immobilizzazione del carbonio del terreno. Con

l'aumento della sostanza organica, inoltre, si è aumentata la resilienza e la biodiversità con un effetto ambientale complessivo di tutto rilievo.

IMPRONTA DEL CARBONIO NELLA PRODUZIONE DI BIOMETANO

Dall'analisi dell'impronta del carbonio è stato possibile notare come, in comparazione con le emissioni medie della produzione di combustibili fossili, la produzione di biometano con sistema tradizionale (monocoltura + reflui) emetta il 79% in meno. Ancora minori sono risultate le emissioni di CO_2 nel caso venga applicato il modello Biogasdoneright® con colture sequenziali (-86,5%) (Fig. 2).

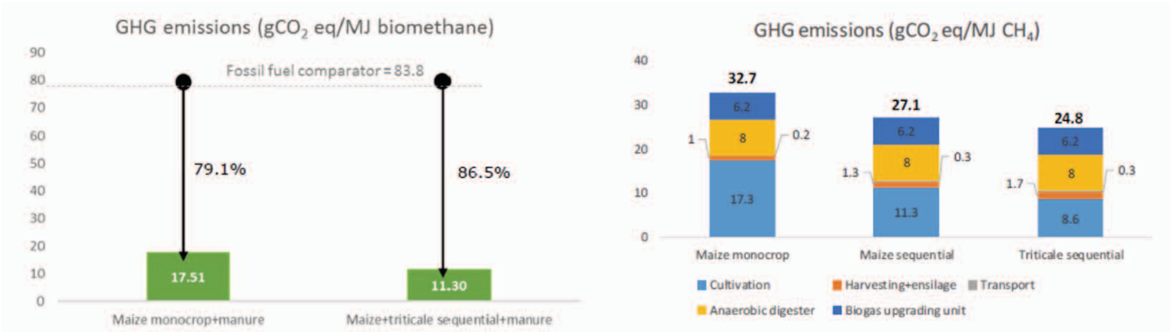


Fig. 2: On left, biomethane GHG emission save with use of maize and manure or double crop and manure.On right, step of factors of GHG emission for monocrop or double crop..

Fig. 2: A sinistra, riduzione di emissioni di CO_2 nella produzione di biometano con mais e reflui e doppia coltura e reflui. A destra misura dei vari fattori di emissione di CO_2 per singola e doppia coltura.

Per quanto riguarda l'apporto dei vari fattori di emissione, si può notare che in tutti i casi il fattore con maggiore impatto sia risultata la fase di coltivazione. Tuttavia, in ogni caso, a parità di coltura (mais) si può notare come la tecnica tradizionale incida maggiormente in termini di emissioni per la produzione di biometano rispetto a quando coltivata in sistema sequenziale (32,7 gCO_2 eq/MJ CH_4 rispetto a 27,1 gCO_2 eq/MJ CH_4).

SOSTENIBILITÀ ECONOMICA

Dai risultati ottenuti dall'analisi dei costi reali di coltivazione in azienda, il costo della coltivazione tradizionale a mais risulta mediamente inferiore di circa 400 € ha^{-1} rispetto al costo complessivo della doppia coltura (triticale + mais). A fronte dell'aumento di costi per la doppia coltura, si registra una maggior resa a ettaro media pari a circa 13 t ha^{-1} di s.s. (33 t ha^{-1} della doppia coltura contro 20 t ha^{-1} della coltura tradizionale) pari a un incremento medio di circa 10.000 UF ha^{-1}.

Ne consegue che, in termini di costi relativi, con la doppia coltura è stato possibile ottenere una riduzione di costi per l'alimentazione degli animali pari al 21% rispetto alla coltura tradizionale e una riduzione di costi per l'alimentazione del biogas pari al 42%.

Conclusions

I risultati ottenuti danno indicazioni positive e analoghe per tutti gli appezzamenti studio considerati. Tale valutazione è di rilievo considerando che le misurazioni e le elaborazioni sono state eseguite su scala reale. Il modello Biogasdoneright®, quindi, permette di produrre un raccolto per il mercato e un raccolto per il digestore nello stesso anno in maniera efficiente e sostenibile. Ciò significa che una quantità significativa di biomassa da destinare alla produzione di energia viene prodotta con un basso rischio ILUC (Indirect Land Use Change- cambio di destinazione dei suoli), dato che il carbonio per il digestore è addizionale rispetto a quello che si produce con una monocoltura coltivata in modo convenzionale.

Inoltre, lo studio mostra come nell´azienda agricola che pratica il Biogasdoneright® migliori la qualità del suolo cosi come aumenta il suo contenuto di nutrienti e biodiversità. Allo stesso tempo, mantenere il suolo coperto tutto l´anno rispetto alla situazione precedente ha effetti sicuramente positivi su fenomeni erosivi, il dilavamento dei nutrienti e dei nitrati, con un impatto complessivamente positivo sull´ambiente. L'impatto ambientale complessivo della produzione di biometano, infine, risulta avere un'impronta carbonica molto migliore rispetto ai combustibili tradizionali e, più in generale, rispetto al biogas tradizionale.

In conclusione, quindi, si può affermare che il Biogasdoneright® sia un modello produttivo capace di aumentare la capacità produttiva dell'azienda agricola rendendola più efficiente, sostenibile e a ridotta impronta di carbonio.

References

Valli L. et al., 2017 in pub. Greenhouse gas emissions of electricity and biomethane produced using the Biogasdoneright™ system: four case studies from Italy - Accepted for publication on Biofuels, Bioproducts & Biorefining.

Dale B. et al., 2016. Biogasdoneright™: An innovative new system is commercialized in Italy. Biofuels, Bioprod. Bioref. 10:341–345 (2016); DOI: 10.1002/bbb.

Bezzi G. et. al., 2016. BiogasDoneRight® model: soil carbon sequestration and efficiency in agriculture. Proceedings of European Biomass Conference EUBCE, Amsterdam 9 June 2016, pp. 1387-1389.

Peters D. et al., 2016. ECOFYS report - Assessing the case for sequential cropping to produce low ILUC risk biomethane. https://www.consorziobiogas.it/wpcontent/uploads/2017/02/Ecofys_Assessing-the-benefits-ofsequential-cropping-for-CIB_Final-report.pdf.

Acknowledgments
Lo studio qui esposto è stato validato da ECOFYS, società di consulenza olandese leader nell'energia rinnovabile, nell'efficienza energetica e nel carbonio, nei sistemi e nei mercati energetici e nella politica energetica e climatica per la Commissione Europea.

NITROGEN FERTILIZER REPLACEMENT VALUE AND RESIDUAL EFFECTS OF UNDIGESTED SLURRY AND DIGESTATES APPLIED TO SILAGE MAIZE

VALORE FERTILIZZANTE EQUIVALENTE DELL'AZOTO ED EFFETTI RESIDUI DI UN LIQUAME E DI DIGESTATI APPLICATI AL MAIS DA TRINCIATO

Daniele Cavalli[1*], Giovanni Cabassi[2], Lamberto Borrelli[2], Luigi Degano[2], Luca Bechini[1], Pietro Marino Gallina[1]

[1] Dipartimento di Scienze Agrarie ed Ambientali, Università degli Studi di Milano, Via Celoria 2, 20133, Milano
[2] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria – CREA ZA, Lodi, Italia

*daniele.cavalli@unimi.it

Abstract

Animal manures can be suitable nitrogen (N) fertilizers if crop N uptake is maximized, and air and water pollution are avoided. Literature review suggested that short-term net mineralization of manure organic N is low. Conversely long-term supply of manure N to crops depends on the (re)mineralization of previously added N (*i.e.* on residual N effects). Thus, in-season N availability of manure N often equals the mineral N content of the manure.

In 2011 we started a field experiment to test this hypothesis for digestates applied to silage maize followed by unfertilized Italian ryegrass. In 2015, after four years of repeated manure additions, the experiment was modified because we interrupted fertilization to study residual N effects of manures on silage maize growth. Results of the year 2014 confirmed the experimental hypothesis for all manures. However, for the solid fraction of the digestate, repeated manure additions were required to satisfy such a relation. Indeed, residual N effects for the solid fraction were clearly evident on both Italian ryegrass and on maize in 2015, and contributed to reduce within year net N immobilization.

Keywords: animal manure, apparent nitrogen recovery; mineralization; immobilization; anaerobic digestion.
Parole chiave: effluenti zootecnici; recupero apparente dell'azoto; mineralizzazione; immobilizzazione; digestione anaerobica.

Introduction

Animal manures contain nitrogen (N) in both organic and mineral forms. Mineral N is readily available for crops, and is mostly responsible for short-term N effects, while organic N contributes to long-term fertilization and to residual fertilizer effects (Gutser et al., 2005). Efficient use of manures requires that manure N availability meets plant N demand both in terms of timing and amounts; in this way losses of N in the environment are limited, and manure N efficiency is maximized.

Manure physical-chemical properties strongly affect the efficiency of manure N; in addition, application period and method, as well as manure treatments further influence manure N availability. For instance, anaerobic digestion generally enhances the ammonium (NH_4-N) share of manures, reduces and stabilizes their organic matter, and reduces their C to N ratio; thus, crop available N is potentially higher for digestates than for undigested manures (Möller and Müller, 2012). Moreover, separation of manures provides on one side a liquid fraction with low dry matter (DM) content, low C to N ratio, and with high N and NH_4-N content, and on the other side a solid fibrous fraction with high DM content, large C to N ratio, and low NH_4-N content (Möller and Müller, 2012). Indeed, liquid fractions are supposed to supply more available N to crops than solid fractions, at least in the short-term (Gutser et al., 2005).

Nitrogen use efficiency of organic and mineral fertilizers is usually assessed through apparent N recovery (ANR), representing the fraction of fertilizer N taken up by the crop. In addition, N use efficiency of organic fertilizers can be provided in terms of N fertiliser replacement value (NFRV), equals the organic fertiliser ANR divided by the mineral fertiliser ANR (Muñoz et al., 2004). Both indices can be also calculated for NH_4-N applied with manures providing $ANR_{NH4\text{-}N}$ and $NFRV_{NH4\text{-}N}$ values, respectively. Literature review had shown that first-year crop available manure N often approximates the NH_4-N content of manures (thus NFRV approximately equals the manure NH_4-N to total N ratio) (Chantigny et al., 2008; Delin et al., 2012; Gale et al., 2006; Muñoz et al., 2004; Saunders et al., 2012; Sørensen et al., 2002; Sørensen and Fernández, 2003; Sørensen et al., 2003; Sørensen, 2004; Schröder et al., 2013).

To test this hypothesis for digestates, we established a field experiment in 2011 (Cavalli et al., 2016) to measure the NFRV of undigested and digested cattle manure applied to silage maize named SINBION-Field. Moreover, in the last season of the experiment (2015-2016), we studied residual N effects of previous fertilizations on silage maize growth. Results for the period 2011-2013 had been already published (Cavalli et al., 2016). Here we will report the results of the last two years of the experiment (2014-2015 and 2015-2016). However, a brief full description of the experiment is provided in the materials and method section for clarity.

Materials and Methods

Experimental site and design

The experiment field was located in Montanaso Lombardo (Lodi), Italy (45°20’32” N, 9°26’43” E, altitude 80 m asl). The experiment started in May 2011 on a field that had been cultivated with barley (*Hordeum vulgare* L.) and silage maize (*Zea mays* L.), and that did not receive organic fertilizations in the previous ten years. The 0–30 cm soil profile had the following characteristics: loam texture; pH(H_2O) of 5.8; total N, 1.01 and organic C, 8.44 (both g kg^{-1}); extractable P, 61 mg kg^{-1} per Bray and Kurtz method; exchangeable K, 167 mg kg^{-1}; bulk density, 1.49 g cm^{-3}. The area was charcterized by average (for the period 1993–2010) accumulated annual rainfall of 875 mm and mean air temperature of 13.4°C.

The experiment involved six treatments arranged in a randomized block designed with four replicates: 1) unfertilised control (CON); 2) ammonium sulphate (AS); 3) unseparated digestate from a mix of cattle slurry and maize (DSMM); 4-5) the liquid (LF) and solid (SF) fractions of DSMM; 6) unseparated anaerobically stored cattle slurry (US). Starting from 2011, fertilizers were annually applied to the same plots (112 m^2) in spring, immediately before maize sowing. Liquid slurries were spread using trailing hose technique and incorporated (depth 10 cm) within minutes into the soil with a rotary harrow during 2011, or injected to a depth of 15 cm in years 2012-2014. Application rate of manures was calculated in order to supply the same amount of NH_4-N to all fertilized treatments, allowing to compare NH_4-N recovery across treatments. However, due to differences between manures composition estimated before (that used to calculate the rate) and at the time of spreading, effective NH_4-N application rates sometime deviated from intended rates. The AS and SF were hand spread and incorporated into the soil with a rotary harrow within minutes. In the same days, CON and AS plots were fertlized with triple superphosphate (40 kg P ha^{-1}) and potassium chloride (230 kg K ha^{-1}).

During the maize-ryegrass season 2015-206, maize N fertilization was interrupted, with the aim of studying residual N effects. However, we introduced a fertilized treatment to compare 2015-2016 N use efficiency of mineral fertilizer with that of previous years (2011-2014). The additional treatment (AS_{150}) was imposed on half of the plot belonging to AS, and received 150 kg N ha^{-1} as ammonium sulphate, according to average 2011-2014 AS application rates.

Within three days after fertilization, the field was ploughed (depth 30 cm), harrowed, and sown with maize (Hybrid PR33M15, Pioneer Hi-Bred Italia S.r.l.) at a plant density of ≈ 7 plants m^{-2}. Surface-irrigation schedule for maize was defined according to irrigation water availability and precipitations. Every year, the whole maize plants were harvested for silage (end of August-beginning of October) and, within two weeks post maize harvest, the field was sown with Italian ryegrass (*Lolium multiflorum* Lam., cultivar Asso). Italian ryegrass was not fertilized and was grown until May.

Manure collection

Manures were collected every year from the same facilities. The DSMM came from a commercial biogas plant and was a mix of cattle slurry co-digested with silage maize and (≈30% on a fresh matter basis) and beet pulp or tomato peels (≈1% on a fresh matter basis). The LF and SF were obtained after screw press mechanical separation of DSMM. Cattle slurry (US) was collected from a second dairy farm where the storage tank lay beneath the litter-free, gridded stable floor.

Aboveground biomass sampling and analysis

Maize plants were sampled at the following phenological stages (Ritchie et al., 1996): V3, V6, V9, R1, and dent maturity (R5 harvest stage for silage production) during 2011-2013, and at V6, V9 and R5 during 2014 and 2015. Italian ryegrass was sampled in May. At each date, aboveground biomass (AGB) and its N concentration were determined.

Statistical analysis

Analysis of variance (ANOVA) was performed separately for each year, crop, and sampling date using the SPSS procedure UNIANOVA (SPSS Versions 22.0.0 and 24.0.0). The ANOVA model considered the treatment as a fixed factor and block as random. The homogeneity of variances was evaluated using the Levene test ($P < 0.05$). Significant effects of treatments are reported when the P is below 0.05. Treatments were grouped according to the HSD Tukey test ($P < 0.05$).

Results

Aboveground biomass and N uptake

In 2014, addition of fertilizers significantly enhanced maize AGB (on average +8 t ha^{-1}) and N uptake (on average +95 kg N ha^{-1}) compared to CON (Figure 1). Differences among fertilizers were not significant for both variables. In the following year, maize AGB (10-16 t ha^{-1}) and N uptake (17-50 kg N ha^{-1}) were low in all treatments (Figure 1). Despite lack of fertilization, SF significantly produced 50% more maize AGB and took up 100% more N compared to other treatments.

Italian ryegrass AGB (2-6 t ha^{-1}) and N uptake (17-52 kg N ha^{-1}) showed approximatively the same range of variability in both years, irrespective of the suspension of N fertilization. Both variables differed among treatments and followed the order CON<AS<liquid digestates<US<SF, even if not always significantly.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

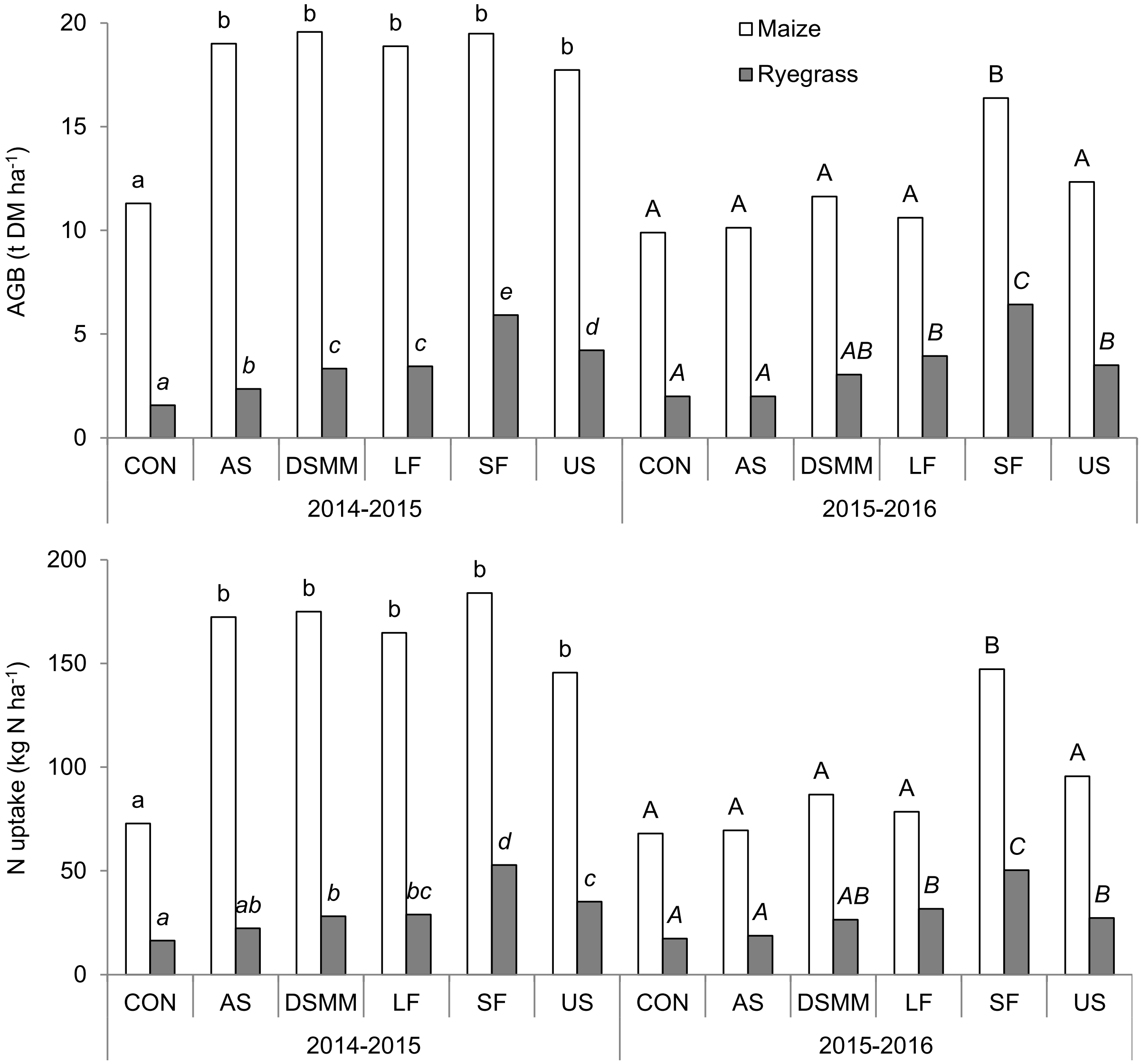


Figure 1. Aboveground biomass (AGB) and N uptake of maize and Italian ryegrass at harvest. CON, unfertilized control; AS, ammonium sulphate; DSMM, unseparated digestate from a mix of cattle slurry and maize; LF, liquid fraction of DSMM; SF, solid fraction of DSMM; US, unseparated anaerobically stored cattle slurry. Significant differences ($P < 0.05$) among treatments are indicated by letters (HSD Tukey test), separately for year and crop.

Figura 1. Biomassa aerea (AGB) ed asportazione di N alla raccolta del mais e del loglio italico. CON, controllo non concimato; AS, solfato d'ammonio; DSMM, digestato da liquame bovino e trinciato di mais; LF, frazione liquida di DSMM; SF, frazione solida di DSMM; US, liquame bovino non separato stoccato anaerobicamente. Le lettere indicano, separatamente per anno e per coltura, le differenze significative ($P < 0.05$) tra i trattamenti (test di Tukey).

Apparent N recovery and N fertilizer replacement value

In 2014, ANR (% applied N) in maize was significantly about twice for AS than for manures (Figure 2). Conversely, no significant differences were found among manures (ANR in the range 22-41% of applied N). As a consequence of similar ANRs, NFRV (Figure 3) was also not significantly different among manures, ranging from 32 to 62%.

Considering the solely contribution of added NH_4-N, a different figure was obtained: $ANR_{NH4\text{-}N}$ of manures, was close to, and not significantly different from that of AS (46-105% of applied NH_4-N). However, SF showed much higher $ANR_{NH4\text{-}N}$ (105% of applied NH_4-N) and $NFRV_{NH4\text{-}N}$ (204%, Figure 3) compared to others, even if significant only compared to US.

Additional N taken up by Italian ryegrass during the autumn-spring period accounted for 4-10% and 4-34% of applied N and NH_4-N, respectively (Figure 2). Recovery was only significantly higher in SF compared to other treatments.

Due to the low contribution of Italian ryegrass to total (maize + Italian ryegrass) N uptake, ANR and $ANR_{NH4\text{-}N}$ of whole crop rotation followed a pattern close to that observed for maize (Figure 2).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

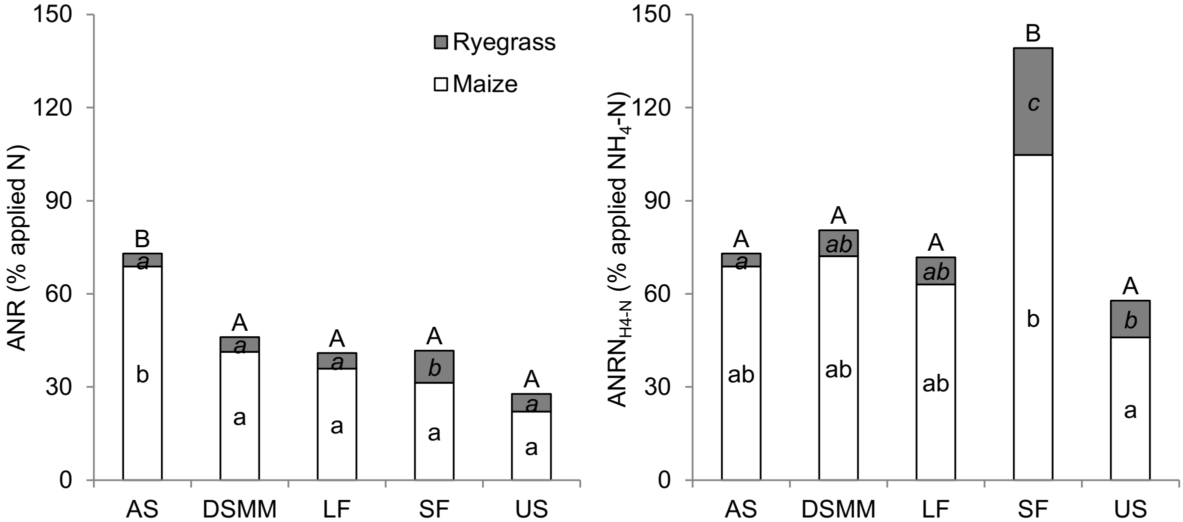


Figure 2. Apparent recovery of total N (ANR) and NH_4-N (ANR_{NH4-N}) in maize and Italian ryegrass at harvest. See Figure 1 for treatment description. Letters indicate significant differences (P < 0.05) among treatments (HSD Tukey test), separately for maize (lowercase letters), Italian ryegrass (lowercase letters in italic) and their sum (uppercase letters).
Figura 2. Recupero apparente dell'N totale (ANR) e dell'NH_4-N (ANR_{NH4-N}) nel mais e nel loglio italico alla raccolta. Vedere Figura 1 per la descrizione dei trattamenti. Le lettere indicano differenze significative (P < 0.05) tra i trattamenti, separatamente per mais (lettere minuscole), loglio italico (lettere minuscole in corsivo) e loro somma (lettere maiuscole).

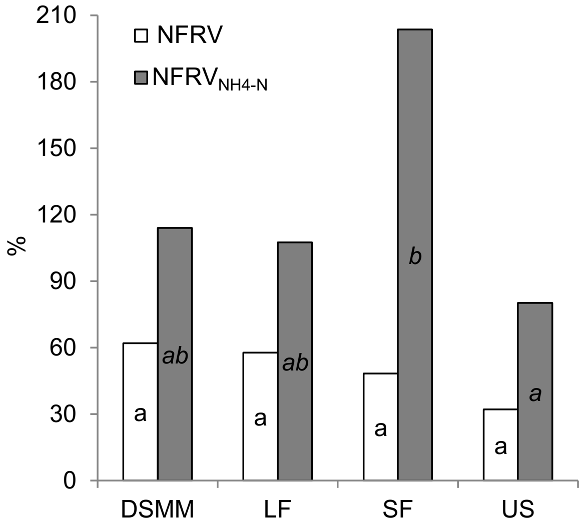


Figure 3. Nitrogen fertilizer replacement value of manures, in terms of manure total N (NFRV) and manure NH_4-N ($NFRV_{NH4-N}$). Estimations refer to maize harvested for ensiling. See Figure 1 for treatment description. Letters indicate significant differences (P < 0.05) among treatments, separately for NFRV and $NFRV_{NH4-N}$.
Figura 3. Valore fertilizzante equivalente degli effluenti, calcolato in base all'N totale (NFRV) e all'NH_4-N ($NFRV_{NH4-N}$). Le stime si riferiscono al mais raccolto per l'insilamento. Vedere Figura 1 per la descrizione dei trattamenti. Le lettere indicano differenze significative (P < 0.05) tra i trattamenti, separatamente per NFRV e $NFRV_{NH4-N}$.

Discussion

Similar AGB and ANR among manures at 2014 maize harvest confirmed the results obtained in 2013 (Cavalli et al., 2016). Organic N in SF and (to a lesser extent in US) likely accumulated after each manure addition, and was mineralized in the subsequent years, providing additional N that balanced the lower short-term N availability suggested by measurements taken in 2011 (*i.e.* after a single manure addition; Cavalli et al., 2016). Differently from US and SF, ANR and NFRV in liquid digestates were high already from the first years of the experiment, possibly due to their lower C to N ratio and lower content of n-poor fibrous fractions (Cavalli et al., 2016). However, it must be noticed that 2014 ANR and ANR_{NH4-N} in maize for SF were slightly overestimated. In fact, N applied in 2014 (354 kg N ha^{-1}) was about half of that applied in previous years (606-703 kg N ha^{-1}) and thus, residual N effects contributed more to 2014 ANRs and NFRVs calculations. Nevertheless, results of 2015 undoubtedly confirmed that residual N effects for SF on maize AGB and N uptake were sizable and significantly higher compared to other manures. The larger accumulation of organic N was partially due to the method used to calculate application rates that aimed at providing equal amounts of NH_4-N for all treatments. Thus, organic N annually supplied to SF was three times that supplied with other manures. Residual N effects of SF were also evident for Italian ryegrass in both years. Thus, late mineralization of SF occurred during the autumn-spring period; this suggests potentially higher risk of NO_3^- leaching from SF compared to other treatments when winter crops are not cultivated.

The hypothesis of NFRV equal to the NH_4-N to N ratio of the manure was confirmed for the year 2014. Excluding results for the year 2011, it is evident that NFRV values measured in this experiment tended to approximate the regression line (and also the 1:1) relating NFRV to NH_4-N to N ratio of manures based on literature data (Figure 4).

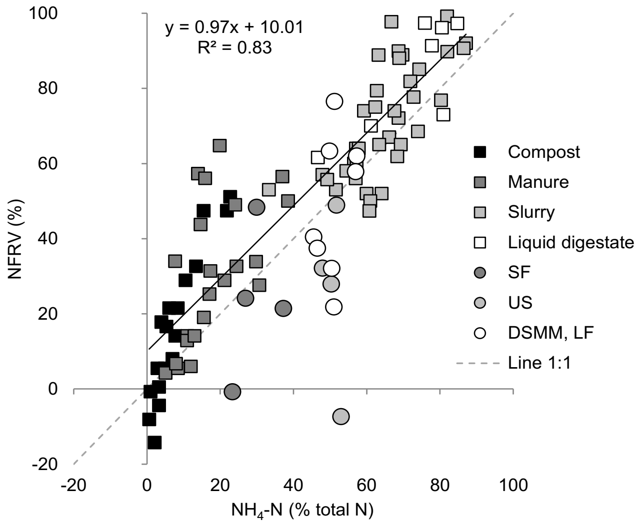


Figure 4. Relationship between N fertilizer replacement value (NFRV) of organic fertilizers and the percentage of fertilizer N in NH_4-N form. Data were collected from literature of field experiments involving different organic fertilizers applied to different crops. Data of this work were added to the chart for comparison with literature data. See Figure 1 for treatment description.

Figura 4. Relazione tra il valore fertilizzante equivalente dell'N (NFRV) di diversi fertilizzanti organici e la percentuale di N del fertilizzante presente come NH_4-N. I dati sono stati raccolti dalla letteratura riguardante esperimenti di campo nei quali diversi fertilizzanti organici sono stati applicati a diverse colture. I dati di questo esperimento sono stati aggiunti per comparazione con i dati di bibliografia. Vedere Figura 1 per la descrizione dei trattamenti.

Conclusions

Results of this experiment confirmed that in-season manure N available for crops approximate manure NH_4-N content. However, for manures that immobilize consistent amounts of N during decomposition in soil, such relation applies only after repeated additions. In fact, it is necessary that mineralization of residual N balances yearly net N immobilization.

References

Cavalli D., Cabassi G., Borrelli L., Geromel G., Bechini L., Degano L., Marino Gallina P., 2016. Nitrogen fertilizer replacement value of undigested liquid cattle manure and digestates. European Journal of Agronomy 73: 34-41.

Chantigny M.H., Angers D.A., Bélanger G., Rochette P., Eriksen-Hamel N., Bittman S., Buckley K., Massé D., Gasser M., 2008. Yield and nutrient export of grain corn fertilized with raw and treated liquid swine manure. Agronomy Journal 100: 1303-1309.

Delin S., Stenberg B., Nyberg A., Brohede L., 2012. Potential methods for estimating nitrogen fertilizer value of organic residues. Soil Use and Management 28: 283-91.

Gale E.S., Sullivan D.M., Cogger C.G., Bary A.I., Hemphill D.D., Myhre E.A., 2006. Estimating plant-available nitrogen release from manures, composts, and specialty products. Journal of Environmental Quality 35: 2321-2332.

Gutser R., Ebertseder T., Weber A., Schraml M., Schmidhalter U., 2005. Short-term and residual availability of nitrogen after long-term application of organic fertilizers on arable land. Journal of Plant Nutrition and Soil Science 168: 439-446.

Möller K., Müller T., 2012. Effects of anaerobic digestion on digestate nutrient availability and crop growth: a review. Engineering Life Sciences 12: 242-257.

Muñoz G.R., Kelling K.A., Powell J.M., Speth P.E., 2004. Comparison of estimates of first-year dairy manure nitrogen availability or recovery using nitrogen-15and other techniques. Journal of Environmental Quality 33: 719-727.

Ritchie S.W., Hanway J.J., Benson G.O., 1996. How a corn plant develops. Spec. Rep. 48. Rev. ed. Iowa State Univ. Coop. Ext. Serv., Ames.

Saunders O.E., Fortuna A., Harrison J.H., Whitefield E., Cogger C.G., Kennedy A.C., Bary A.I., 2012. Comparison of raw dairy manure slurry and anaerobically digested slurry as N sources for grass forage production. International Journal of Agronomy 2012: 1-10.

Sørensen P., Amato M., 2002. Remineralisation and residual effects of N after application of pig slurry to soil. European Journal of Agronomy 16: 81-95.

Sørensen P., Fernández J.A., 2003. Dietary effects on the composition of pig slurry and on the plant utilization of pig slurry nitrogen. The Journal of Agricultural Science 140: 343-55.

Sørensen P., Weisbjerg M.R., Lund P., 2003. Dietary effects on the composition and plant utilization of nitrogen in dairy cattle manure. The Journal of Agricultural Science 141: 79-91.

Sørensen P., 2004. Immobilisation, remineralisation and residual effects in subsequent crops of dairy cattle slurry nitrogen compared to mineral fertiliser nitrogen. Plant and Soil 267: 285-296.

Schröder J.J., de Visser W., Assinck F.B.T., Velthof G.L., 2013. Effects of short-term nitrogen supply from livestock manures and cover crops on silage maize production and nitrate leaching. Soil Use and Management 29: 151-160.

APPLICATIONS OF BIOSTIMULANTS TO IMPROVE THE YIELD AND QUALITY OF CROPS

APPLICAZIONE DEI BIOSTIMOLANTI NEI SISTEMI COLTURALI PER MIGLIORARE LA RESA E LA QUALITÀ DELLE COLTURE

Roberta Bulgari[1], Giacomo Cocetta[1], Giulia Franzoni[1], Livia Martinetti[1], Antonio Ferrante[1*]

[1] Dipartimento Scienze Agrarie e Ambientali – Produzione, Territorio, Agroenergia, Università degli Studi di Milano.
*antonio.ferrante@unimi.it

Abstract

Agricultural systems are oriented to reduce the use of natural resources and limiting the external inputs. Biostimulants as agronomic tools in the crops management have been increasing in different cropping systems. They are obtained from different organic matrixes and their properties depend from the organic materials used for the preparation. At European level, there is a great interest to regulate the biostimulants commercialization and applications. They are neither fertilizers nor plant growth regulators; therefore, they need a specific regulation. In this work, different biostimulant prototypes were tested to counteract water and salinity stresses. Treatments were applied to improve the water use efficiency in tomato and maize and reduce the salinity stress in lettuce. Results demonstrated that different prototypes were efficiently able to reduce the negative effect of water reduction in both tomato and maize. Treatments activate the accumulation of abscisic acid, which increased the water stress tolerance. In salinity stress, the prototype 51266 at 20 L/ha dose and in the highest salinity concentration 1,8 dS/m provided the best results. In conclusion, the biostimulants can be effectively used as tools for improving the crops performance under stressful conditions.

Keywords: biostimulant prototypes, nitrate, quality, salinity, water stress.
Parole chiave: prototipi, nitrate, qualità, salinità, resa.

Introduction

The Biostimulants are widely applied in the different cropping systems to optimize the use of soil resources and increase tolerance to abiotic stresses. The biostimulants are neither fertilizers nor plant growth regulators. They have intermediate proprieties and the concentrations commonly used are lower than fertilizers and higher than phytohormones. They are obtained from different organic matrixes. The composition of biostimulants usually includes: mineral elements, vitamins, amino acids, chitin, chitosan, poly- and oligosaccharides (Berlyn & Russo, 1990; Hamza & Suggars, 2001; Kauffman et al., 2007; Du Jardin, 2015). Biostimulants composition is partly unknown and most of components are present in trace under the detection limits of the analytical instruments. Moreover, they are obtained from heterogeneous organic materials and most of the raw materials are not constant in compositions, therefore the standardization of biostimulants production is quite complex. The efficacy of biostimulants depends from the content of bioactive molecules and crop sensitivity to these compounds. It is common that the biostimulants do not work in all crops or have different efficiency in different species.

The application of biostimulants in the cropping systems are oriented to reduce the environmental impact and provide innovative and sustainable production.

In the recent years, biostimulants are often applied in both open field crops and protected cultivations. These applications should provide the benefit of crop rotations that with the crop residues of the previous cultivation release with the degradation specific bioactive molecules. In vegetables production, the biostimulants can reduce the typical problems related to short growing cycles, lack of organic substances in soils, and frequent soil tillage related problems (Bulgari et al., 2015).

In the present work, the biostimulants were studied to improve crops performance under drought and salinity stresses. The work was carried out on maize, tomato, and lettuce.

Materials and Methods

Processing tomato (*Solanum lycopersicum* L.), maize (*Zea mays* L.) and lettuce (*Lactuca sativa* L.) were grown in greenhouse and used for the experiments. Tomato and maize were used for the water use efficiency and lettuce for the salinity experiments. Biostimulant prototypes were applied as spray treatments with different timing and concentrations considering the crop and abiotic stress to cope.

In maize cv. Ronaldinio, the treatments were applied in two different phenological stages: at V/VI leaf and before flowering. In tomato, impact F1 hybrid, four treatment applications were carried out every 10 days, starting from the flowering stage. The water reduction, for both crops, was set to -20-30% of the crop requirements.

Salinity stress was applied in lettuce var. longifolia, supplying three salinity solutions: 0.8 dS/m (Control), 1.3 dS/m (threshold stress for lettuce), and 1.8 dS/m as stressful treatments. Biostimulant prototypes were applied at the doses of 10 or 20 L/ha and four applications were performed every week. The effects of treatments were evaluated monitoring the

DOI 10.6092/unibo/amsacta/5692

photosynthesis activity (gas exchange), the osmolytes, sugars content, chlorophyll, nitrates, and yield.

Results and Discussion

Biostimulant treatments were able to enhance crop tolerance to water stress and allowed the reduction of water supply, without compromise the quality and yield. Maize treated with biostimulant prototypes showed no reduction in WUE, increase of abscisic acid and proline. Yield was higher in treated plants compared with stressed and non-stressed control (30-40%). In tomato, instead, the biostimulant prototypes increased the yield compared with stressed control by 20-30%, but showed a 30-40% yield losses if compared with non-stressed control. The application of biostimulants can be used to increase crop drought tolerance in summer when water availability is limited. Analogously, they can be also applied where crop management has to be carried out with reduction of water irrigation i.e. 70-80% of the crop requirements.

In leaf vegetables, the biostimulants stimulated the metabolism and improved the nitrate assimilation, with reduction of the leaf nitrate content. The application of biostimulants can enhance the nitrate reductase enzyme of key step of nitrate assimilation in plants. The reduction of nitrate content in leafy vegetables is particular important since the free commercialization among EU countries is allowed only if the nitrate contents are lower than limits reported in the regulation 1258/2011. At physiological level, treated plants show higher chlorophyll content, photosynthetic activity, osmolytes, and sugars. Lettuce treated with biostimulant prototypes showed higher yield compared with control even at higher salinity stress 1.8 dS/m. The best crop performance was obtained in treatment with 51266 at 20 L/ha dose at the highest salinity level.

Conclusions

These results suggest that biostimulants can be applied to counteract water stress in areas with low water availability. Regarding the salinity, the results suggest that biostimulants can be a valid support to grow crops in locations with high salinity such as seaside with infiltration problems of marine water. The biostimulants represent the innovation of crop management system and can be a valid support to improve yield and quality under sub-optimal environmental conditions.

References

Berlyn GP, Russo RO., 1990. The use of organic biostimulants to promote root growth. Belowground Ecol. 2:12-13.

Bulgari, R., Cocetta, G., Trivellini, A., Vernieri, P., Ferrante, A., 2015. Biostimulants and crop responses: a review. Biol. Agric. Hortic. 31, 1-17. doi: 10.1080/01448765.2014.964649

du Jardin, P., 2015. Plant biostimulants: definition, concept, main categories and regulation. Scientia Horticulturae. 196, 3–14.

Hamza B, Suggars A., 2001. Biostimulants: myths and realities. Turfgrass Trends, 10:6-10.

Kauffman GL, Kneivel DP, & Watschke TL., 2007. Effects of a biostimulant on the heat tolerance associated with photosynthetic capacity, membrane thermostability, and polyphenol production of perennial ryegrass. Crop science, 47(1), 261-267.

OPERATIONALIZING THE INCREASE OF WATER USE EFFICIENCY AND RESILIENCE IN IRRIGATION (OPERA)

SISTEMATIZZARE L'AUMENTO DELL'EFFICIENZA DELL'USO DELL'ACQUA E LA RESILIENZA NELL'IRRIGAZIONE

Filiberto Altobelli[*1], Marius Heinen[2], Claire Jacobs[2], Jochen Froebrich[2], , André Chanzy[3], Dominique Courault[3] Willem De Clercq [4], Sara Muñoz Vallés[5], Antonio Díaz Espejo[6], Karolina Smarzynska[7], Wieslawa Kasperska[7], Leszek Labedzki[7] , Anna Dalla Marta[8].

[1] Center for Policies and Bioeconomy, Council for Agricultural Research and Economics (CREA PB - CREA), Italy
[2] Wageningen Environmental Research (Alterra), The Netherlands
[3] French National Institute for Agricultural Research (INRA – EMMAH), France
[4] Stellenbosch University (SU), South Africa
[5] Evenor Tech (Evenor), Spain
[6] Instituto de Recursos Naturales y Agrobiologia de Sevilla (IRNAS – CSIC), Spain
[7] Institute of Technology and Life Sciences (ITP), Poland
[8] DiSPAA – Department of Agrifood Production and Environmental Sciences
*filiberto.altobelli@crea.gov.it

Abstract

Extreme climatic events have negatively affected crop productivity during the first decade of the 21st century in Europe and this is expected to further increase yield variability under climate change. The EU project OPERA is under the Water Joint Programming Initiative "Water Challenges for a Changing World" and the 2015 ERA-NET Cofund Waterworks 2016. OPERA aims to fill the existing gap in applying the necessary combination of present techniques and developments in remote sensing products, soil moisture and plant based sensors, and models to analyse soil water dynamics and crop growth, in order to predict the upcoming water demands within a region in the very short term (up to 15 days ahead). OPERA is implementing an innovative transdisciplinary approach to ensure the joint learning and co-development with all relevant stakeholders throughout the project, promoting new insights on opportunities for desired robustness and accuracy of the ICT tools and innovative service models to bring the information to the farmers.

Keywords: precision irrigation; precision farming; smart irrigation; irrigation advisory service.

Parole chiave: agricoltura di precisione; irrigazione di precisione; sistemi di consulenza all'irrigazione.

Introduction

Extreme climatic events have negatively affected crop productivity during the first decade of the 21st century in Europe and this is expected to further increase yield variability under climate change (EAA,2014).Information is needed on when and where water shortage is to be expected and if there are alternative market opportunities for drought tolerant crops. Sustainable agricultural water management requires the best fitting of water supply to the actual demand in a more flexible way. Precision irrigation must be realized both at field scale, but also at the territory scale. Actual water demand is not only dependent of the growth stage of the plant, but also on the remaining soil water availability. Recent decades provided massive developments in remote sensing products, soil moisture sensors, plant based sensors, and models to analyse soil water dynamics and crop growth. For individual products, operational services have been also established in the market. However, there is a significant gap in applying the necessary combination of such techniques in order to predict the upcoming water demands within a region.
In contrary to technological driven research projects, OPERA will apply a transdisciplinary approach (Scholz, R.W et al. 2015) to identify jointly:
i. The user demands of farmers, farmer associations, extension services as well as water management organizations, ii. Best possible combinations of information technologies (sensors, models, remote sensing), and iii. Innovative service models to realize a practical transition towards an increased use of precision irrigation in practice.

Materials and Methods

OPERA will strengthen farmers' adaptation to climate change and applies a transdisciplinary approach to identify jointly:
I. How farmers and irrigation organizations can react more flexible to predicted water variability.

II. Adequate combinations of soil and crop sensors, remote sensing, weather forecast and simulation models for better consideration of rainfall, evapotranspiration and soil moisture in irrigation scheduling (Fig.1).
III. Integrate experience in operationalizing precision irrigation from various climatic zones in Europe and South Africa to identify the best applicable service models to realize a practical transition towards an increased use of precision irrigation in practice.

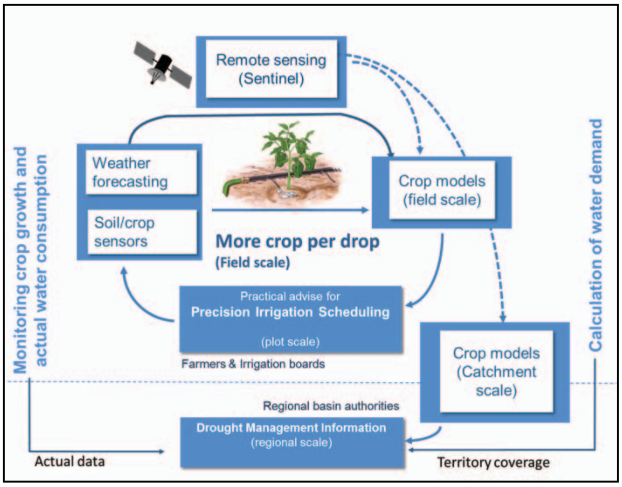


Fig. 1: Operationalizing the increase of water use efficiency and resilience in irrigation.
Fig. 1: Sistematizzare l'aumento dell'efficienza dell'uso dell'acqua e la resilienza nell'irrigazione

The project is divided in 5 actions, each led by a lead from the participating EU countries:

1.Identifying sector needs to increase resource use efficiency, (INRAS, Spain). This action is dedicated to the involvement of stakeholders, both in the case studies and at national/ European level. Stakeholder involvement will play a key role to identify market driven needs and to increase water use efficiency.
2.Forecasting water availability and critical water demand, (INRA, France). Objectives of this action are to develop innovative methods to assess water availability, irrigation needs and the impact of water stress on production.
3.Guidance for optimal irrigation water strategies, case studies, (ITP, Poland). Objective of the action is to synthesize results and testing of practical guidance in the field as proof of principle (case studies). Testing will be carried out during two growing seasons in several case studies.
4.Conceptualization of practical service models for irrigation (Alterra, Netherlands). This action aims to investigating the roles, institutions and potential markets for operationalizing services to the irrigation sector capable of providing benefits to the user community.
5.Project management and dissemination. This work package involves project management, the organization of transdisciplinary approach, co-learning and evaluation during the project period. The general objective of this work package is to coordinate and administer the project smoothly and to disseminate the project results to a wider audience.

Case study approach

A series of case studies (France, Italy, Spain, Poland, The Netherlands and South Africa) demanding increased water use efficiency and resilience are used to test transversal research lines: a) The use of remote sensing data at high resolution for water demand, b) Improving soil water content knowledge using sensors and up scaling, c) Ensemble weather forecast and decision making under water uncertainties with farmers (Fig. 2).

Fig. 2: Case study sites in Europe and South Africa
Fig.2: Casi studio in Europa e Sud Africa

Conclusions

OPERA contributes to optimal watering strategies and water saving, and an increase of farm competitiveness in the agricultural market. The short term impact of OPERA will be the possibility to pick up elaborated combinations of ICT products to forecast agricultural water needs. The mid term and long term benefits will result from realizing a better advisory service in the agricultural sector under anticipation of climate variability and critical moments of water scarcity.

Acknowledgements

The authors would like to thank the EU and The Ministry of Economic Affairs (The Netherlands), CDTI (Spain), MINECO (Spain), ANR (France), MIUR (Italy), NCBR (Poland) and WRC (South Africa) for funding, in the frame of the collaborative international consortium OPERA financed under the ERA-NET Co fund WaterWorks2015 Call. This ERA-NET is an integral part of the 2016 Joint Activities developed by the Water Challenges for a Changing World Joint Programme Initiative (Water JPI).

References

European Environment Agency (EEA), Water-limited crop productivity, 2014.
Scholz, R.W. and G. Steiner. 2015. Sustain. Sci. 10: 521. doi:10.1007/s11625-015-0338-0.

ARTIFICIAL WATER BASIN IN EMILIA ROMAGNA GEOGRAPHICAL DATABASE'S UPDATE

AGGIORNAMENTO DELLA BANCA DATI GEOGRAFICA DEI BACINI IDRICI ARTIFICIALI IN EMILIA-ROMAGNA

Luca Tosi[2], Giulio Coffa[2], Andrea Spisni[1], Luca D. Sapia[1], Valentina Ciriello[2], Vittorio Marletto[1]

[1] Arpae Emilia - Romagna – Servizio Idro Meteo Clima, viale Silvani 6, 40122, Bologna (BO)
[2] Università di Bologna – Dipartimento di Ingegneria Civile Chimica Ambientale e dei Materiali, Scuola di Ingegneria e Architettura, Viale del Risorgimento, 2, 40136, Bologna
luca.tosi8@studio.unibo.it - giulio.coffa@studio.unibo.it

Abstract
In the last few years, important crop evolution and changes took place in Emilia-Romagna. The bigger extraction of water depends from meteorological changes and replacement of traditional crop, as vine and peach tree, with fruits more profitable but with high water consume, for example the tree of actinidia (kiwi). With less intense rainfall, the extraction of river water is an important source to irrigate plants. Therefore, the inland water basins are important sources of fresh water storage, which allow to evaluate throughout time not only climatic evolutions, but also the development of new strongly water demanding crops.
The aim of this study is to update the geographical database (last revised in 2011) of artificial water basin in Emilia-Romagna, through Sentinel-2A satellite imagery and with the support of Google Earth and Bing.

Keywords
Satellite imagery, artificial water basins, ponds, geographical database
Parole chiave
Immagini satellitari, bacini idrici artificiali, laghetti, banca data geografica

Introduzione

Negli ultimi decenni in Emilia-Romagna si è osservato una importante evoluzione e cambiamento colturale. I maggiori prelievi di acqua in un territorio derivano, oltre che dalle mutate condizioni meteorologiche che inducono sensibili aumenti evapotraspirativi, anche dalla progressiva sostituzione delle colture tradizionali, quali la vite e pesco, a favore di colture redditizie, ma ad alto consumo idrico, come l'actinidia (kiwi), e dal progressivo aumento dell'irrigazione. Il prelievo da fiume, diretto nel periodo irriguo, o indiretto per stoccaggio in bacini artificiali, rappresenta la principale fonte di approvvigionamento irriguo dell'area di studio, escludendo il contributo dovuto alle precipitazioni. Tale prelievo risulta essere spesso incontrollato da parte di privati ed aziende, in quanto non esiste una vera e propria legge che disciplini in materia. Questo porta per i corsi d'acqua al rischio, specialmente durante i periodi estivi, di avere un livello idrico al di sotto del deflusso minimo vitale, ovvero quella portata d'acqua al di sotto del quale non è più garantita sopravvivenza dell'ecosistema associato al corso d'acqua stesso. Perciò i bacini idrici interni costituiscono un'importante fonte di stoccaggio di acqua dolce, i quali permettono di valutare nel tempo non solo le evoluzioni climatiche, ma anche lo sviluppo di nuove colture fortemente idroesigenti.
Nel presente lavoro, infatti, si è provveduto ad aggiornare, mediante il software QGIS, l'elenco dei bacini idrici interni ricadenti nell'ambito territoriale dell'Emilia-Romagna. L'aggiornamento è stato ottenuto a partire da immagini satellitari Sentinel-2A col supporto degli strumenti Google Earth e Bing. Il dato vettoriale di partenza proviene dal database topografico regionale (dbtopo 2011).

Materiali e metodi

L'aggiornamento è stato eseguito a partire dal database topografico 2011 della Regione Emilia-Romagna.
Come supporto interpretativo sono state preparate delle immagini a falsi colori acquisite dal satellite europeo Sentinel-2A.
Per una successiva valutazione statistica sui laghetti, a ognuno di essi viene associato una porzione particolare della regione, ovvero le macroaree: infatti, per la gestione delle emergenze di Protezione Civile e per la valutazione del rischio idrico, il territorio regionale è suddiviso in otto macroaree, individuate tenendo conto dell´omogeneità climatologica e idrologica e, quando possibile, rispettando i confini amministrativi (Fig. 1).

Fig. 1 - Suddivisione in Macroaree dell'Emilia-Romagna.
Fig. 1 – Macroarea subdivision of Emilia-Romagna.

Sono stati aggiornati diversi attributi all'interno del database topografico dei laghetti e tra quelli di maggiore importanza si evidenziano i seguenti:
- "*Tipo fonte*", ovvero la fonte che verrà utilizzata per l'aggiornamento. Verranno utilizzate il Sentinel-2 (S2A), Google Earth (Google Satellite) e Bing Maps;
- "*Shape_Leng*", la lunghezza dei contorni dei laghetti, ovvero il perimetro;
- "*Shape_Area*", ovvero le dimensioni dell'area di ogni laghetto;
- "*Tag*", ovvero l'aggiornamento geometrico vero e proprio identificato tramite un numero e relativa descrizione:
  - *0*, laghetto non modificato
  - *1*, laghetto ingrandito
  - *2,* laghetto rimpicciolito
  - *3*, laghetto frastagliato cancellato
  - *4,* laghetto non più visibile (senza acqua)
  - *5*, laghetto aggiunto
  - *6*, laghetto non più visibile (scarsa risoluzione satellite)
  - *7,* impossibilità esistenza laghetto (presenza di una casa, passaggio di un fiume)
  - *8*, unione di diversi laghetti in uno singolo;
- "*Data aggiornamento",* che risulta essere fissa solamente per il Sentinel-2A, ovvero 10 Maggio 2016;
- "*Agro*", che identifica con un numero se il laghetto in questione è utilizzabile per fini agricoli:
  - *0*, acqua non utilizzabile per l'irrigazione (si tratta di aree costiere e riserve naturali);
  - *1*, acque interne utilizzabili per l'irrigazione.

Per quanto riguarda il tipo di fonte utilizzata e quindi di conseguenza la data di aggiornamento, il lavoro è stato svolto dando priorità alle immagini Sentinel-2A, trattandosi dell'informazione mediamente più recente a disposizione. Sussiste un importante aspetto da considerare durante il lavoro. Il Sentinel-2A riesce a identificare bene solamente la presenza di bacini di dimensioni sufficientemente grandi, infatti la sua risoluzione geometrica è pari a 10 m. Per tale motivo si è ricorsi a Google Earth e Bing Aerial, i quali, utilizzando immagini aree con risoluzione geometrica fino a un metro, permettono di ingrandire bene l'area di interesse, senza sgranamenti e quindi consentendo di derivare informazioni per laghetti di dimensioni molto piccole.

Risultati e discussioni

Attraverso l'aggiornamento si è visto come dei 25.925 laghetti iniziali, 8.901 sono andati persi o comunque non sono più saturi d'acqua, mentre quelli aggiunti sono 1.644. La Tabella 1 permette di osservare quanti laghetti risultano essere visibili dopo l'aggiornamento.
Altro aspetto importante riguarda l'utilizzo delle fonte e quindi valutare se il sensore più utilizzato per l'aggiornamento è stato quello del satellite Sentinel-2A. Infatti 934 laghetti sono stati aggiornati con Bing Aerial, 7.498 con Google Earth e infine 18.493 con il Sentinel-2A. La Figura 2, distribuisce le fonti per macroarea.

Tab. 1 - Number of ponds for Macroarea in the 2011 database and visible in 2016 on satellite images and web services (ponds visible "tag": 0-1-2-3-5-8)
Tab. 1 – Numero di laghetti per Macroarea presenti nel database 2011 e visibili al 2016 sulle immagini da satellite e servizi web (laghetti visibili "tag": 0-1-2-3-5-8)

Macroarea	Laghetti database 2011	Laghetti visibili 2016
A	1.465	878
B	3.930	2.701
C	3.781	2.232
D	6.657	5.101
E	2.593	1.522
F	4.983	3.566
G	904	478
H	2.612	1.546
Totale	*26.925*	*18.024*

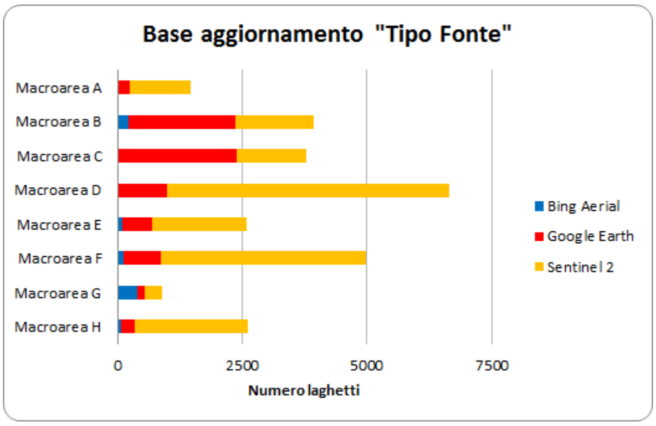


Fig. 2 - Distribution of the "Source Type" attribute for the various Macroarea of Emilia-Romagna
Fig. 2 - Distribuzione dell'attributo "Tipo Fonte" per le varie Macroaree dell'Emilia-Romagna

Risulta infine importante conoscere quanto è effettivamente la superficie d'acqua dei bacini che copre la Regione Emilia-Romagna utilizzabile per fini agricoli. Per tale motivo devono essere escluse dall'analisi le aree costiere quali le Valli Bertuzzi (FE) e la Piallassa della Baiona (RA), le Saline di Cervia e quella di riserva naturale, come la Riserva Naturale di Comacchio. In Tabella 2 vengono quindi analizzate le aree, espresse in ettari, dei laghetti al 2011 (colonna "Area Db 2011"), dei laghetti saturi aggiornati al 2016 (colonna "Area saturi 2016") e l'area dei laghetti al 2016 utili per praticare irrigazione (colonna "Area irrigazione").

Tab. 2 - Area (ha) of ponds for each Macroarea divided according to their utility.
Tab. 2 - Area (ha) dei laghetti per ogni Macroarea suddivise in base alla loro utilità.

Macroarea	Area Db 2011	Area saturi 2016	Area irrigazione
A	318,5	271,4	271,4
B	4.4695,1	4.419,8	1.445,4
C	824,7	707,7	707,7
D	31.393,4	30.958,5	7.671,5
E	543,4	452,0	452,0
F	2.676,5	2.260,7	2.260,7
G	338,0	295,7	295,7
H	1.098,9	854,2	854,2
Totale	*41.888*	*40.220*	*13.959*

Conclusioni
Si può desumere che sulla base dei risultati, sia il numero di laghetti che la superficie d'acqua, negli anni sia andata calando. Infatti, complessivamente, si è visto come rispetto al 2011, al netto dell'anno 2016 sussistono 7.257 laghetti in meno. A ciò corrisponde una mancanza di superficie d'acqua di 1.668 ettari, ma in realtà si è visto come dei 40.220 ettari di risorsa idrica esistente, neanche 14.000 possono in realtà essere utilizzati per l'irrigazione. Sono perciò sicuramente i cambiamenti climatici, più siccitosi e meno piovosi e la crescita di nuove colture fortemente idroesigenti come il kiwi, ad attribuire il cambiamento topografico dei laghetti appena visto.

EVALUATION OF IRRIGATIONAL REQUIREMENTS OF FRUIT-GROWING HILLY AREAS USING CONSORTIUM ARTIFICIAL BASINS' WATER

STIME DEI FABBISOGNI IRRIGUI DI AREE FRUTTICOLE COLLINARI SERVITE DA BACINI ARTIFICIALI CONSORTILI

Luca Tosi[2], Luca D. Sapia[1], Andrea Spisni[1], Gabriele Minardi[3], Matteo Verlicchi[3], Valentina Ciriello[2], Vittorio Marletto[1]

[1] Arpae Emilia - Romagna – Servizio Idro Meteo Clima, Viale Silvani 6, 40122, Bologna (BO)
[2] Università di Bologna – Dipartimento di Ingegneria Civile, Chimica, Ambientale e dei Materiali, Scuola di Ingegneria e Architettura, Viale del Risorgimento 2, 40136, Bologna
[3] Consorzio di Bonifica della Romagna Occidentale – Via Castellani 26, 48018, Faenza (RA)
luca.tosi8@studio.unibo.it

Abstract
The knowledge of crop water requirements (CWR) is an essential information in the management of irrigation in agriculture, especially in arid and semi-arid regions where irrigation is the largest consumer of water.
Starting from observation made by modern satellite sensors, in the regions of the visible and near infrared electromagnetic spectrum, it is possible to extract information on the status of crops and phenological characteristics of the canopy of vegetation that, combined with the use of agro-meteorological data, and following appropriate methodologies, allow to evaluate with high spatial accuracy the crop water consumptions.
In this study, the first step is to estimate, with remote sensing data, water losses of different fruit crops through the K_c-NDVI method; the second step is to evaluate if rainfalls and water of artificial basins can satisfy crop water requirements of the entire study area.

Keywords
Remote sensing, crop water requirements (CWR), evapotranspiration, Kc-NDVI method, water balance
Parole chiave
Telerilevamento, fabbisogno idrico delle colture (CWR), evapotraspirazione, metodo Kc-NDVI, bilancio idrico

Introduction
Over the last years, the possibility of obtaining satellite data has enormously grown thanks to the increasing number of sensors available to observe Earth. The strength point of remote sensing is its capability of obtaining data and information on a great scale, which is particularly useful in those areas of Earth of hard access and in the developing countries. The ease in tracing multispectral high resolution data and the ever shorter times of revisiting the same area by modern satellites are traits particularly useful for evaluating the crop water requirements with a reasonable accuracy and economical efficiency. Moreover, nowadays images are distributed through the internet in a few hours after being collected, so they can be fastly treated in order to obtain the final product and to distribute it to the end users, almost in real time.
In this work, 14 satellite images from both Landsat-8 and Sentinel-2A have been analyzed in order to evaluate water loss of the crop in the studied area, during 2016's irrigation season. After calculating crop water consumption, it was evaluated whether the contribution of rainfall and irrigation (from the many artificial basins located in the studied area) is enough to satisfy those crop water requirements.

Materials and methods
The study of crop water requirements has been performed on three Consortium artificial basins denominated Renzuno, Isola and Paglia-Albonello, all managed by Consorzio di Bonifica della Romagna Occidentale, and located in the hilly area in the province of Ravenna, under the tract of the Via Emilia between the cities of Imola (BO) and Faenza (RA). Spatial and temporal variability of water requirements, estimated thanks to satellite data, has been evaluated for the following crops: kiwi tree, apricot tree, cherry tree, kako tree, corn, apple tree, cantaloupe, horticles, pear tree, peach tree, plum tree and grapevine. Monitoring was performed during 2016's irrigation season (1st of May - 30th of September), thanks to the obtaining of fourteen satellite multispectral high definition images – seven from satellite Landsat-8 and seven from satellite Sentinel-2A.
The first goal was evaluating the quantity of water lost by plants because of evapotranspiration, using the method K_c-*NDVI*, through a linear relation which connects the vegetation index with the crop coefficient:

$$K_c = 1{,}25 \cdot NDVI + 0{,}2$$

The crop coefficient Kc incorporates and recaps in itself all the effects on evapotranspiration connected to the morphological and physiological characteristics of the different species, to the phenological phases and the degree of soil coverage, and allows to extract –known ET0, potential evapotranspiration for an hypothetical area of reference– the evapotranspiration of the crop under unlimited water availability in the soil (ET_c):

$$ET_c = K_c \cdot ET_0$$

In order to determine potential evapotranspiration, it has been employed the equation of Hargreaves & Samani, which uses data of of maximal and minimal daily temperature and the potential radiation in absence of atmosphere:

$$ET_0 = 0{,}0023 \cdot \frac{A_{stronomica}}{2{,}456} \cdot \left(\frac{T_{max} - T_{min}}{2} + 17{,}8\right) \cdot (T_{max} - T_{min})^{1/2}$$

CWR and ET_c are two terms representative of the same water quantity: the first one refers the the water quantity needed to be provided in order to compensate for the loss; the second one represents indeed the quantity of water lost because of evapotranspiration, always considering the hypothesis of having optimal water condition in the soil.

In the second phase of this work, it was evaluated whether rainfall and irrigation are able to satisfy the crop water requirement in each consortium; each of them is supplied by one or more artificial basin, filled through derivation from river/creek. Daily rainfall measurement has been proceeded from the database ERG-5 by ARPA-SIMC, supplied by over 200 measurement stations located all over the territory of Emilia-Romagna. Irrigation, instead, has been evaluated in two steps, since at some point during irrigation season the derivation from river has been interrupted in order to not undergo the Minimum Vital Outflow: this results in a pre-closing period, in which the water to irrigate crops is collected directly from the river, and a post-closing period, during which irrigation is supplied by the artificial basin.
It is important to underline that during the river drainage, part of the water resource is used to irrigate, while another part is employed to fill the basin.

Results and discussion

The evaluation of the results was carried out considering two different scenarios of analysis: the first considers the total water requirement of all crops; in the second, instead, the vine requirement has been reduced to 25%, as this crop mainly undergoes rescue irrigation so it's not irrigated throughout all the irrigation season. Evaluating the results in the latter case, it has been seen that within the Consortium Renzuno and Paglia-Albonello the main water requirement derives from actinidia (kiwi), which is also the most water-demanding crop of the existing ones. In the Isola Consortium, the prevailing one is vine.

In terms of water requirements, obtained by subtracting the rain from the ETC, it can be satisfied only in May and September, and only thanks to the precipitations, for the Consortiums Renzuno and Isola (Tab.1 and Tab.2). In the remaining months, we can not satisfy plants' lack of water, neither with the contribution of precipitation nor with that of irrigation. In the Paglia-Albonello Consortium, however, no month of the irrigation season is completely satisfied (Tab. 3).

Tab. 1 - Volume (m^3) of Irrigation Consortium Renzuno.
Tab. 1 - Volumi (m^3) Consorzio irriguo Renzuno.

	ETc	Pioggia	Fabb. Idr	Irrigazione
Maggio	113.690	154.828	- 41.138	13.110
Giugno	133.366	92.268	41.098	15.379
Luglio	164.713	21.996	142.717	18.994
Agosto	118.560	23.424	95.136	20.016
Settembre	81.627	122.834	- 41.207	14.452

Tab. 2 - Volume (m^3) of Irrigation Consortium Isola.
Tab. 2 - Volumi (m^3) Consorzio irriguo Isola.

	ETc	Pioggia	Fabb. Idr	Irrigazione
Maggio	111.412	146.390	- 34.978	6.925
Giugno	132.462	68.434	64.028	8.233
Luglio	154.489	40.069	114.421	9.603
Agosto	120.346	42.647	77.699	10.439
Settembre	82.364	166.622	- 84.258	7.501

Tab. 3 - Volume (m^3) of Irrigation Consortium Paglia-Albonello.
Tab. 3 - Volumi (m^3) Consorzio irriguo Paglia-Albonello

	ETc	Pioggia	Fabb. Idr	Irrigazione
Maggio	648.341	534.419	113.922	54.071
Giugno	713.974	259.908	454.065	64.722
Luglio	867.462	202.232	665.230	153.323
Agosto	722.902	70.818	652.085	127.772
Settembre	464.214	313.204	151.010	82.049

Conclusions

For a correct analysis of the results, it is first and foremost necessary to emphasize that the ETc values, obtained by satellite, represent an overestimation of the real consumption of water by the crops, since it is case of the first groundwater hypothesis: the soil is in optimal conditions, meaning that is saturated with water. A more accurate assessment of the real water needs of crops could be carried out by integrating the satellite data with a modeling system of soil water balance, which would reduce the ETc values estimated by the satellite depending on the water content in the soil layer involving plants' roots.

In the most realistic analysis scenario, in which vine's life expectancy has been reduced to 25%, the results underline what was expected, that is, enough water supply in the rainy months and a water stress in the hottest ones. This is not the case for the Paglia-Albonello Consortium, given the fact that more than 50% of water required by the consortium comes from the crop with the major water consumption (kiwi).

References

Marletto V., Zinoni F., Botarelli L., Alessandrini C., Fontana G., Spisni A., 2005, Ottimizzazione della gestione delle risorse idriche in agricoltura in ambienti vulnerabili a processi di desertificazione, Atti VIII° Convegno Nazionale di Agrometeorologia AIAM 2005 , Caramanico Terme (PE) 3-5/05/2005, p. 40-41.

Spisni A., Cassani G., Marletto V., 2006, Analisi dei fabbisogni irrigui in comprensorio frutticolo, Atti IX Convegno nazionale di agrometeorologia AIAM 2006, Torino, 6-8 giugno 2006.

DECISION SUPPORT SYSTEMS (DSS) TO WATER RESOURCES MANAGEMENT AND PLANNING: IRRINET-IRRIFRAME AS CASE STUDY IN EMILIA-ROMAGNA REGION

SISTEMA DI SUPPORTO ALLE DECISIONI PER LA GESTIONE E PIANIFICAZIONE DELLA RISORSA IDRICA: IRRINET-IRRIFRAME COME CASO DI STUDIO NELLA REGIONE EMILIA-ROMAGNA

Maria Valentina Lasorella[1], Roberto Genovesi[2], Gioele Chiari[2], Carlo Malavolta[3]

[1] Council for Agricultural Research and Analysis of Agricultural Economics, Politics and bioeconomics - Via di Corticella 133, 40127, Bologna
[2] Canale Emiliano Romagnolo (CER)Via Masi,8 40137 Bologna (Italy)
[3] Emilia-Romagna Region – Sustainable Agriculture, Viale della Fiera, 8 - 40127 - Bologna (BO) Italia

Corresponding author e-mail -*mvalentina.lasorella@crea.gov.it

Abstract
Water scarcity and droughts are already a serious problem in the Euro-Mediterranean regions and that situation is expected to worsen as a consequence of climate change. Considering the recent drought events in Italy and in particular in some areas of Po valley, Regional Managing Authority has put pressure to improve water use efficiency, introducing on one hand new criteria regarding water resources governance and management by water authorities and agencies involved in this, and on the other, developing innovative techniques that may enable farmers to improve overall economic and sustainable production by adopting rigorous innovative techniques such as water scheduling. A great effort on this matter has been made through a decision support system IRRINET-IRRIFRAME, a decision support system which was supported and co-funded by the Emilia-Romagna Region and ANBI (National Association of Reclamation and Irrigation) in collaboration with CER (Canale Emiliano Romagnolo). The tool have been used in the last 5 years from more than 30.000 users to help farmers to improve overall economic and sustainable production and using water in a more efficient way. Since 2012 IRRINET-IRRIFRAME has been used in Rural Development Programme (RDP) of Emilia Romagna Region and integrated as voluntary additional commitments with a funding support for farmers of 15 euro per ha.

Keywords: decision support system, water planning, water policy, Emilia-Romagna Region, Agro-environmental-climate measures
Parole chiave: sistemi di supporto alle decisioni, gestione della risorsa idrica, pianificazione risorsa idrica, Regione Emilia-Romagna, misure agro-climatico-ambientali

Introduction
The demand for water resources continue to increase in many European countries. Many efforts have been made at local, national and European levels to regulate the uses of water in order to mediate between conflicting demands. Seventeen years ago, the European Union issued the “Council Directive establishing a framework for Community action in the field of water policy” (2000/60/EC), known as the Water Framework Directive (WFD), which defines common principles which Member States will have to orientate their efforts. The management of economic aspects, such as “full cost recovery” and guidelines for the management of planning aspects, such as “catchment based management” and the achievement of “good ecological status” for water bodies by the year 2015 are crucial aspect to be reached by each MS. In Italy, the water consortium bodies fragmentation and the lack of territorial plan management represented an obstacle for the WFD implementation. For this reason Italian Regional Managing Authorities have put pressure to improving water efficiency by using innovative techniques and smarter drive support systems to face the water management problem. In this context IRRINET-IRRIFRAME aspires to be an operational tool which meets the needs of European water management authorities and facilitates the implementation of the EU Water Framework Directive. In fact from 2014 the IRRINET-IRRIFRAME platform is also supported by the Italian Ministry of Agriculture (MIPAAF) for the planning of policies for agriculture in response to the Commission's observations about water savings.
IRRINET-IRRIFRAME consists of a set of cloud-based tools both for final water users (farmers) and for water managers (boards) to provide recommendation on the best water allocation and on how to save irrigation water without decreasing the quality of crop production. The application-driven approach IRRINET-IRRIFRAME have been developed by Water Boards Italian Association (ANBI) with the scientific background of the Canale Emiliano Romagnolo (CER) and the consortium members to ensure an efficient use of water resources in the agricultural sector. The DSS IRRINET IRRIFRAME hope to achieve a high water efficiency by a better water management of irrigation. On this concern the promotion and increasing numbers of IRRINET-IRRIFRAME users to support farmers for irrigation according to water availability (rainfall, rivers

level, ground-water level) and water balance along the irrigation period (e.g., spring-summer) is one of the project achievements.
In the RDP 2007-2013 and 2014-20 Emilia Romagna Region promotes the implementation of IRRIFRAME-IRRINATE to support farmers for irrigation according to water availability (rainfall, rivers level, ground-water level) and water balance along the irrigation period (e.g., spring-summer). In fact, in the RDP 2014-20 beside the integrated and organic production additional commitments and ad hoc operations on water management have been integrated in the Measure 10.1 and 11 providing to farmers a funding support of around 15 euro per ha irrigated with the utilization of IRRINET-IRRIFRAME. Nowadays specific advices for farmers irrigation management are supplied weekly (provincial bulletins) on all regional territory and a new web-system has been developed by Emilia Romagna Region in cooperation with CER. About 12,000 are IRRINET users (about 25% of the total irrigated surface in the region). In the future one of the final achievements is to provide the IRRINET-IRRIFRAME at National level to all farmers. It also underlines the need to promote water efficiency and water demand management through a combination of different tools.

Materials and Methods
Emilia-Romagna region is located in the northern part of Italy; it stretches from the Apennines to the Adriatic sea and covers a big part of Po valley; the regional territory occupies about 22.500 (twenty-two thousand and five hundred) Km², and it is about 48% low-laying, 27% hilly and 25% mountainous. The Emilia-Romagna Region is a leader region for the Italian agricultural production with more than 84.000 farms and 1.064.214 hectares invested. Apart from cereals (427.422 Ha) the most important horticultural crops are fruit crops (67.454 ha), grapevine for vine production (55.929 ha) and vegetables for both fresh market and industrial processing (55.626 ha). Agricultural land covers 60% of the entire regional territory. About 33% of the regional farms include irrigated land. The most used irrigation system in the region is sprinkler (59% of the total irrigated area) followed by micro-irrigation (24%), furrow and border irrigation (12%), and submersion irrigation (3%) (ISTAT 2010). Fresh water is relatively abundant in the Emilia-Romagna region although changes in the geographical distribution of rainfall have caused significant water deficit in some areas and episodes of water shortage are expected to increase in the future. Water is more abundant in the north-west side of the region (called Emilia), whereas in the south-east side (called Romagna) surface water has always been limited. This situation has been partly compensated by the construction (started in 1955) of an artificial canal conveying irrigation water called Canale Emiliano Romagnolo (CER). However the inefficient use of the water distributed to farms by land reclamation consortiums is becoming a problem due to the increasingly inefficient use than ever before. For this reason Italian Regional Managing Authorities have put pressure to improving water efficiency by using innovative techniques and smarter drive support systems to face the water management problem. In this context IRRINET-IRRIFRAME aspires to be an operational tool supporting farmers scheduling water management.

Results and Discussion
The irrigation model has been developed by CER and has been validated locally over 30 years. The model consider the soil, plant, atmosphere continuum and it is based on water balance, where crop water requirement is calculated from evaporimetric data, corrected for crop coefficients (Kc) field trials (Giannerini, 1993). The input date are: type of crop and soil, geographic location, meteorological and soil data and the characteristics of the irrigation system used in the farm. Meteorological data are from Regional Agro meteorological Service Net, the soil database is from Regional Geological Service, and crop parameters obtained from local experiment are from CER databases. The main structure of the model is described in Fig. 1.

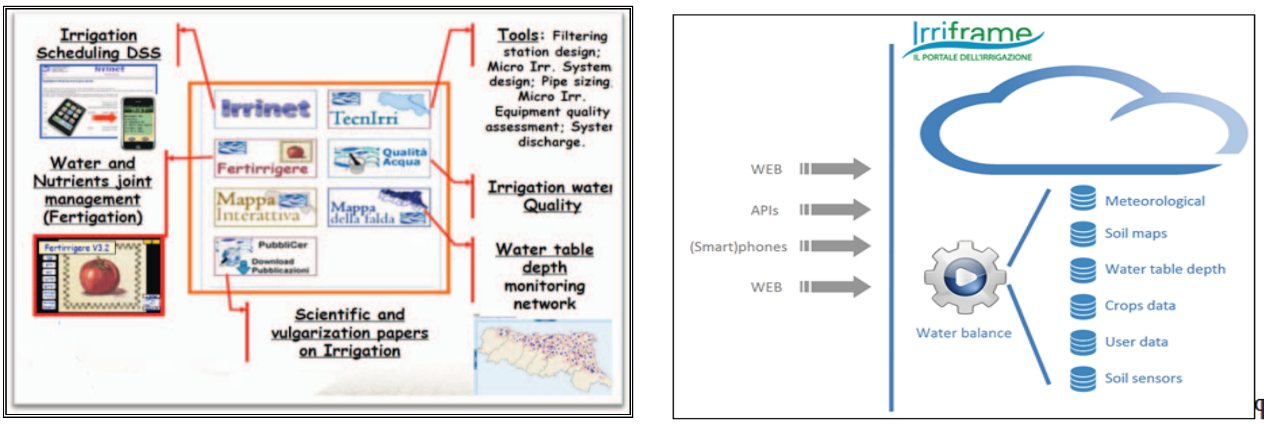


Fig. 1: Irrinet-Irriframe platform architecture (Giannerini, 2013).
Fig.1: Architettura del Sistema di support Irrinet-Irriframe (Giannerini, 2013).

DOI 10.6092/unibo/amsacta/5692

In 2016 IRRINET-IRRIFRAME service involves more than 40.000 farms, covering almost 40% of the irrigated area in the region. Its application in the last RDP 2007-13 allowed a water saving for more than 50 million m^3 in the Emilia Romagna region. As far as the technical point of view is concerned the development group is working both on a closer integration with open GIS information layers that may reduce the amount of data the users are requested to register in the system and the use of satellite information to determine the effective crop coefficients (Kc) for the water balance calculation. In 2013, about 55% of Italian irrigated land has been managed by IRRINET - IRRIFRAME saving about 100 million m^3 per year. In the first semester of 2014, 1.000 new users registered to the system.

Conclusions

In the new RDP period the funding support for the utilization of IRRINET-IRRIFRAME by measure 10.1 aims to promote the necessary changes in agricultural practices between farmers and land managers to reduce the pressure on natural resources and in particular on water management. Enhancing the positive role that farmers decision could have on the protection of soil, water resources, mitigate and adapt to climate change is one of the mission of the new RDP. Despite the active participation of end-users in the utilization of IRRINET-IRRIFRAME have been recognised as a factor improving the acceptance of the DSS and contributing to the success of the project, however additional work is still needed on the implementation of the DSS and on the promotion and integration of the system in most of irrigated Italian farms.

References

CER, 2012. *Sustainable, Knowledge based Irrigation Management: the IRRINET package*. Presentation by Battilani A., Mannini P. at the International Conference The Water Challenge. Every Drop Counts. Green Week 2012. Brussels, 22-25 May 2012.

EC (European Commission), Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Official Journal of the European Communities, L 372 (43), 1-73, 2000.

Giannerini G., Mannini P., Genovesi R., 2013. ‘Irriframe as Italian national platform for water management’ EFITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013.

ISTAT, 2010. Censimento Agricoltura 2010. Database available at: http://dati-censimentoagricoltura.istat.it/.

AGROMETEOROLOGY FOR THE APPLICATION OF NITRATES DIRECTIVE
L'AGROMETEOROLOGIA NELL'APPLICAZIONE DELLA DIRETTIVA NITRATI

Gabriele Antolini[1], Monica Bassanino[2], Alberto Bonini[3], Federica Checchetto[3], Lorenzo Craveri[4], Irene Delillo[3], Francesco Domenichini[3], William Pratizzoli[1], Carlo Riparbelli[4*]

[1]ARPAE Servizio Idro-Meteo-Clima, Via Silvani 6, Bologna
[2]Regione Piemonte Direzione Agricoltura Settore Produzioni Agrarie e Zootecniche, C.so Stati Uniti 21, Torino
[3]ARPAV Dipartimento Regionale per la Sicurezza del Territorio Servizio Meteorologico, Via Marconi 55, Teolo (PD)
[4]Ente Regionale per i Servizi all'Agricoltura e alle Foreste, Via Pola 12, Milano
[*]carlo.riparbelli@ersaf.lombardia.it

Abstract
The so-called Nitrates Directive (91/676/EEC) promotes a rational use of livestock manures in agriculture, according to crop requirements and environmental standards. A recent Italian legislation stated that the Regions may define, by means of agrometeorological bulletins in November and in February, the livestock manures spreading periods, considering the meteorological conditions and its consequences on the correct soil and crop management.
In this paper are summarized the different methodologies and experiences of four North Italy regions where livestock farming is particularly intensive, resulting in a potential pollution risk of local water resources.

Keywords: agrometeorology, nitrates, livestock manure, soil.
Parole chiave: agrometeorologia, nitrati, effluenti di allevamento, suolo.

Introduction
The Nitrates Directive (91/676/EEC) is the European Union regulatory reference for the protection of water and soil from pollution caused by nitrates from agricultural sources. National legislation with Ministerial Decree April 19th 1999 (Code of Good Agricultural Practice – COGAP), Legislative Decree 152/2006 and the Ministerial Decree February 25th 2016 defined common rules for the Regions for the adoption of the Nitrates Directive by the regional governments. According to national legislation, the Regions are tasked to define Nitrate Vulnerable Zones and drafting their Action Plans reviewed and updated at four-year intervals. The recent Ministerial Decree February 25th 2016 "General criteria and technical standards for the regional discipline of the agronomic utilization of livestock manure and digestate" by the Ministry of Agriculture and Forestry establishes, the methods of agronomic use, application doses and periods of prohibition of the use of manure, slurry, sludges, sewage, and other organic and nitrogen fertilizers for the autumn and winter season in the NVZs. The article 40 states that the Regions and Autonomous Provinces may provide for an organization of different ban periods, considering the specific local weather conditions and its consequences on crop management. Under these conditions, the Action Programs of the Padano-Veneto basin regions set a 60-day continuous winter banning period in December and January and a further 30 days, even non-continuous, to be settled in November and in February.
The climatic conditions of the Po Plain in February are already favorable for the soils preparation for the spring-summer crops and, consequently, for the distribution of livestock manure. During this period rainfall is basically low and the air temperature and the potential evapotranspiration start to increase, resulting in a decrease of soil moisture. Under such conditions, microbiological soil activity, which regulates the transformation of nitrogen into mineral forms, is still strongly slowed down, resulting in low nitrates leaching. On the other hand, also in the first days of November soils are often still dry in several areas of the Po Plain.
In order to define livestock manure distribution periods and areas, the Regions have developed specific agrometeorological bulletins for farmers.

Materials and Methods
The four regions of the Po Plain have split the territory into homogeneous areas in order to modelling the agrometeorological conditions (e.g. rainfall forecast, calculated evapotranspiration), the soil characteristics (e.g. texture, available water content), the kind of crop (e.g. meadow, winter crop) and the crop/soil management (e.g. soil preparation for early or late autumn sowing, crop residues, soil trafficability).

PIEDMONT REGION
Within the NVZs of Piedmont, 6 reference macro-areas (Fig. 1) have been identified; each area hosts a regional agrometeorological network (RAM) station representative of the local conditions and providing precipitation data in the relevant period (November-February). With the support of IPLA s.p.a., each meteo-climatic area has been superimposed on the information layer of the Regional Pedological Chart (1:250,000) in order to identify a reference pedotype for modeling analysis. Pedological data available for each macro-area (granulometry, bulk density and skeleton) were used as input in the IRRIGUIDA simulation model, along with meteorological data (minimum and maximum air temperature, minimum and maximum relative humidity, precipitation) with the aim of simulating the dynamics of water in the soil for the horizon 0-60 cm. These simulations, carried out in collaboration with the

Phytosanitary Sector – Agrometeorology Section – of the Piedmont Region, were applied from the first saturating autumn rain until the end of February on all available weather data available. These modeling assessments defined, in collaboration with the Department of Agricultural Sciences of the University of Turin, the field capacity, i.e. the water content of the soil in the optimum conditions, as the threshold beyond which in the autumn-winter season the risk of percolation is significant. For each macro-area, IRRIGUIDA was applied using the meteo-climatic data of the reference station and the pedological data of the reference pedotype This simulation, conducted with the same frequency as ARPA Piedmont weather reports, defined the water deficit needed to overcome the field capacity: if the weather forecast indicates a drop in water from the water deficit, spreading activity is blocked, for the validity of the bulletin; if the forecast indicates no rainfall, or a water supply less than or equal to the deficit, spreading activity is permitted.

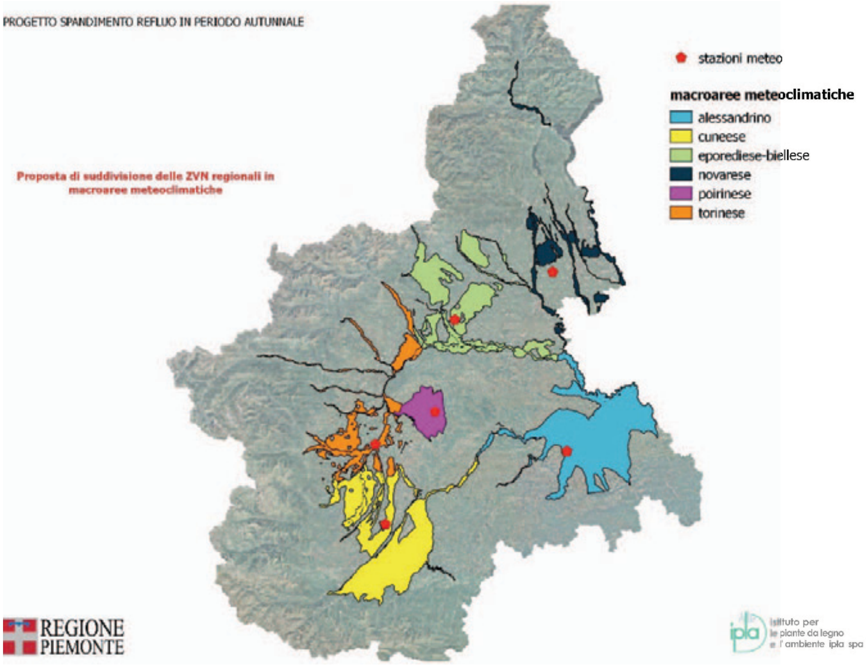


Fig. 1: The 6 macro-areas of Piedmont.
Fig. 1: Le 6 macro-aree del Piemonte.

LOMBARDY REGION

Since October 31th 2016, the regional Agency for the Agriculture and Forest Services of Lombardy (ERSAF), based on the weather information of Environmental Protection Agency of Lombardy (ARPA Lombardy), has carried out the "Nitrate Bulletin".

The information support is based on:

- 6 soil stations of the regional network ARMOSA, dedicated to monitor the behavior of nitrogen and phosphorous in soil-climate-crop systems to obtain data for the soil water balance;
- Daily data on rainfall, temperature, wind, solar radiation, relative humidity and evapotranspiration of the reference agrometeorological stations covering the Lombardy;
- Precipitation forecast the days following the release of the Bulletin based on ECMWF and COSMO (7km grid) weather models. The reference precipitation threshold has been set at 5mm cumulated average in 24 hours (Fig. 2).

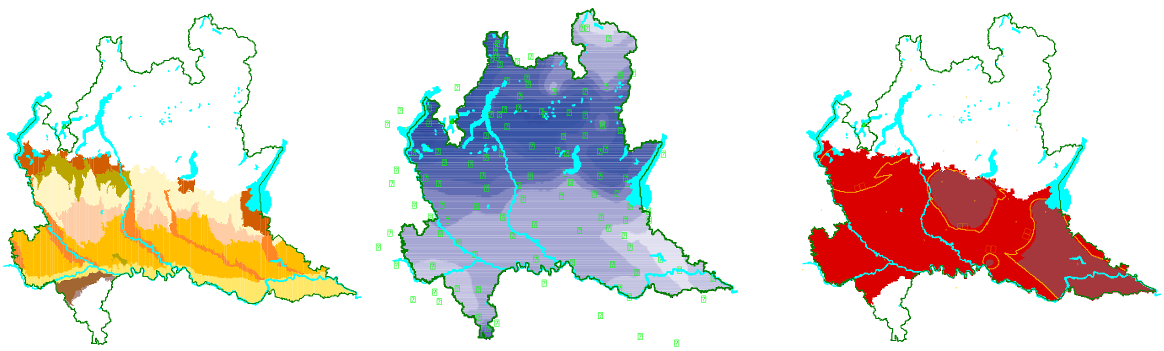


Fig. 2: Lombardy data set; from left: soil map at scale 1:250,000, cumulated annual average rainfall, average annual temperature.
Fig.2: Data set della Lombardia; da sinistra: carta dei suoli a scala 1:250.000, precipitazioni medie annuali, temperatura media annuale.

The integrated analysis of soil and agrometeorological data allowed to identifying 6 macro-areas, each one defined by a dominant soil and a reference meteorological station. Green and red colors define in an intuitive way the permission or the ban to spread livestock manure in each macro-area (Fig. 3).

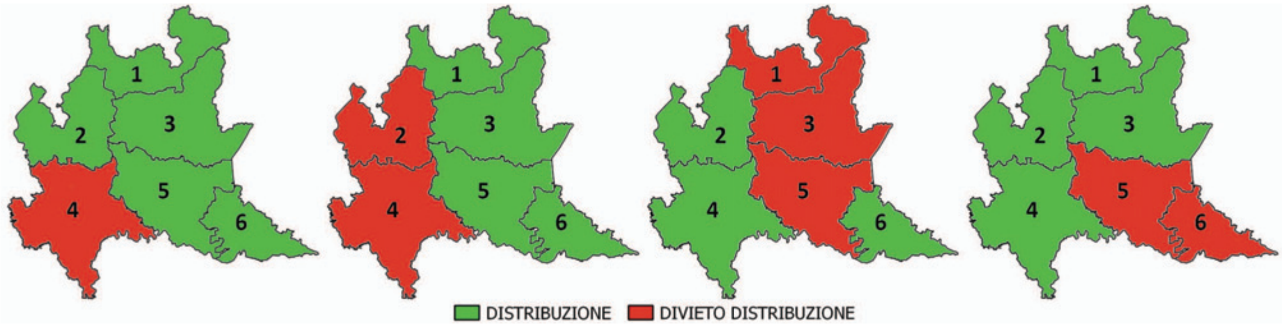


Fig. 3: The 6 macro-areas of Lombardy.
Fig. 3: Le 6 macro aree della Lombardia.

A table summarizes the prohibition days still to be counted, counted from the first day after the validity of each bulletin issued twice a week (Tab. 1).

Nr.	MACRO-AREA	04-nov	05-nov	06-nov	07-nov	Nr. OF DAYS TO BE REGULATING
1	Alpi	SI	SI	NO	SI	89 days
2	Prealpi occidentali	SI	NO	SI	SI	89 days
3	Prealpi orientali	SI	SI	NO	SI	89 days
4	Pianura occidentale	NO	NO	SI	SI	88 days
5	Pianura centrale	SI	SI	NO	NO	88 days
6	Pianura orientale	SI	SI	SI	NO	89 days

Tab. 1: An example of a table of the Lombardy region Nitrate Bulletin.
Tab. 1: Un esempio di tabella del Bollettino Nitrati della regione Lombardia.

EMILIA ROMAGNA REGION

In Emilia-Romagna region, the definitions of the procedures for the application of Regional Regulation no. 1 of year 2016 and the new draft for 2017 are in progress. The draft has been produced in accordance with the Ministerial Decree February 25th 2016. By the end of 2017, specific agrometeorological bulletins will be produced, at least weekly, which will point out the days of possible spreading for homogeneous pedoclimatic areas. The support information for the bulletins will be provided by the Land, Climate and Agrometeorology Office of ARPAE-SIMC, and will include the following products:

- map of available soil water content (Fig. 4);
- maps of soil water deficit with respect to the field capacity condition, for the first 100 and 25 cm (Fig. 5);
- maps of daily precipitation for the following 7 days;
- probability table of daily average precipitation threshold exceeding for the following 7 days;
- maps of current and forecast (for the following day) concentrations of particulate matter (PM10).

The information on particulate matter, although not relevant for legislation, are essential in the Po Valley, where PM10 concentrations can reach levels of health hazard during the winter months. Some nitrogen compounds, particularly ammonia, emitted into the atmosphere from livestock manure, are important precursors of PM10.

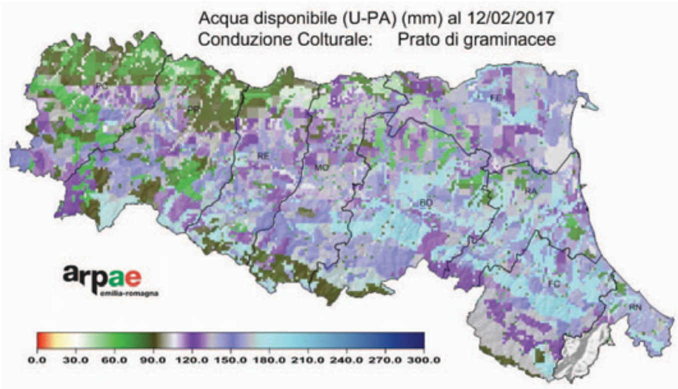


Fig. 4: Map of the water content of the soils in terms of available water in the soil.
Fig. 4: Mappa del contenuto idrico dei terreni in termini di acqua disponibile nel suolo.

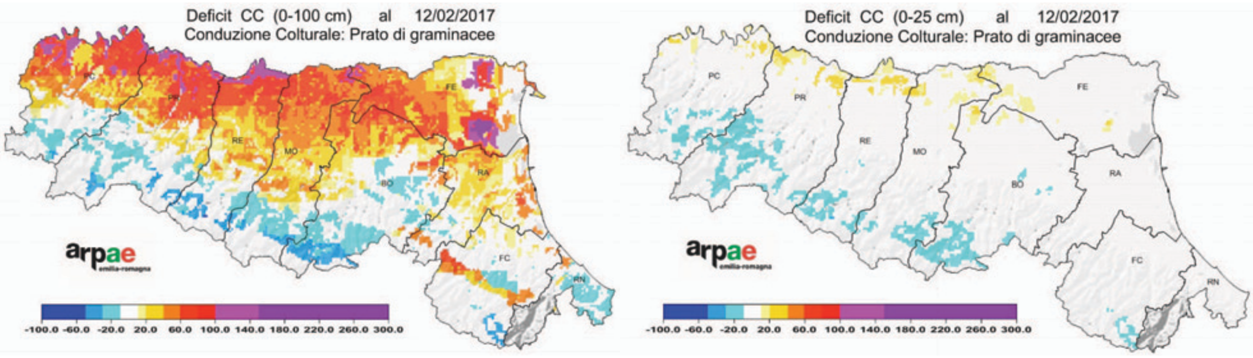


Fig. 5: Water deficit maps with respect to the field capacity condition, relative to the first depth meter and the first 25 cm.
Fig. 5: Mappe di deficit idrico rispetto alla condizione di capacità di campo, relativo sia al primo metro di profondità che ai primi 25 cm.

VENETO REGION

In order to evaluate the presence of conditions suitable or unsuitable for livestock manure spreading in the winter, two sources of information were considered: the data of the ARPAV network stations to evaluate, albeit in large lines, the humidity of the ground based on precipitation, and the EPS (Ensemble Prediction System) produced at ECMWF to estimate the amount of precipitation expected in the following days. Each of the 15 homogeneous macro-areas have been associated with the rain stations and the forecasting points of the meteorological model. Precipitation data is recorded in the previous 3 days and up to the time the bulletin was issued. The condition necessary to suspend the distribution ban is that the average precipitation value in the stations located within the meteorological macro-areas of interest is equal to or less than 10 mm total cumulated.

The prediction system used is a model packet (51) that represents a swarm of variants of the prediction (deterministic model) obtained by appropriately modifying the initial conditions. These variants of the model are considered to be equally probable; Of each of the 51 models is taken into account the accumulated precipitation expected from the issuance date of the bulletin to the next 3 days. The results obtained are translated into a probability of exceeding the 10mm precipitation accumulated over the entire period. The possibility of spreading slurries is only allowed if both requirements are met: the first "dry" soil at the time of issue of the bulletin; The second, that the suitability of soil moisture conditions will remain for at least another 3 days. The result of this evaluation process is produced for each municipality in the region. For each municipality, a red box (persistence of the manure distribution ban) or green color (suspension of the ban) is assigned for the day following the publication of the bulletin. There are also indications of the trend for the next two days. In this case the boxes are pink when forecasts do not seem to favor this operation or light green if, on the contrary, they seem fit (Fig. 6).

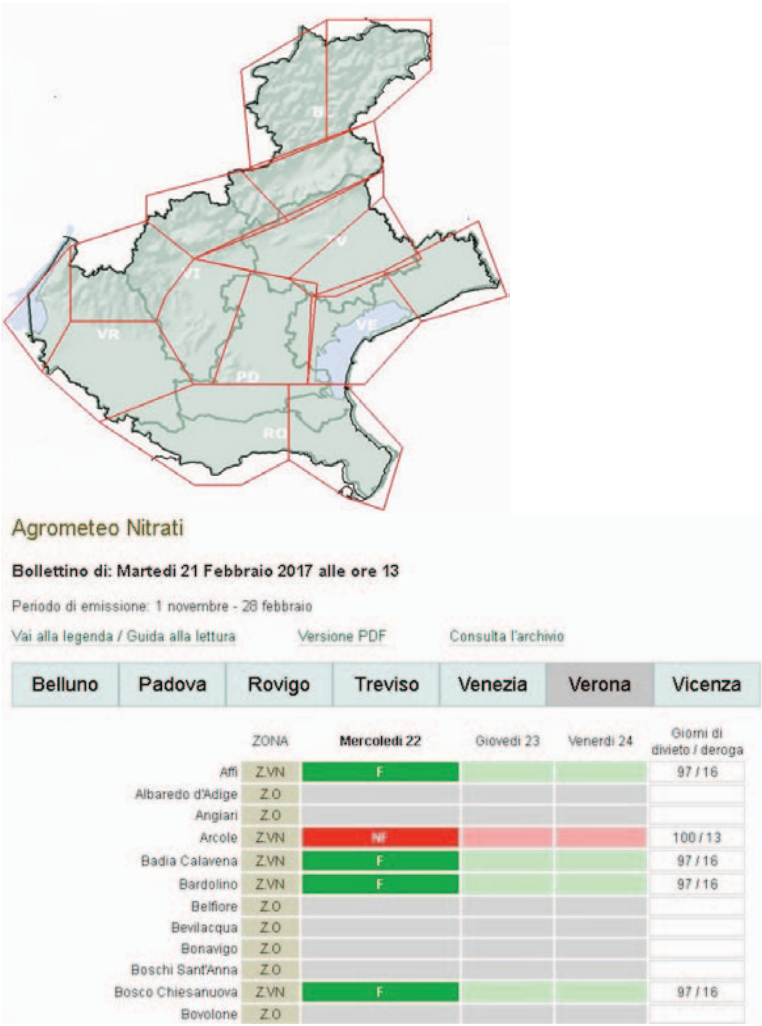


Fig. 6: The 15 Veneto macro-areas and an example of the "Agrometeo Nitrati" bulletin as it appears on ARPAV's website.
Fig. 6: le 15 macro-aree del Veneto e un esempio di Bollettino Agrometeo Nitrati così come appare su sito web di ARPAV.

Results and Discussion

The objective of Ministerial Decree 25th February 2016 and consequently of nitrate bulletins is to manage manure distributions in a more adhering manner to meteorological conditions and soil water content than to a calendar ban (90 consecutive days from the first decade of November to the end of February) imposed by the previous regulations. This regulation often caused difficulties to operators resulting in requests of derogation to the ban on spreading where the meteorological conditions and soil water content were favorable to spreading.

The main knowledge base on the nitrate bulletins is the forecast of weather conditions, with particular reference to precipitation in both quantitative and temporal terms. In fact, rain facilitates nitrate leaching towards the deeper horizons of the soil, increasing the risk of contamination of shallow groundwater. The second element contributing to the definition of spreading periods is the soil water content which, in addition to affecting the leaching, determines, particularly in fine textured soils, the trafficability, i.e. the possibility of fertilizing.

It should be pointed out that farmers must still comply with the Code of Good Agricultural Practice, which lays down the ban on the use of agronomic fertilizers on rainy days and on the following days, on saturated water, on ice and snowy soils and on shallow groundwater, in order the avoid soil leaching and the soil constipation.

The methodology of the nitrate bulletin was shared with the Farmers' Professional Organizations in order to gather remarks and suggestions useful for creating a synthetic product, understandable to the user, and easily disseminated, including mail and messaging services.

In Lombardy region, the bulletin is published on the websites and is sent by e-mail to a mailing list that in early 2017 amounted to about 6,000 subscribers on a potential base of 15,000 companies. In Piedmont region, the bulletin is published twice a week on the regional web page dedicated to agrometeorological services. In Veneto region, the bulletin is issued by the local Environmental Protection Agency (ARPAV) every day, from November to February and is published on the web-site. In all regions, mobile-specific applications are being developing.

Conclusions

The bulletins described are an example of a modern agrometeorological application that derives from a specific regulatory requirement that can improve the management of the livestock manure spreading from the environmental and business point of view.

The new formulation of the regulatory periods of autumn and winter banning provided by DM 25 February 2016 has allowed the regions of Northern Italy to address this complex issue by using their specific meteorological and agronomic knowledge bases.

References

Commissione Europea, 1991. Direttiva relativa alla protezione delle acque dall'inquinamento provocato dai nitrati provenienti da fonti agricole, nr. 676;

G. Antolini, N. Benatti, L. Botarelli, G. Cassanelli, E. Di Giacomo, N. Laruccia, V. Marletto, A. Pasquali, W. Pratizzoli, F. Siviero, 2016. Web service of the Emilia-Romagna for the reduction of the risk of nitrogen fertilizers being diluted. "Nuove avversità e nuovi servizi per gli agroecosistemi", Prooceedings AIAM Conference, June 14-16th 2016 Bologna;

Repubblica Italiana, 1999. Ministerial Decree: Codice di Buona Pratica Agricola – CBPA;

Repubblica Italiana, 2006. Legislative Decree nr. 152;

Repubblica Italiana, 2016. Ministerial Decree: "Criteri e norme tecniche generali per la disciplina regionale dell'utilizzazione agronomica degli effluenti di allevamento e delle acque reflue, nonché per la produzione e l'utilizzazione agronomica del digestato";

Regione Lombardia, 2016. Decree of Regional Agriculture Directorate nr. 10607: "Individuazione dei divieti temporali di utilizzazione agronomica nella stagione autunno vernina 2016/2017 in applicazione del DM 25 febbraio 2016";

Regione Piemonte, 2007. Resolution of the President of the Regional Council nr. 10/R. Regional Rule: "Disciplina generale dell'utilizzazione agronomica degli effluenti zootecnici e delle acque reflue e programma di azione per le zone vulnerabili da nitrati di origine agricola";

Regione Piemonte, 2016. DD nr. 1055: "Regolamento regionale 29 ottobre 2007, n. 10/R. Modalità operative per la definizione dei calendari invernali di sospensione dell'utilizzo agronomico di cui all'articolo 25 comma 2";

Regione Veneto, 2016. Resolution of the President of the Regional Council nr. 1835.

DEVELOPMENT AND ASSESSMENT OF OLIVE ORCHARD GROWTH MODEL

SVILUPPO E VALUTAZIONE DI UN MODELLO MECCANICISTICO PER L'OLIVETO

M. Moriondo[1*], L. Brilli[1], L. Leolini[2], C. Dibari[2], R. Tognetti[1], B. Rapi[1], P. Battista[1], G. Caruso[3], R. Gucci[3], G. Argenti[2], S. Costafreda-Aumedes [2], M. Bindi[2].

[1] IBIMET-CNR, Via Madonna del Piano 10, 50019 Sesto Fiorentino (Fi), Italy
[2] University of Florence, DiSPAA, Piazzale delle Cascine 18, 50144 Firenze, Italy.
[3] University of Pisa, DISAAA-a, Via del Borghetto, 80, 56124, Pisa, Italy.
[*]marco.moriondo@cnr.it

Abstract
In the last decades, several crop simulation models have been developed and applied worldwide. The majority of these models was focussed on simulating growth cycle and related yields of most traditional annual crops (wheat, maize, etc.). By contrast, only few models were developed to simulate perennial crops such as olive orchard. The scarcity of these models was probably due to the complexity at reproducing dynamics between ground and tree vegetation. In this work, a simplified process-based approach was used to estimate soil water dynamics and daily biomass accumulation considering the competition for soil water availability on both ground and tree biomass production. Preliminary results confirmed the reliability/possibility of this simple approach at reproducing daily water and carbon dynamics within olive orchards.

Keywords: Olive orchards, Modelling, Net primary production, Soil water dynamics
Parole chiave: Oliveto, Modellistica, Produzione primaria netta, Dinamiche idriche del suolo

Introduction
Simulation models were extensively applied to assess the potential of several ecosystems (i.e. crop, grassland, forests) at different levels of aggregation (farm, region, nation) for a broad gradient of geographical and climatic conditions (Brilli et al., 2017). The majority of these models were focused on simulating crop growth cycle and yield of traditional annual crops (i.e. wheat, maize, etc.). By contrast, just few models were developed to simulate perennial crops such as olive orchards. The inter-dynamics between ground and tree vegetation (i.e. interaction between layers with different eco-physiological characteristics) and the effects of agricultural practices commonly applied in orchards (i.e. tillage, pruning, irrigation, etc.) makes the modelling of these systems a challenge. So far, some models have been proposed: Abdel-Razik (1989),Sinoquet et al. (2001), Díaz-Espejo et al. (2002), Díaz-Espejo et al. (2006), Villalobos et al. (2006), Maselli et al. (2012), Viola et al. (2012) and Morales et al. (2016). Many of these, however, show some limitations such as the need of a complex parametrization (i.e. high costs due to data required from specific test-site), lack of environmental stresses – which are typical in Mediterranean environments within simulated processes, low quality model outcomes at site-scale investigation (i.e. remote sensing models). In order to overcome many of these limitations, we developed a model to simulate daily biomass accumulation of an olive orchard using a simplified approach which takes into account the competition for soil water between grass cover and olive tree. Preliminary results confirmed the reliability of this simple approach at reproducing daily water and carbon dynamics within an olive orchard.

Materials and Methods
Model description: The model simulates on a daily time step the growth and development of olive agroecosystem, including olive tree and grass cover growth and their competition for water (Fig.1). A phenological sub model simulates the sequence of vegetative and reproductive stages of olive tree for determining changes in biomass allocation along olive tree. Final yield is calculated at the end of the growing season as a fraction of total olive tree biomass accumulation (harvest index, HI). The key process of the model is the simulation of daily potential biomass increase (g dry matter m^{-2}) for both layers as dependent on the relevant intercepted (INT.RAD, %) daily photosynthetic active radiation (RAD, MJ m^{-2}), and Radiation Use efficiency (RUE, g MJ^{-1}). The fraction of transpirable soil water, (FTSW. i.e. the ratio between the actual and total soil water content) is used as index to rescale potential growth and leaf area of olive tree and grass cover to their actual values).
Study area: Experimental data from two different sites located in Tuscany region (Italy) were used to calibrate and validate the growth model: *i)* FTSW measured in a 25 years old orchard located at Istituto Tecnico Agrario Statale (ITAS) farm (Florence, 10.35 E, 43.5 N); *ii)* Net Primary Production (NPP) extrapolated from three years eddy covariance data (2010-2012) in a rainfed olive orchard located in "S. Paolina" experimental farm of National Research Council (Follonica. 42.55N, 10.45E).

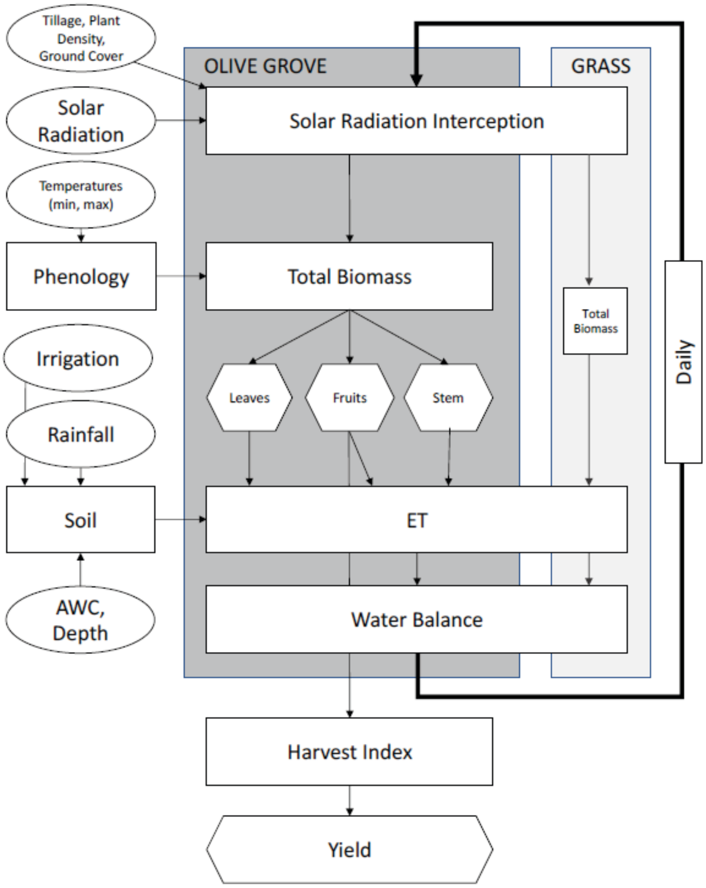


Fig.1 - State flow chart of the olive orchard model
Fig. 1 – Diagramma di flusso del modello di crescita dell'olivo e del cotico erboso

Results and Discussion

Preliminary results for the FTSW simulation over the soil profile indicated that the model correctly simulated the daily course of FTSW in the layer explored by both grasses and olive tree rooting system (0-30 cm, r^2=0.91).

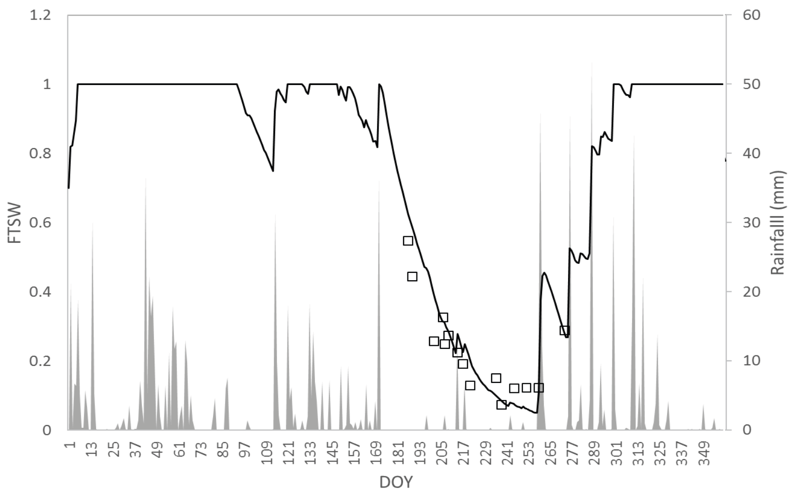


Fig.2 - Daily course of observed and simulated FTSW in 2016 at 30 cm
Fig. 2 – Andamento di FTWS osservata e simulata nel 2016 a 30 cm di profondità a scala giornaliera

In particular, the model simulated correctly both the drought stress experienced by the orchard during summer 2016 and the soil water recharge after early autumnal rainfalls (i.e. DOY 262).

The model was additionally tested against three years of eddy covariance data (2010-2012) to simulate daily NPP. The daily trend of NPP simulated in 2010 (Fig. 3a) showed the ability of the model to detect and reproduce the two main peaks of dry matter production of the orchards (i.e. early and late springtime). On yearly basis, the model slightly underestimated the olive orchard biomass (745 g dw m^{-2}) compared to the observed (827 dw g m^{-2}).

The model was able to well reproduce the daily NPP trend also in the following years (2011 and 2012, Fig. 3b, c). In particular, the model was able to reproduce the effect of prolonged drought periods on NPP in both years. In 2011 and 2012 the olive orchard experienced lower assimilation rate with respect to 2010 since the cumulated rainfall were approximately 57% of the rainfall occurred in 2010 (450 mm). The lower amount of rainfall resulted in an observed decrease of biomass accumulation, which resulted in a total cumulated NPP of 585 and 518 g dw m^{-2} for 2011 and 2012 respectively. The model correctly simulated this pattern, showing good performances especially in 2011 where the simulated olive orchard cumulated NPP (595 g dw m^{-2}) was close to the observed one. In 2012, despite the daily trend of NPP was well captured by the model (Fig. 3c), the simulated pattern overestimated (620 g dw m^{-2}) the observed one (518 g dw m^{-2}). This was mainly due to a higher autumnal photosynthetic activity. Overall, the model was able to reproduce the yearly trend of three contrasting years, capturing changes of carbon driven by climatic variables, thus resulting a reliable tool for olive orchards biomass prediction.

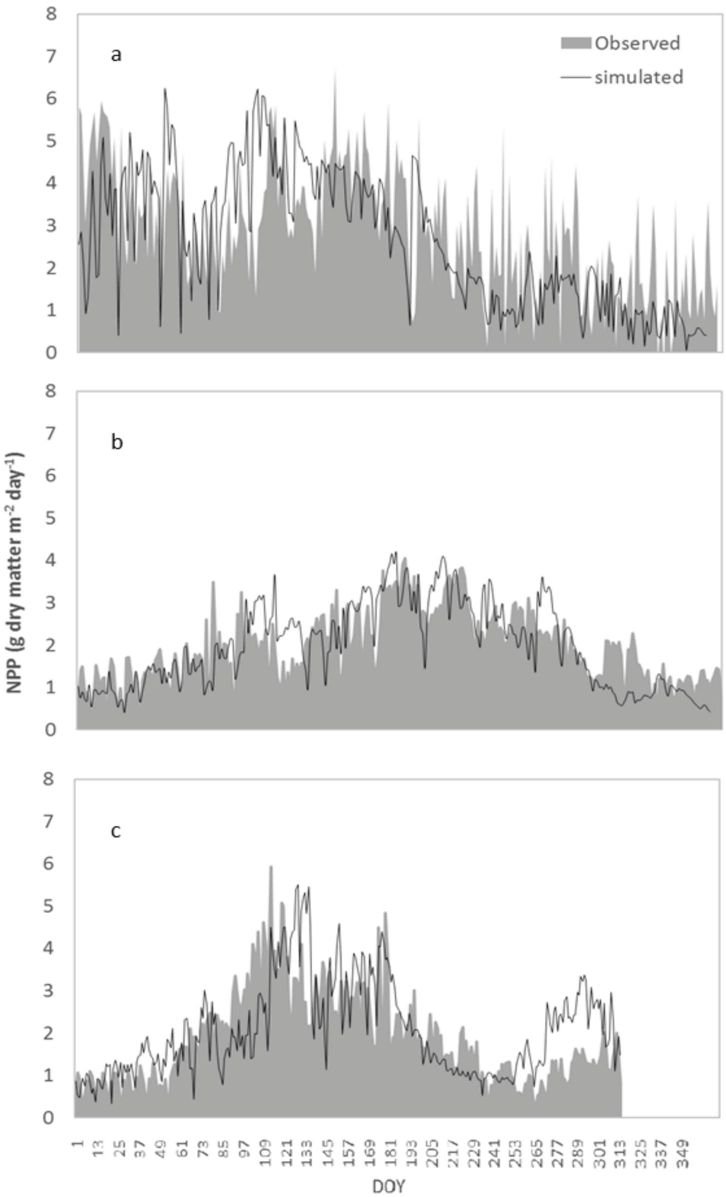


Fig.3 - Daily pattern of observed (grey area) and simulated (solid line) NPP of olive orchard at S. Paolina for 2010 (a), 2011 (b) and 2012 (c)

Fig.3 – Trend giornaliero di NPP osservata (area grigia) e simulata (linea continua) dell'oliveto di S. Paolina per il 2010 (a), 2011 (b) e 2012 (c)

Conclusions

The olive orchard growth model is able to reproduce olive orchard biomass production by assessing the relative contribution of grasses and olive tree to dry matter production taking into account competition for soil water availability by both systems. Results showed high performances at reproducing FTSW dynamics and daily NPP trend under different climate conditions. These results suggest the reliability of this tool at quantifying and reproducing daily olive grove dynamics (i.e. water and carbon), highlighting also the potential of this tool to enhance olive orchards biomass prediction. Further efforts are needed to improve model structure and performances, also employing new field experiments and new algorithms to release a complete and reliable model specific for olive tree systems.

References

Abdel-Razik M, 1989. A model of the productivity of olive trees under optional water and nutrient supply in desert conditions. Ecol Modell 45:179–204.

Brilli L., Bechini L., Bindi M., Carozzi M., Cavalli D., Conant R., Dorich C., Doro L., Ehrhardt F., Farina R., Fitton N., Francaviglia R., Grace P., Iocola I., Klumpp K., Léeonard J., Martin R., Massad R.S., Recous S., Seddaiu G., Sharp J., Smith P., Smith W., Soussana J.F., Bellocchi G. 2017. Review and analysis of strengths and weaknesses of agro-ecosystem models for simulating C and N fluxes. Sci Total Environ 598:445–470. doi: 10.1016/j.scitotenv.2017.03.208

Diaz-Espejo, A., Hafidi, B., Fernandez, J.E., Palomo, M.J., 2002. Transpiration and photosynthesis of the olive tree: a model approach. In: Vitagliano, C., Martelli, G.P. (Eds.), Proc 4th IS Olive Grow 586, 457–460.

Díaz-Espejo A, Walcroft AS, Fernández JE, Hafridi B, Palomo MJ, Girón IF 2006. Modeling photosynthesis in olive leaves under drought conditions. Tree Physiol 26:1445–1456.

Maselli F, Chiesi M, Brilli L, Moriondo M, 2012. Simulation of olive fruit yield in Tuscany through the integration of remote sensing and ground data. Ecol Modell 244:1–12. doi: 10.1016/j.ecolmodel.2012.06.028

Morales A, Leffelaar PA, Testi L, Orgaz F, Villalobos FJ, 2016. A dynamic model of potential growth of olive (Olea europaea L.) orchards. Eur J Agron 74:93–102. doi: 10.1016/j.eja.2015.12.006

Moriondo M, Ferrise R, Trombi G, Brilli L, Dibari C, Bindi M. 2015. Modelling olive trees and grapevines in a changing climate. Environ Model Softw 72:387–401. doi: 10.1016/j.envsoft.2014.12.016

Sinoquet H, Le Roux X, Adam B, Ameglio T, Daudet FA. 2001. RATP: a model for simulating the spatial distribution of radiation absorption, transpiration and photosynthesis within canopies: application to an isolated tree crown. Plant Cell Environ 24:395–406.

Villalobos FJ, Testi L, Hidalgo J, Pastor M, Orgaz F. 2006. Modelling potential growth and yield of olive (Olea europaea L.) canopies. Eur J Agron 24:296–303. doi: 10.1016/j.eja.2005.10.008

Viola F, Noto LV, Cannarozzo M, La Loggia G, Porporato A. 2012. Olive yield as a function of soil moisture dynamics. Ecohydrology 5:99–107. doi: 10.1002/eco

A COMPARATIVE STUDY OF THE EFFECT OF BIOCHAR AND HYDROCHAR ON THE WATER BALANCE IN SANDY SOILS

UNO STUDIO COMPARATIVO DELL'EFFETTO DI BIOCHAR E HYDROCHAR SUL BILANCIO IDRICO SU SUOLI SABBIOSI

Antonio Volta[1*], Giulia Villani[2], Gabriele Antolini[3], Fausto Tomei[3], William Pratizzoli[3], Giuseppe Gherardi[4], Vittorio Marletto[3], Lucio Botarelli[3]

[1] Dipartimento di Scienze Agrarie, Università di Bologna, Viale Fanin 44, 40127, Bologna
[2] Dipartimento di Scienze e Tecnologie Agro-Alimentari, Università di Bologna, Viale Fanin 50, 40127, Bologna
[3] ARPAE SIMC, viale Silvani 6, 40122, Bologna
[4] ET Ecoinnovative Technologies, vie del Borgo di San Pietro 26, 40125 Bologna
*avolta@arpae.it

Abstract
Adaptation to Climate Change (CC) is necessary due to the strong effects we started to experience in the last years. One of the main issue in agriculture is how to make production more resilient to CC in terms of water. Severe droughts are much more common than before. Years 1998, 2003, 2007, 2012, 2015, and 2017 showed all criticalities connected to irrigation water supply, although the supply chain in this region is very efficient.
Biochar (obtained by pyrolysis) and hydrochar (obtained by hydrothermal carbonization) were vastly studied in literature as a potential breakthrough to make agriculture sustainable. In this study we perform an analysis of the water balance on crop systems on sandy soils. Both biochar and and hydrochar show an undeniable improvement of physical soil properties in terms of water retention. This feature could be a key driver to cope with many problems we have in the traditional soil management.

Keywords: biochar, hydrochar, irrigation, corn, agrometeorological modelling.
Parole chiave: biochar, hydrochar, irrigazione, mais, modellistica agrometeorologica.

Introduction
The first documented uses of char as soil amendment come from the Amazon basin, in the so called "terra preta de Indio". Indios of Northern Brazil discovered that such a material was helpful to make soil suitable for crop production.
The char can be produced in different ways. Different thermochemical treatments produce the so called biochar (by pyrolysis) and hydrochar (by HTC, Hydrothermal Carbonization Process) (Kambo and Dutta, 2015). The first one is ideal if produced by low water content biomass, whereas hydrochar is a process happening at 40-70% of water content.
In the last two decades char was vastly studied as potential element for a sustainable agriculture. Indeed the use of char as amendment is a smart technique to store recalcitrant C in soil (mitigation measure). Moreover it was noticed that presence of biochar in soil increases the organic matter improving fertility and retains plant nutrients within the first soil layers (Grossman et al., 2010).
Besides the positive mitigation effects, char drastically modifies the physical soil properties bringing several soils positive effects about water retention (adaptation measure). Water dynamics is completely different if compared with a "standard" soil. In this work, we try to investigate how biochar and hydrochar influence the water balance and the irrigation management for a staple crop as corn in a temperate climate such as in Emilia-Romagna.

Materials and Methods
This study provides a simulation of the water balance during the years 2003-2007.
We used the CRITERIA software to simulate the water balance (Campi et al., 2014). Time series were taken from the grid 1362 of the CREA-CMA grid centred in Zattaglia (lat: 44.20078, lon: 11.68779, altitude: 180 m a.s.l.). No water table was taken into account. We chose corn as test crop, because of its high water demand. CRITERIA was set in order to provide irrigation as long as necessary during the vegetative season. Seven kind of different soils were tested: control, biochar_1, biochar_5, hydrochar_1, hydrochar_5. The suffix number of the soil tag identifies the percentage of char (in weight) inserted into the soil profile. The sandy soil has texture 91.6% sand, 7% silt, 1.4% clay, soil depth was set at 200 cm and supposed homogenous throughout all the profile. Water retention curves used were the van Genuchten with the parameters defined in Abel *et al*., 2013. Types of biochar and hydrochar used for simulations have also the characteristics of those in Abel *et al*., 2013. Saturated water conductivity (Ksat) was deduced by Barnes *et al.*, 2014. They report that Ksat in amended sandy soil drops up to 92%. We maintain this ratio for the full amended soil while for biochar_1 and hydrochar_1 we decreased Ksat by 18.4% by assuming linearity in Ksat reduction.

Results and Discussion

Irrigation (mm)	control	biochar_1	biochar_5	hydrochar_1	hydrochar_5
2003	256	250	100	200	26
2004	203	150	50	100	0
2005	207	200	50	150	0
2006	175	150	50	100	31
2007	241	200	50	200	35

Tab. 1: Maize irrigation water needs from 2003 to 2007 for the five different tests.
Tab. 1: esigenze irrigue di mais dal 2003 al 2007 per i cinque diversi trattamenti.

Drainage (mm)	control	biochar_1	biochar_5	hydrochar_1	hydrochar_5
2003	505	416	455	363	438
2004	570	441	327	403	303
2005	776	681	570	636	567
2006	328	281	360	248	340
2007	284	188	127	160	129

Tab. 2: Deep drainage from 2003 to 2007 for the five different tests.
Tab. 2: drenaggio profondo dal 2003 al 2007 per i cinque diversi trattamenti.

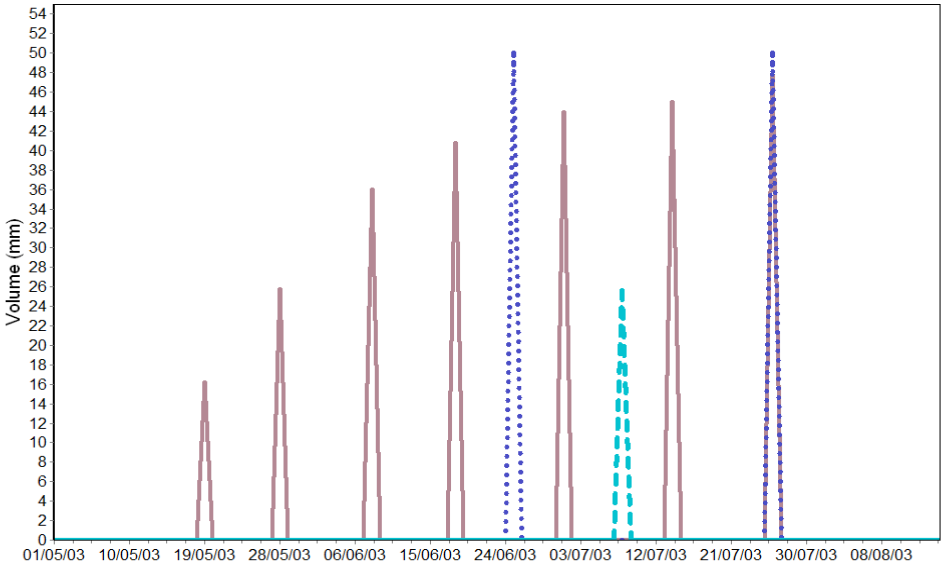


Fig. 1: Irrigation in 2003 dates and volumes: control (solid line), biochar_5 (dotted line), hydrochar_5 (dashed line).
Fig. 1: Irrigazione 2003 date e volumi: controllo (linea continua), biochar_5 (linea punteggiata), hydrochar_5 (linea tratteggiata).

Table 1 shows the irrigation water requirement for maize field in mm. Table 2 shows the deep drainage in mm for the different situations.
Compared to the control plot (100%) the yearly mean water demand was 87%, 27%, 68% and 8% for biochar_1, biochar_5, hydrochar_1, hydrochar_5 respectively.
Compared to the control plot (100%) the yearly mean deep drainage was 80%, 75%, 71% and 72% for biochar_1, biochar_5, hydrochar_1, hydrochar_5 respectively.
In Fig. 3 we show as example the 2003 season in terms of irrigation as established by the CRITERIA rules. Instead of the 7 interventions required by the control starting on May 19th (solid line), biochar_5 irrigation season starts on June 25th and on hydrochar_5 July 8th. The delay and shortening of the irrigation season is a big advantage for water authorities in terms of water, energy supply and, as consequence, of money. In extreme drought cases, the char soil amendment can save the crop yield (see for instance the 2012 season).

Conclusions

In this work, we have simulated the water balance through the CRITERIA model starting from observed weather data.
Simulations clearly show that in sandy soils the char amendment could be a breakthrough in water management in a

climate such as that of the Emilia-Romagna region and can be seen as an important measure for CC adaptation. The theoretical simulations here represented are unrealistic for real soils because of soil and root depth. However this study gives a clear idea about the contribution of char. We recommend to carry out experiments to assess our theoretical findings. Moreover, it would be very interesting to work on further soils present in our region in order to get a map of potential water saving due to amendment.

References

Barnes, R.T., Gallagher M.E., Masiello C.A., Liu Z., Dugan B., 2014. Biochar-Induced Changes in Soil Hydraulic Conductivity and Dissolved Nutrient Fluxes Constrained by Laboratory Experiments. PlosOne 9 (9): 1-9.

Campi P., Modugno F., Mastrorilli M., Tomei F., Villani G., Marletto V., 2014. Evapotranspiration of tomato simulated with the CRITERIA model. Italian Journal of Agronomy 9 (2): 93-98.

Grossman J.M., O'Neill B.E., Tsai Ss.M., Liang B., Neves E., Lehmann J. ,et al., 2010. Amazonian anthrosols support similar microbial communities that differ distinctly from those extant in adjacent, unmodified soils of the same mineralogy. MicrobEcol 60:192–205.

Kambo H.S., Dutta A., 2015. A comparative review of biochar and hydrochar in terms of production, physico-chemical properties and applications. Renewable and Sustainable Energy Reviews 45: 359–378.

PREDICTION OF WHEAT YIELD USING RELATIONSHIP BETWEEN VEGETATION INDICES, PLANT N AND BIOMASS AT HEADING
PREVISIONE DELLA RESA DEL FRUMENTO ATTRAVERSO INDICI IPERSPETTRALI, AZOTO, E BIOMASSA A SPIGATURA

Pasquale De Vita[*1], Sergio Saia[1], Salvatore Antonio Colecchia[1], Ivano Pecorella[1], Costanza Fiorentino[2], Bruno Basso[3]

[1] Council for Agricultural Research and Economics, Cereal and Industrial Crops Research Centre (CREA-CI), SS 673 km 25+200, 71122 Foggia, Italy
[2] School of Agriculture, Forestry, Food, and Environmental Science, University of Basilicata, Viale Ateneo Lucano 10, 85100 Potenza, Italy
[3] Department of Geological Science and Kellogg Biological Station, Michigan State University, 288 Farm lane, East Lansing, MI 48823, USA
*pasquale.devita@crea.gov.it

Abstract
The ability to predict wheat yield in a Mediterranean environment is limited by a number of factors. These include the variability of soil N that is available within a growing season and between years, and the highly variable nature of climatic conditions in this environment. These factors interact to confound the relationship between N inputs and actual N that is available for plants at a given phenological stage or period of the year. We measured passive reflectance by crop with a proximal hyper-spectral sensor and computed 38 indexes related to various canopy traits at heading and related their integration to grain yield. The experiment was conducted over 2 growing seasons for 2 durum wheat cultivars subjected to 6 fertilization strategies and two fungicide treatments at heading. Relatively high coefficients of determination were obtained by modelling yield by the indexes used and some plant traits at heading, including heading date. We conclude that this was due to the reflectance indexes rather than crop biomass, N or heading date. Among predictors, chlorophyll vegetation index (CVI) was frequently included in the models, which could depend on the ability of CVI to capture the variability of biomass and its N concentration. However, since both of the cropping seasons had adequate rainfall and homogeneous rainfall distribution, additional research is still needed to model wheat yield by proximal sensing in environments or years with lower and/or more erratic rainfall.

Keywords: proximal sensing, reflectance, grain yield, quality, yield prevision.
Parole chiave: proximal sensing, riflettanza, resa in granella, qualità, previsione della resa.

Introduction
Climatic conditions in Mediterranean semiarid environments are erratic which results in difficult correlating N inputs and actual N availability for plants at key phenological stages or period of the growing season. Because of this high degree of variability, fertilization strategies such as split application or modulating its amount can help in enhance crop responses to fertilizers (Colecchia et al., 2013). In Mediterranean environment, this prediction is partly allowed by the dependence of the wheat biomass and N uptake at harvest by the corresponding traits at heading (Masoni et al., 2007; Barraclough et al., 2014). However, measuring biomass and N uptake at given phenological stages is costly and time consuming. We investigated the use of proximal hyper-spectral sensing to capture the variability in yield and grain N uptake explained by biomass and its traits at heading. In the present study, data for 38 reflectance-derived indexes, biomass and N content recorded at heading stage were used to forecast wheat yield and grain N uptake of two semi-dwarf durum wheat cultivars under 6 fertilization strategies.

Materials and Methods
The experiment reported here was performed at the CREA-CI of Foggia, Italy in the 2012-13 and 2013-14 on a Typic Chromoxerert as a split-plot (4 replicates) with the following treatments: main plots were cultivar (CV, PR22D89 and Iride) and fertilization strategy (see table 1 for the explanation of the treatments); split-plot was fungicide application; size of the split-plot was 1.5 m × 7.5 m. The crop was sown at 380 viable seeds m^{-2} at 17.5-cm wide rows and an herbicide was used to control weeds. The degree of infection by rust was evaluated at heading time. Reflectance was recorded with a FieldSpec® Hand-Held Pro portable spectroradiometer (Analytical Spectral Device, Boudler, CO, USA) which had a spectral range from 350 to 1100 nm and FOV of 25º. The following indices were derived from proximally-sensed, hyper-spectral reflectance data (psHRDIs): WDVI; GNDVI; TVI; CRM; CVI; CGM; PVI; SAVI; TSAVI; SAVI2; MSAVI1; MSAVI2; EVI; EVI2; eta; GEMI; OSAVI; NDVI; NDRE; NDRE2; MTCI; CARI; TCARI; MCARI; MCARI1; MCARI2; SARVI; MTVI; MTVI2; TCARI/OSAVI; MCARI/OSAVI; MCARI/MTVI; MCARI/MTVI2; NDRE1/NDVI; NDRE2/NDVI; MSAVI; CCCI; CCCI*NDVI. Definitions and formulae for these indices can be found in Basso et al. (2016).

Tab. 1: Code, timing and amount of fertilizer N (kg N ha^{-1}) applied in the various fertilization strategy treatments.
Tab. 1: Codice, momento di applicazione e quantità (kg N ha^{-1}) di fertilizzante applicato nei diversi trattamenti di fertilizzazione.

code	pre-sowing	early tillering	late tillering	stem elongation (2nd node)	booting	*total N applied*
T0	0	0	0	0	0	***0***
T1	36	54	0	0	0	***90***
T2	36	64	0	40	0	***140***
T3	36	64	0	30	10	***140***
T4	36	54	54	27	0	***171***
T5	36	27	0	27	10	***100***

Correlations were calculated at heading stage among psHRDIs and between each psHRDI with biomass and N content using SAS/STAT software (CORR). Grain yield was modelled by means of stepwise regression analyses (REG procedure, with slentry=0.10 slstay=0.05 options), taking into account the collinearity among the predictor used (Collin option), thus retaining only those non-significantly correlated (at a Pearson p statistic higher than F at 5% probability level). Stepwise regression analysis included or not plant biomass, its N content and date of heading (expressed as days from the fist of April). Data on yield, biomass, N contents and grain quality at grain maturity were subjected to analysis of variance (Glimmix procedure) according to the experimental design. Differences among means were compared by applying t-grouping with Tukey-Kramer correction at the 5% probability level to the LSMEANS p-differences. Finally, 3 orthogonal contrasts were computed. The first contrast represents the effect of fertilization and is calculated as (T0) vs (mean of all others). A second contrast represents the increase of N availability and stem elongation and booting calculated as (T1) vs (mean of T2 and T3) and a third contrast represents the increase of N availability at late tillering (T4) vs (mean of T2 and T3)

Results and Discussion

RAINFALL AND TEMPERATURES AND CROP BIOMASS, YIELD AND N CONTENT

Total rainfall, in both cropping seasons, was close to the long-term mean (479 mm year^{-1}) and very well distributed (De Vita et al. 2017). Fall temperatures in both years and winter temperatures in 2013-14 were higher than the long-term mean. Spring temperatures lower than the long-term mean for both years. This likely favoured the expression of the yield potential in both cultivars and for the N treatments as confirmed by the small differences in grain yield among fertilization strategies (4.46 versus 5.42-5.84 t grain ha^{-1} in unfertilized and fertilised treatments, respectively). However, high rainfall and temperatures also favoured rust infection in all treatments (data not shown). Indeed, fungicide treatment increased rain yield by 11.1% with few differences among other treatments. Differences among treatments in N uptake, and thus grain protein concentration (11.1-13.2%) were slightly higher than differences in grain yield. This suggests that N accumulation was limited by N availability and not by fertiliser splitting or other ecological conditions. This likely occurred due to the low N use efficiency achievable when high water availability occurs. In the present work, an apparent N agronomic efficiency analysis suggested that N derived from soil at increasing application rates of fertilisers ranged between 79 and 99 kg N ha^{-1} and apparent fertiliser N uptake efficiency was around 26.2%±3.36% depending on the genotype and fungicide treatment (fig. 1). These results are in agreement with those obtained by applying ^{15}N to trace N movements from soil to plants in other genotypes of the same species (Saia et al., 2014).

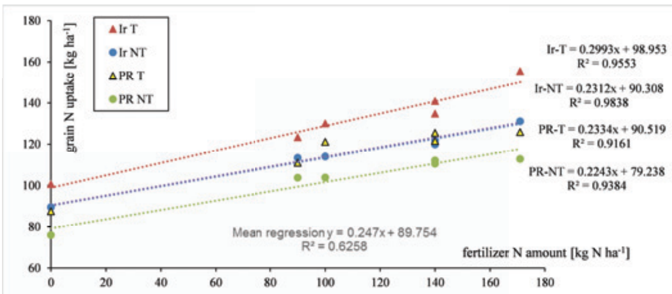


Fig. 1: Relationship between fertilizer N applied in the various fertilization scenarios and grain N uptake for the cultivars Iride (Ir) or PR22D89 (PR) treated with a fungicide at heading (T) or not treated (NT). Linear regression equation per treatment and mean are shown.
Fig. 1: Relazione tra quantità di N fornito col fertilizzante nei vari scenari di fertilizzazione azotata e azoto accumulato nella granella delle cultivar Iride (Ir) e PR22D89 (PR) trattate con un fungicida alla spigatura (T) o non trattate (NT). Le regressioni lineari per trattamento e media sono mostrate.

GRAIN YIELD PREDICTION

Prediction of grain yield by the use of psHRDIs, crop traits (biomass and N content and concentration) at heading stage or both resulted in various level of prediction ability. Coefficients of determination (R^2) were relatively high when psHRDIs were included in the modelling phase with R^2 values that ranged from 0.58 to 0.81. Slightly lower R^2 values (0.38 to 0.76) resulted when sole crop traits were used (table 2). These coefficients of regression are higher than those found in other studies that included fewer indices than we used (Raun et al., 2001) and similar to the R^2 values found by data mining reflectance data (Thorp et al., 2017). When psHRDIs and crop traits were at the same time used in the modelling procedure, very few differences were found with the models built with psHRDIs. In particular, only the stepwise regression built for the PR22D89 data (untreated+fungicide treated data pooled) differed in psHRDIs+crop traits compared to psHRDIs only (data not shown). In particular, inclusion of crop traits at heading stage increased R^2 of the model to 0.75, decreased intercept to –11.86 t grain ha^{-1}, and increased NDRE1/NDVI (the most important predictor) beta coefficient to 39.3 t grain unit $index^{-1}$. Among crop traits, only heading date was retained in this latter analysis, but its contribution to the total regression was negligible (β=0.12 t grain day^{-1}). Despite intecept of the models were never significantly negative (table 2, p not shown), they varied widely among treatments. Similarly the variables taken into account by the modelling procedure varied by the subpopulation of yield data modelled and no common predictor among models was found.

Tab. 2: Beta coefficients, intercepts and R^2 of the stepwise regression models built with all data (Tot, n=192), with data split per genotype [G] (Iride or PR22D89, n=96), or per fungicide treatments [F] (fungicide treated [Fu-TR] or untreated [UnTR]) or G×F interaction (n=48). Negative intercept values were not different than 0 at p<0.05. All beta coefficients were significantly different than 0 at p<0.05.
Tab. 2: Coefficienti angolari, intercette e R^2 dei modelli di regressione stepwise costruiti con tutti i dati (Tot, n=192), per singoli genotipi [G] (Iride o PR22D89, n=96), trattamento fungicida [F] (trattato [Fu-TR] o controllo non trattato [UnTR]) o interazione G×F (n=48). Le intercette negative non erano significativamente diverse da zero a p<0.05. Tutti i coefficienti angolarierano significativi a p<0.05.

	Iride		PR22D89		Iride	PR22D89	UnTR	Fu-TR	Tot
	UnTR	Fu-TR	UnTR	Fu-TR					
beta coefficients of proximally sensed hyperspectral reflectance derived indexes (psHRDIs), only									
Intercept	2.61	3.00	-2.10	4.99	2.77	-1.39	1.23	0.84	0.62
NDRE									
CRM								2.48	1.91
CVI		-0.93	-0.71	-0.51	-0.52	-0.61		-0.93	-0.69
NDRE1/NDVI			24.79			22.50		14.54	13.39
MTCI	1.84	5.06			3.66				
GEMI							2.22		
CCCI				6.47			3.46		
R^2	***0.72***	***0.71***	***0.81***	***0.71***	***0.58***	***0.69***	***0.72***	***0.70***	***0.63***
beta coefficients of crop traits at heading (heading date [HD], biomass [HB] and N [HN]), only									
Intercept	2.19	3.04	-0.42	1.51	2.71	0.29	1.39	2.37	1.88
HD (days from 1st of april)	0.12	0.10	0.20	0.17	0.10	0.19	0.11	0.09	0.10
HB (t ha^{-1}) at heading	0.08				0.10		0.14	0.16	0.15
HN (kg N ha^{-1}) at heading		0.01	0.01			0.00			
R^2	***0.60***	***0.38***	***0.76***	***0.64***	***0.41***	***0.63***	***0.61***	***0.45***	***0.47***

Conclusions

Modelling yield by the psHRDIs and some plant traits at heading stage, including heading date, yielded relatively high coefficients of determination. This agrees with results obtained by Thorp et al. (2017), who found that crop reflectance derived indices at key phenological stages, especially heading, are related to grain yield more than some crop biomass or N traits. This can explain why when we used only psHRDIs or both psHRDIs and crop traits, very few differences in the predictors selected were found. However, since no predictor was constantly retained in all the models, other plant or canopy traits related to yield determinants (e.g. water availability, temperature stress or other genetic traits) should be included as a predictor. Among predictors, chlorophyll vegetation index (CVI) was frequently included in the model, which could depend on its ability to capture the variability of biomass and its N concentration (Vincini et al., 2014). And indeed we found that it correlated with biomass at heading at R=-0.76. Further results are needed, however, to model wheat yield by proximal sensing coupled with a crop simulation model in environments or years different that what than occurred in the study presented here to be able to transfer these results over space and time.

Acknowledgments
This research was funded by Apulia and Molise Regions, within the Rural Development Program (PSR) 2007-2013 of the Apulia and Molise Region - misura 124 - projects PIF Filiera Cerealicola Legacoop and FERTINNOVA, respectively.

References

Barraclough, P.B., R. Lopez-Bellido, and M.J. Hawkesford. 2014. Genotypic variation in the uptake, partitioning and remobilisation of nitrogen during grain-filling in wheat. F. Crop. Res. 156: 242–248.
Basso, B., C. Fiorentino, D. Cammarano, and U. Schulthess. 2016. Variable rate nitrogen fertilizer response in wheat using remote sensing. Precis. Agric. 17(2): 168–182.
Colecchia, S.A., B. Basso, D. Cammarano, A. Gallo, A.M. Mastrangelo, P. Pontieri, L. Del Giudice, D. Pignone, and P. De Vita. 2013. On the relationship between N management and grain protein content in six durum wheat cultivars in Mediterranean environment. J. Plant Interact. 8(3): 271–279.
Marino, S., C. Cocozza, R. Tognetti, and A. Alvino. 2015. Use of proximal sensing and vegetation indexes to detect the inefficient spatial allocation of drip irrigation in a spot area of tomato field crop. Precis. Agric. 16(6): 613–629.
Masoni, A., L. Ercoli, M. Mariotti, and I. Arduini. 2007. Post-anthesis accumulation and remobilization of dry matter, nitrogen and phosphorus in durum wheat as affected by soil type. Eur. J. Agron. 26(3): 179–186.
Raun, W.R., J.B. Solie, G. V. Johnson, M.L. Stone, E. V. Lukina, W.E. Thomason, and J.S. Schepers. 2001. In-Season Prediction of Potential Grain Yield in Winter Wheat Using Canopy Reflectance. Agron. J. 93(1): 131.
Saia, S., E. Benítez, J.M. García-Garrido, L. Settanni, G. Amato, and D. Giambalvo. 2014. The effect of arbuscular mycorrhizal fungi on total plant nitrogen uptake and nitrogen recovery from soil organic material. J. Agric. Sci. 152(3): 370–378.
Thorp, K.R., G. Wang, K.F. Bronson, M. Badaruddin, and J. Mon. 2017. Hyperspectral data mining to identify relevant canopy spectral features for estimating durum wheat growth, nitrogen status, and grain yield. Comput. Electron. Agric. 136: 1–12.
Vincini, M., S. Amaducci, and E. Frazzi. 2014. Empirical estimation of leaf chlorophyll density in winter wheat canopies using Sentinel-2 spectral resolution. IEEE Trans. Geosci. Remote Sens. 52(6): 3220–3235.

THE NEW SEED-APPLIED FUNGICIDE SEDAXANE IMPROVES DROUGHT TOLERANCE IN EARLY GROWTH STAGES OF MAIZE
IL NUOVO FUNGICIDA CONCIANTE DEL SEME SEDAXANE MIGLIORA LA TOLLERANZA ALLA SICCITÀ NEGLI STADI INIZIALI DEL MAIS

Manuel Ferrari, Cristian Dal Cortivo, Giuseppe Barion, Teofilo Vamerali*,

[1] Dipartimento di Agronomia Animali Alimenti Risorse Naturali e Ambiente, Università di Padova, Viale dell'Università 16, 35020, Legnaro (Padova)
*teofilo.vamerali@unipd.it

Abstract
This work investigates the effect of a new seed-applied fungicide (Sedaxane; Syngenta) in maize subjected to progressive water stress. The dynamic of relative transpiration was measured in relation to the fraction of transpirable soil water (FTSW) in a pot experiment. Compared with conventional fungicides (Fludioxonil + Metalaxil), the addition of Sedaxane allowed young plants to transpire at maximum rate down to a similar FTSW – much lower than untreated controls - and to increase significantly root growth and branching.

Keywords: drought, seed-coating, fungicides, maize.
Parole chiave: stress idrico, concia del seme, fungicidi, mais.

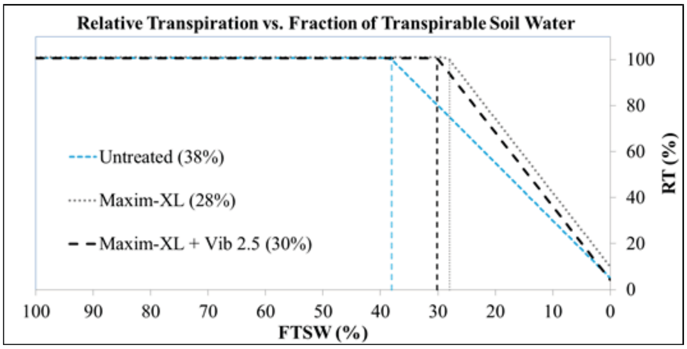
Introduction
Water availability is increasingly becoming a limiting factor worldwide, and drought can drastically reduce the final crop yield in maize. Young plants are currently protected against seed-born and soil-born fungal pathogens by using a combination of seed-applied fungicides, a practice also suitable for reducing the amount of pesticides spread into the environment. Research pay now great attention in discovering new fungicide molecules having both protecting and bio-stimulating effects (Gomes Bezerra *et al*., 2015). The purpose of this work was to evaluate the effect of the seed-coating treatment Maxim XL (Syngenta), widely used in maize, in combination or not with Sedaxane, a new SDHI fungicide, on plant growth and transpiration under progressive water stress.

Materials and Methods
The trial was set at the experimental farm of the University of Padova at Legnaro (Padova), using SY-HYDRO (Syngenta) as hybrid (FAO class 600) during year 2016. Using a completely randomized experimental scheme, we have compared 6 treatments: 3 different seed-coatings (untreated control; Maxim XL; Maxim XL + Vibrance 2.5 mL/50 Kseeds at 50% w/w of Sedaxane) and 2 different water regimes: optimal water supply (daily water transpiration restored by irrigation) and progressive water stress down to the wilting point (water lost by transpiration not restored by irrigation). Compared with Fludioxonil and Metalaxil contained in Maxim XL, Sedaxane is known to increase the protection against *Rhizoctonia solani* and *Sphacelotheca reiliana*. Maize was grown in 6-L PVC pots filled with a mixture of sand and silty-loam soil (1:1 w/w), placed in a controlled environment within a greenhouse. Three seeds of maize per pot were sown at 3 cm of depth, leaving only one plant after emergence. The relative transpiration (RT) was detected following the procedure of Vamerali et al. (2003) by daily weighting the pots after sealing at the 3-leaf-stage. RT was plotted against the fraction of transpirable soil water (FTSW), and regressed with a linear plateau model. In the harvested plants, free phenolic acids (caffeic, syringic, vanillic, p-coumaric and t-ferulic) were detected in shoot tissues by HPLC.

Results and Discussion
Based on the results of the overall leaf transpiration over the whole experiment, under optimal water supply, treated plants increased the amount of transpired water by 26% and 24% for Maxim XL and Maxim XL + Vibrance, respectively, compared with untreated controls. This effect was due to higher shoot and root growth of treated plants (data not shown).
Under progressive water stress, no differences were found among treatments in terms of total transpiration, as the experiment lasted at wilting point. However, the dynamics of leaf transpiration over FTSW differed among treatments: with Maxim XL transpiration started to decrease at a FTSW value of 28%, and for Maxim XL + Vibrance at 30% (Fig. 1). Instead, untreated controls showed an early stomatal closure (FTSW = 38%), which can lead in the long-term to yield losses (Schimdt *et al*., 2011). It seems that seed treatments with fungicides retard transpiration decline, probably through a delay in stomatal closure, an effect that in open field can increase productivity in environments with fluctuating rainfall.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Fig. 1: Linear plateau regressions of relative transpiration (RT) plotted vs. fraction of transpirable soil water (FTSW) of pot-cultivated maize under progressive water stress. Transpiration measured over 27 days after pot closure. In brackets: FTSW values at which RT starts to decline.
Fig. 1: Regressione (linear plateau) della traspirazione relativa (RT) in funzione della frazione di acqua disponibile nel terreno (FTSW) di mais coltivato in vaso con stress idrico progressivo. Traspirazione misurata per 27 giorni dalla chiusura dei vasi. In parentesi: valore di FTSW al quale RT inizia a diminuire.



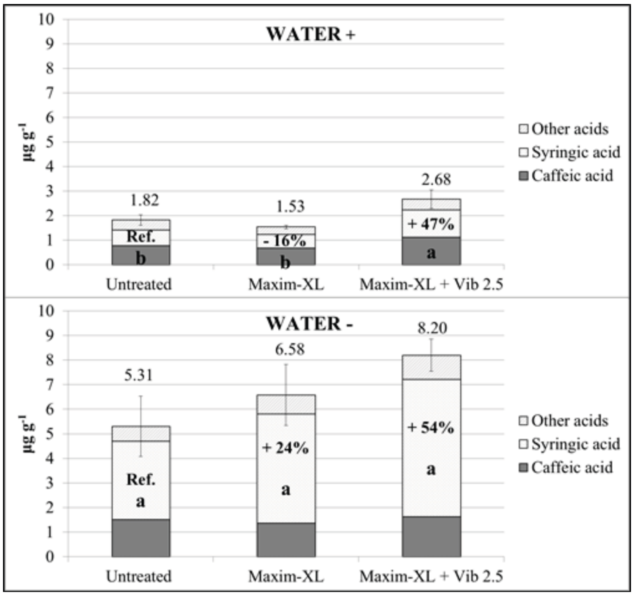


Fig. 2: Antioxidant activity (phenolic acids) (mean ± S.E., n = 4) in shoot tissues of pot-cultivated maize under optimal water supply (water +) and in progressive water stress (water -) (Newman-Keuls test, P≤0.05). Letters for statistical comparisons.
Fig. 2: Attività antiossidante (acidi fenolici) (media ± E.S., n=4) nei tessuti epigei di mais in condizioni di apporto idrico ottimale (acqua +) e con stress idrico progressivo (acqua -). (Test Newman-Keuls, P≤0.05). Lettere per comparazione statistica.

Regarding the abundance of phenolic acids in shoot tissues, the biosynthesis of these antioxidants was stimulated by water stress, with a high increase with Vibrance mainly due syringic acid, and secondly by vanillic, p-coumaric and t-ferulic acids, although there were no statistical differences from controls. Under optimal water supply, Vibrance significantly increased phenolic acid content (+47% vs. control; $P \leq 0.05$), particularly syringic and caffeic acids (Fig. 2). Sedaxane, as a systemic active ingredient, may interfere with some physiological mechanisms of the plant, probably involving abscisic acid, which induces stomata closure. We hypothesized that a higher concentration of phenolic compounds can decrease the abscisic acid content in plant tissues, particularly by vanillic and p-coumaric acid. Such an effect is interesting because these phenolic acids perform many positive functions on the plant, by making cell wall more rigid and resistant and defending the plant against pathogens. Sedaxane probably works by altering the expression of key genes in plant physiology, that code for specific proteins and helping the plant to overcome stressful conditions (Ajigboye *et al.*, 2017).

Conclusions
Under progressive water stress, plants treated with seed-applied fungicides can delay the stomata closure in early stages, thus increasing resilience to fluctuating soil water availability and possibly protecting yield potential of maize.

References

Ajigboye O.O., Lua C., Murchie E.H., Schlatter C., Swart G., Ray, R.V., 2017. Altered gene expression by sedaxane increases PSII efficiency, photosynthesis and growth and improves tolerance to drought in wheat seedlings. *Pestic. Biochem. Phys.*, 137: 49-61.
Gomes Bezerra A.R., Santos Silva F.C., Ferreira Silva A., Almeida Álvares C.H., Sediyama T., 2015. Effect of biostimulants and seed treatment with fungicide on the germination and vigor of soybean seedlings. *Appl. Res. & Agrotec.*, 8: 27-35.
Schimidt J.J., Blankenship E.E., Lindquist J.L., 2011. Corn and Velvetleaf (*Abutilon theophrasti*) transpiration in response to drying soil. *Weed Sci.*, 59: 50-54.
Vamerali T., Saccomani M., Bona S., Mosca G., Guarise M., Ganis A.A., 2003. A comparison of root characteristics in relation to nutrient and water stress in two maize hybrids. *Plant Soil*, 255: 157-167.

A BENZIMIDAZOLE PROTON PUMP INHIBITOR IN ANIMALS INCREASES GROWTH AND TOLERANCE TO SALT STRESS IN TOMATO

UN INIBITORE BENZIMIDAZOLICO DELLA POMPA PROTONICA IN CELLULE ANIMALI INCREMENTA LA CRESCITA E LA TOLLERANZA ALLO STRESS SALINO IN POMODORO

Michael J. Van Oosten[1], Silvia Silletti[1], Gianpiero Guida[2], Valerio Cirillo[1], Emilio Di Stasio[1], Petronia Carillo[3], Pasqualina Woodrow[3], Albino Maggio[1]* and Giampaolo Raimondi[1]

[1] Dipartimento di Agraria, Università degli Studi di Napoli Federico II, Via Università 100, 80055 Portici (NA);
[2] Consiglio Nazionale delle Ricerche, Istituto per i Sistemi Agricoli e Forestali del Mediterraneo, Via Patacca, 85, 80056 Ercolano NA;
[3] Dipartimento di Scienze e Tecnologie Ambientali Biologiche e Farmaceutiche, Università degli Studi della Campania Luigi Vanvitelli, Via Vivaldi, 43 - 81100 Caserta
*almaggio@unina.it

Abstract
Pre-treatment of tomato plants with micromolar concentrations of omeprazole (OP), a benzimidazole proton pump inhibitor in mammalian systems, improves plant growth in terms of fresh weight of shoot and roots by 49 and 55% and dry weight by 54 and 105% under salt stress conditions (200 mM NaCl), respectively. Assessment of ion distribution profile in different organs strongly indicates that OP interferes with key components of the stress adaptation machinery, including hormonal control of root development (improving length and branching), protection of the photosynthetic system (improving quantum yield of photosystem II) and regulation of ion homeostasis (improving the K^+:Na^+ ratio in leaves and roots). To our knowledge OP is one of the few known molecules that at micromolar concentrations manifests a dual function as growth enhancer and salt stress protectant. Therefore, OP can be used as new inducer of stress tolerance to better understand molecular and physiological stress adaptation paths in plants and to design new products to improve crop performance under suboptimal growth conditions.

Keywords: benzimidazole, chemical priming, omeprazole, proton pump inhibitor (PPI), salt stress.
Parole chiave: benzimidazolo, priming chimico, omeprazole, inibitore della pompa protonica, stress salino.

Introduction
During salt stress adaptation, ion movement through plants cellular compartments is essential to detoxify the cytoplasm and re-establish osmotic balance (Hasegawa, 2013). Plasma membrane and vacuolar H^+-ATPases play a fundamental role in this physiological process since by generating active transport of proton H^+ across the membranes they create pH gradients and electrical potentials that drive transport of ions and molecules across membranes (Deinlein et al., 2014). In animals, homologs of plant proton pumps operate through the H^+/K^+ ATPase mechanism (Axelsen and Palmgren, 1998). Similar to plants, animal proton pumps working across membranes generate acidification of organismal compartments. For decades proton pump inhibitors (PPIs) have been successfully used to inhibit gastric acid secretion and benzimidazole based PPIs are common treatments used with gastro-esophageal reflux disease (GERD) and peptic ulcers (Baumann and Baxendale, 2013).
Omeprazole (OP), the most common benzimidazole proton pump inhibitor (PPI)in animals affects P-Type IIC ATPases. These P-Type IIC ATPases represent a large family of ATP driven transporters, which are responsible for moving ions across membranes (Shin et al.,2009). Plants are not known to possess P-Type IIC ATPases that transport Na^+ or K^+, instead relying on the family of NHX-type NaCand K^+/H^+ antiporters for plasma membrane extrusion and compartmentation into the vacuoles and endosomes. Plants do possess P-Type IIA and IIIATPases, primarily SERCA-like, which are not known to transport Na^+or K^+ (Sweadner and Donnet, 2001). However, while plants are not known to have P-Type IIC ATPases that transport Na+ or K+ which are the target of OP, we wanted to verify whether plant treatment with OP may actually alter the transmembrane control of ion fluxes and disrupt plant tolerance to saline stress. In contrast to what we may have expected based on our current understanding of plant ATPases and plant responses to salt stress, here we demonstrate that tomato treatment with micromolar concentrations of omeprazole greatly enhanced plant growth and improved its tolerance to saline stress.

Materials and methods
Hydroponic Experiment: Tomato seeds (cultivar M82, accession LA3475) obtained from the Tomato Genetics Resource Center (TGRC1) were germinated in plates, transplanted to a hydroponic system and grown with a standard nutrient solution. At 26 Days After Sowing (DAS), the first treatment of OP was added to the nutrient solution (1, 10, and 45 µM). Salt stress was initiated 36 DAS by adding 75 mMNaCl to salt treatments. At 42 DAS the NaCl concentration was increased to 150 mM and on 46 DAS the NaCl concentration was raised to 200 mMNaCl. Destructive harvest and biometrics were taken at 50 DAS (14 days of salt stress). Ions measurements were performed according to a procedure described by Carillo et al. (2011), analyzed by ionexchange chromatography using a DX500 apparatus (Dionex, Olten, Switzerland).
Pot experiment: Seedlings were germinated in previously stated growth and then were transplanted into 5 L pots, filled with soil and fertilized with a commercial formulate. OP treated plants were watered with 500 mL of 1 µM omeprazole at 36, 50, and 68 DAS. At 60 DAS pre-stress physiological measurements were taken and then pots were saturated with 50 mM NaCl and the final salt concentration of 150 mM was achieved at 68 DAS.Gas exchanges and Chl a fluorescence emission were measured using a modulated fluorometer analyzer Li-6400XT (Li-Cor Biosciences, Lincoln, NE, United States).

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Results and discussion

OP treatment with 1 μM increased shoot FW by 49% and DW by 48%. FW of roots was increased by 55% and DW by 56% in the absence of stress (Figure 1). Under saline stress, shoot growth was maintained, with a 56% increase in shoot FW and 54% increase in DW (Figure1). Roots showed the most dramatic phenotype under salt stress, with a doubling of FW and DW over untreated controls. Although this morphological change was not the only component that may have enhanced salt tolerance of OP treated plants, this response may have important implications with respect to growth and adaptation in saline environments (Julkowska et al., 2014; Feng et al., 2016). The actual quantum yield of PSII (PSII) and the photochemical quenching (qP) were improved in the salt stressed leaves by OP addition (Figure 2). Moreover, an observed reduction of photosynthetic rates, stomatal conductance, PSII and qP in non OP and OP treated plants exposed to 150 mM of NaCl compared to the 0 NaCl treatments, indicated that salt stress reduced the efficiency of PSII reaction centers and impaired electron transport in the photosynthetic apparatus (Maxwell and Johnson, 2000; Baker, 2008).

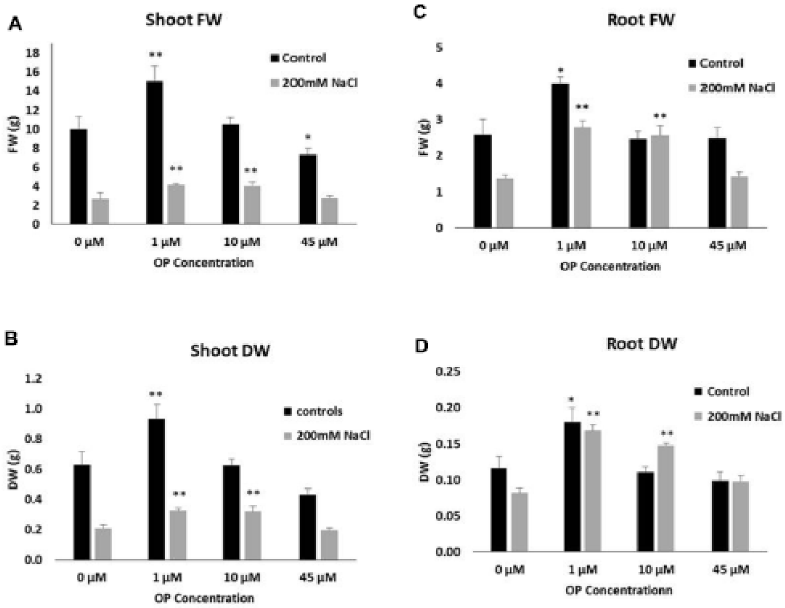


*Fig. 1:Hydroponic Experiment,shoot fresh weight (FW) and dry weight (DW) (A,B) and Root FW and DW (C,D). Values indicate average +/SE (n=7). According to Student test, *, ** significant at P < 0.1 and 0.01 respectively.*

*Fig. 1: Esperimento in idroponica, peso fresco (FW) e peso secco (DW) della parte aerea (A,B) e delle radici (C,D). I valori indicano la media +/- l'errore standard (n=7). *. ** indicano differenze significative a P < 0.1 e 0.01 rispettivamente secondo il test di Student.*

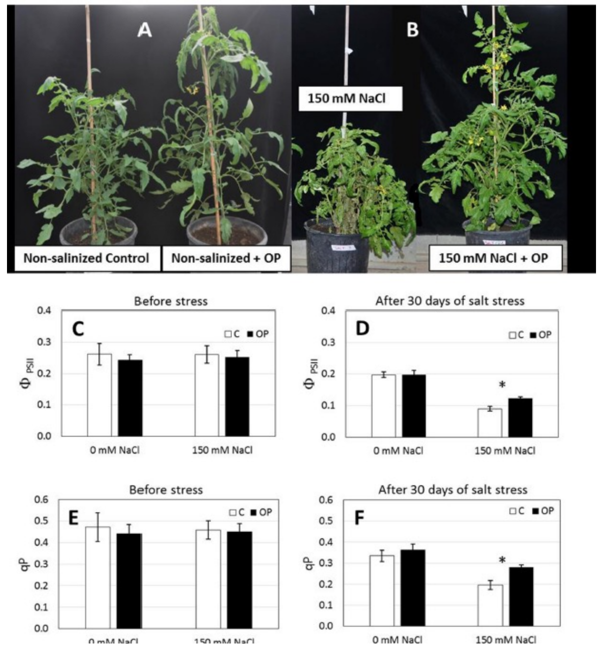


*Fig. 2:Pot Experiment, Photos (A,B) of representative plants were taken at 72 DASand efficiency of Photosystem II (8PSII, C,D) and photochemical quenching (qP, E,F). Values indicate average SE (n = 6). According to Student test, *, ** significant at P < 0.1 and 0.01 respectively.*

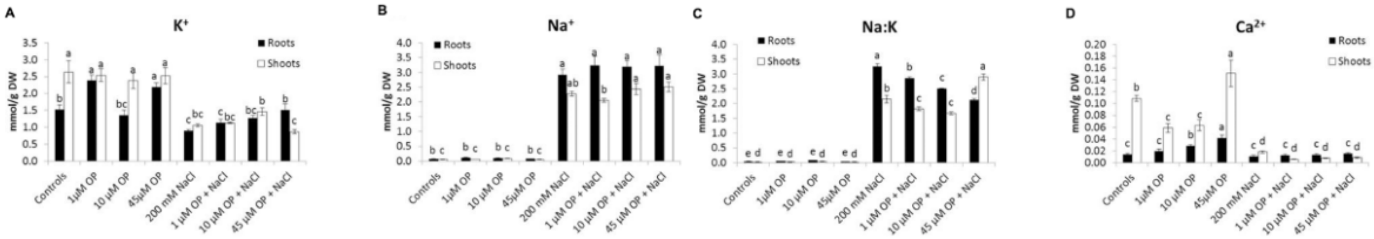
*Fig.2: Esperimento in vaso, foto(A, B) di piante rappresentative a 72 DAS e efficienza del fotosistema II (8PSII, C,D)più quenching fotochimico(qP, E,F).I valori indicano la media +/- ES (n=7). *. ** indicano differenze significative a P < 0.1 e 0.01 rispettivamente secondo il test di Student.*

OP altered the ion accumulation of tomato plants in control conditions and under severe salt stress. In unstressed conditions, OP increased K^+ accumulation in roots treated with 1 μM (Figure 3); OP did affect the Na^+:K^+ ratio of salt stressed leaves and roots. The root Na^+:K^+ ratio of roots under salt stress was reduced by 12, 23, and 35% in 1, 10, and 45 μM OP treated plants, respectively (Figure 3). Calcium accumulation was also affected by OP treatment. In shoot, lower OP concentrations, 1 and 10 μM, decreased shoot calcium concentration significantly. Interestingly, 45 μM OP increased calcium concentration in roots and shoots. Root chloride accumulation was observed to be elevated in roots of plants treated with OP when compared to controls only under stress condition. Treatment with OP was observed to increase nitrate content of roots at 1 and 45 μM.

Under OP we observed a pattern of sodium exclusion and increased potassium uptake, an adaptation mechanism essential in response to high salinity, regulated by several ion transporters.

The low concentrations of calcium found in shoot of OP treated plants at 1 and 10 μM (Figure 3) may have likely been correlated to a reduced calcium entry into the root, and consequently to a possible effect on the selectivity of tonoplast K^+ antiporters, as confirmed by the low Na^+:K^+ ratio of root and shoot of OP treated plants.

DOI 10.6092/unibo/amsacta/5692



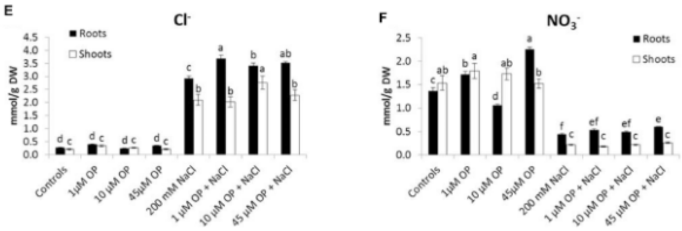


Fig. 3: Ion profiles of Solanum lycopersicum var. Red Setter plants treated with omeprazole. Values indicate average SE (n = 6). Different letters indicate significant differences at P<0.05.

Fig.3: Profilo ionico di piante di Solanum lycopersicum var. Red Setter. I valori indicano la media +/- errore standard (n=6). Lettere differenti indicano differenze significative a P<0.05.

Conclusions

The OP concentrations we used and dose responses, indicate that OP acts with a hormone-like behavior with growth stimulation between 1 and 10 μM and inhibitory effects at higher concentrations. based on the well-characterized function as H^+/K^+-ATPase inhibitor in animal systems, we can also hypothesize that OP is inhibiting an ATPase present in plants. This hypothesis is difficult to come to terms with, since very little room exists in our current paradigm of ATPase driven proton gradients and ion transport, where inhibition of one or more of these components would actually increase growth or tolerance to salinity. Ion homeostasis is key to growth and adaptation to osmotic stress, a clear mechanism for the role of OP does not readily present itself. The possibility that OP is exerting its effect through a mechanism of action which is unrelated to an ATPase inhibitory function in plants should also be considered.

References

Axelsen, K. B., and Palmgren, M. G. (1998). Evolution of substrate specificities in the P-Type ATPase superfamily. J. Mol. Evol. 46, 84–101. doi: 10.1007/ PL00006286.

Baker, N. R. (2008). Chlorophyll fluorescence: a probe of photosynthesis in vivo. Annu. Rev. Plant Biol. 59, 89–113. doi: 10.1146/annurev.arplant.59.032607.092759.

Baumann, M., and Baxendale, I. R. (2013). An overview of the synthetic routes to the best selling drugs containing 6-membered heterocycles. Beilstein J. Org. Chem. 9, 2265–2319. doi: 10.3762/bjoc.9.265.

Carillo, P., Parisi, D., Woodrow, P., Pontecorvo, G., Massaro, G., Annunziata, M. G., et al. (2011). Salt-induced accumulation of glycine betaine is inhibited by high light in durum wheat. Funct. Plant Biol. 38, 139–150. doi: 10.1071/FP10177.

Deinlein, U., Stephan, A. B., Horie, T., Luo, W., Xu, G., and Schroeder, J. I. (2014). Plant salt-tolerance mechanisms. Trends Plant Sci. 19, 371–379. doi: 10.1016/j.tplants.2014.02.00.

Feng, W., Lindner, H., Robbins, N. E., and Dinneny, J. R. (2016). Growing out of stress: the role of cell- and organ-scale growth control in plant water-stress responses. Plant Cell 28, 1769–1782. doi: 10.1105/tpc.16.00182.

Hasegawa, P. M. (2013). Sodium (NaC) homeostasis and salt tolerance of plants. Environ. Exp. Bot. 92, 19–31. doi: 10.1016/j.envexpbot.2013.03.001.

Julkowska, M. M., Hoefsloot, H. C. J., Mol, S., Feron, R., de Boer, G.-J., Haring, M. A., et al. (2014). Capturing Arabidopsis root architecture dynamics with root-fit reveals diversity in responses to salinity. Plant Physiol. 166, 1387–1402. doi: 10.1104/pp.114.248963.

Maxwell, K., and Johnson, G. N. (2000). Chlorophyll fluorescence—a practical guide. J. Exp. Bot. 51, 659–668. doi: 10.1093/jexbot/51.345.659.

Shin, J. M., Munson, K., Vagin, O., and Sachs, G. (2009). The gastric HK-ATPase: structure, function, and inhibition. Pflugers. Arch. 457, 609–622. doi: 10.1007/ s00424-008-0495-4.

Sweadner, K. J., and Donnet, C. (2001). Structural similarities of Na,K-ATPase and SERCA, the Ca(2C)-ATPase of the sarcoplasmic reticulum. Biochem. J. 356, 685–704. doi: 10.1042/bj3560685.

OLIVE-MILL WASTEWATER AND ORGANO-MINERAL FERTLIZERS APPLICATION FOR THE CONTROL OF PARASITIC WEED PHELIPANCHE RAMOSA (L) POMEL IN TOMATO CROP

UTILIZZO DI ACQUE DI VEGETAZIONE PER IL CONTROLLO DELL'INFESTANTE PARASSITA PHELIPANCHE RAMOSA (L) POMEL SU COLTURA DI POMODORO

Grazia Disciglio*[1], Francesco Lops[1], Laura Frabboni[1], Giuseppe Gatta[1], Emanuele Tarantino[1]

[1] Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente Università di Foggia, Via Napoli 25, 71122, Foggia
*grazia.disciglio@unifg.it

Abstract
The parasitic weed specie *Phelipanche ramosa* (L) Pomel is one of the mayor constraints in tomato crops in Apulia region (southern Italy). This study was made to investigate the effect of six organic compounds (Olive miller wastewater, Allil isothiocyanate®, Alfa plus K®, Radicon®, Rizosum Max®, Kendal Nem®) on the naturally infested field of tomato, growing in 2016 season. During the growing cycle of the tomato at 74, 81, 93 and 103 days after transplantation (DAT), the number of parasitic shoots (branched plants) that had emerged in each plot was determined. At harvest, on 13 September 2016, the major quanti-qualitative yield parameters were determined, including marketable yield, mean weight, dry matter, soluble solids, fruit colour, pH and titratable acidity. The results show that none of treatments provided complete control against *P. ramosa.* However, Olive miller wastewater, Alfa plus K®, Rizosum Max® and Kendal Nem® products applied to the soil show the number of emerged shoots significantly lower than Radicon® and especially than the Allil isothiocyanate® treatment and the untreated control. The marketable yield resulted significantly higher in the corresponding treatments which gave the lower *P. ramosa* infestation. No significative differences for the qualitative fruit characteristics were observed.

Keywords: processing tomato crop, *Phelipanche ramosa,* olive-mill wastewater, organic fertilizers.
Parole chiave: pomodoro da industria, *Phelipanche ramosa,* fertilizzazione organica, acque di vegetazione.

Introduction
In tomato (*Lycopersicon esculentum* Mill.) crop in the last years *Phelipanche ramosa* species is continuously expanding into new areas which are considered as parasite free. It causes great yield losses and in case of heavy infestation, complete crop failure (Abu-Irmaillh, 1979). Various methods have been tried to control *P. ramosa,* including preventive measures, physical, chemical, agronomic, biological, biotechnological and integrated methods. It has long been recognized that *P. ramosa* infestation tends to be associated with less fertile soil conditions (Jain and Foy, 1992). Improved soil fertility, additions of organic matter was found to be a potential control of *Pheliphanche* species (Sauborn et al., 2003; Disciglio et al., 2015). The olive-mill wastewater (OMW), directly produced by the olive oil extraction process (i.e. without preliminary treatments), has chemical properties (i.e. organic carbon, potassium and phosphorus contents) that could increase soil fertility (Tomati and Galli, 1992). This wastewater can be applied to the soil for agronomical use at the maximum amount of 80 m^3 ha^{-1} (Law No 574, 1996). For the spring-summer crops such as tomato, applied OMW can be made 35-40 days before planting, without contraindications (Bonari and Ceccarini, 1999; Tarantino et al., 2003). Considering that very little information is available on the effect of organic fertilizers on *P. ramosa* parasite, this paper deals with the results of those materials application to control the infestation in the open field processing tomato crop.

Materials and Methods
The study was carried out during the spring-summer season 2016, at the private "Futuragri" farm, located in an agricultural area of the Foggia district (Apulia Region), where the cultivation of processing tomato crop is very intensive and the infestation of *Phelipanche ramosa* is widely diffuse. The trial was carried on the processing tomato (cultivar "Dres"), to assess the effect of six treatments, corresponding to the application of six products (Olive mill wastewater -OMW-, Allil isothiocyanate®, Alfa plus K®, Radicon®, Rhizosum Max® and Kendal Nem®) to the crop on the control of *P. ramosa* infestation. The above treatments were compared with an untreated control. A randomized block design with 3 replicates was adopted. During the tomato cycle, at 72, 81, 93 and 103 days after transplanting (DAT), *Phelipanche* emerged shoots (branched plants) from soil on a sampling area of 1 m^2 were counted. The tomato fruits were harvested at full-stage of maturity on 13 September 2016, when the marketable yield from each sampling area of 5 m^2 was measured. On a sample of 10 fruits from each plot, the following main quali-quantitative yield parameters were determined: mean weight (g), soluble solids content (°Brix), titratable acidity (TA g citric acid 100 ml fresh juice), dry matter content (% fruit fresh matter), and colour parameters (as a/b ratio). All data were subjected to analysis of variance (ANOVA) and the means were compared by Tukey's test at 5% probability level.

Results and Discussion
As shown in Fig. 1, *P. ramosa* shoots were detected during the growing tomato crop at 72, 81, 93 and 103 days after transplanting (DAT), for all of the tested treatments. In particular, at harvest (103 DAT) the emerged shoots ranged from lower values between 0.3 to 3.0 shoots m^{-2} in OMW, Alfa plus K®, Rhizosum Max® and Kendal Nem® treatments to significantly higher values of 5.7 shoots m^{-2} in Radicon® and 8.8 shoots m^{-2} in Allil isothiocyanate®. The highest significantly value of 13.0 shoots m^{-2} were obtained in the untraded control. This positive results might be due to additive effects of the organic compound along the mineral compounds that could improve the nutrient status of the tomato crop. In fact, the presence in the commercial products of organic and minerals substances as nitrogen, phosphorus and potassium includes negative effects on *P. ramosa* seed germination. This is in agreement with earlier studies witch inorganic compounds as high nitrogen content fertilizers have been shown to reduce *Orobanche* infestation (Westwood and Foy, 1999).

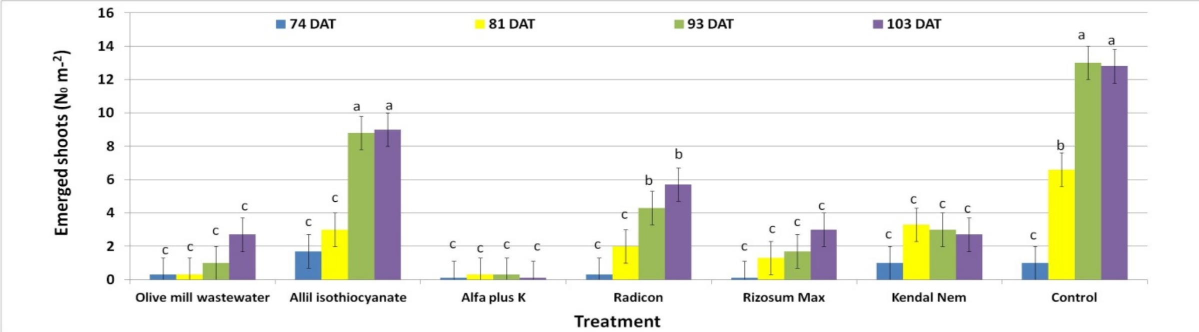


Fig. 1: Number of emerged shoots of P. ramosa at 74, 81, 93 and 103 days after transplanting (DAT) for the different treatments: data are means ± standard error, as measured from each plot of each treatment. Means with different letters are significantly different at P ≤ 0.05
Fig. 1: Numero di turioni emersi di P. ramosa a 74, 81, 93 e 103 giorni dopo il trapianto (DAT) per i diversi trattamenti: i dati sono medie ± errore standard, per trattamento. I valori con differenti lettere sono significativamente diversi a P ≤ 0,05.

Table 1 gives the effects of the different experimental treatments on the quali-quantitative traits of the processing tomato fruits. The highest yield was observed in the Alfa plus K® (114 t ha^{-1}) treatment, although it was not significantly different from the, Rizosum Max® (106 t ha^{-1}), Olive miller wastewater (96.8 t ha^{-1}) and Kendal Nem®(88.2 t ha^{-1}). This result is in agreement with the lower parasite attach observed in tomato plants treated with the above mentioned product. Regarding the qualitative parameters no significant differences were observed.

Tab. 1: Quanti-qualitative traits of the tomato fruit under the different treatments
Tab. 1: Caratteristiche quanti-qualitativi del pomodoro sottoposto ai diversi trattamenti

Treatment	Marketable yield (t ha^{-1}) †	Mean fruit weight (g)	Dry matter (% fresh matter)	Colour coordinate (L)	Colour index (a/b ratio)	Soluble solids content (°Brix)	pH	Titratable acidity (TA g citric acid 100 ml^{-1})
Olive-mill wastewater	96.8±12.0 ab	80.1±7.2	6.6±0.4	50.5±0.3	1.1±0.1	5.2±0.1	4.8±0.1	0.5±0.1
Allil isothiocyanate®	94.3±8.7ab	64.0±4.1	4.7±0.5	49.4±0.6	1.3±0.1	4.1±0.1	4.5±0.2	0.4±0.2
Alfa plus K®	114.2±14.8 a	75.5±4.0	6.8±0.2	49.6±0.5	1.2±0.1	4.3±0.1	4.8±0.1	0.4±0.2
Radicon®	79.7±7.2 b	81.1±5.0	6.8±0.3	49.6±1.0	1.2±0.1	4.0±0.2	4.7±0.2	0.3±0.2
Rizosum Max®	106.0±14.8 a	71.0±4.4	5.7±0.3	49.4±0.5	1.2±0.1	4.2±0.2	4.7±0.1	0.5±0.1
Kendal Nem®	88.2±5.8 ab	89.8±6.0	7.5±0.3	50.3±0.2	1.2±0.1	4.5±0.1	4.5±0.1	0.4±0.1
Control	69.4±2.3 c	75.3±6.2	6.5±0.2	48.7±1.1	1.1±0.1	4.2±0.1	4.4±0.1	0.4±0.1

Statistical differences among mean values are indicated by different letters (0.05 P) according to ANOVA and Tukey test. Where the letters are not reported, not significant differences (P>0.05) were found

Conclusions

The main conclusion to be drawn from this study is that the soil application of organo-mineral fertilizers is particularly suitable to produce lower presence of *Phelipanche* although none of the products tested provides complete control of this parasite . It is assumed that these effects can be improved by combining these treatments with others agronomic methods including crop rotation or intercropping with catch and tomato crop, sowing date, soil management especially for a gradual and continuing reduction of the "seed bank" of the parasite in the soil.

References

- B.E. Abu-Irmaileh., 1979. Effect of various fertilizers on broomrape *O. ramosa,* infestation of tomatoes. Symp. Parasitic Weeds North Carolina State University, Raleigh.

E. Bonari, L. Ceccarini L. 1991. Spargimento delle acque di vegetazione dei frantoi sul terreno agrario. L'Informatore Agrario, 47, 49-57.

G. Disciglio, G.Gatta, F. Lops, L. Libutti, A. Tarantino, E. Tarantino, 2016. Effect of biostimulants to control the *Phelipanche ramosa* L. Pomel in processing tomato crop. World Academy of Science, Engineering and Technology, International Science International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering, 10(4), 212-215.

Jain & CL Foy, 1992. Nutrient effects on parasitism and germination of Egyptian broomrape (*Orobanche aegyptiaca*). Weed Technology 6, 269-275.

J. Sauerborn, B., Kranz, H. Mercer-Quarshie, 2003. Organic amendments to mitigate heterotrophic weed population in savannah agriculture. Applied Soil Ecology, 23, 181-186.

U. Tomati, E. Galli, 1992. The fertilizing value of wastewater from the olive processing industry. In: Kubat, J. (Ed.) Humus, its Structure and Role in Agriculture and Environment. Elsevier, Barking, 117-126.

J.H Westwood., C.L. Foy, 1999. Influence of nitrogen on germination and early development of broom rare (*Orobanche* spp.). Weed Sci. 47, 2-7.

ASSESSING PLANT DENSITY OF ABANDONED OLIVE GROVES: PRELIMINARY RESULTS FROM MONTALBANO CASE STUDY

STIMA DELLA DENSITA' DI IMPIANO DEGLI OLIVETI IN ABBANDONO: RISULTATI PRELIMINARI NEL CASO STUDIO DEL MONTALBANO

Camilla Dibari[1*], Marco Moriondo[2], Sergi Costafreda-Aumedes[1], Lorenzo Brilli[1], Andrea Triossi[3], Marco Bindi[1]

[1] Dipartimento di Scienze delle Produzioni Agraro-alimentari e dell'Ambiente, piazzale delle Cascine18, 50144, Firenze, Agrarie, Università di Bologna,
[2] Istituto di Biometerologia, Consiglio Nazionale delle Ricerca, via Giovanni Caproni 8, 50145, Firenze
[3] D.R.E.AM ITALIA, via Garibaldi 3, 520115, Pratovecchio (AR)
*camilla.dibari@unifi.it

Abstract
Over the last decades olive cultivation has been suffering widespread abandonment especially in hilly lands across the Mediterranean basin, including in the Tuscany region, where olive orchards are traditional, i.e. low-intensity production systems, with low plant density, low inputs, small yields and managed at familiar level. The main purpose of this paper is to present preliminary results deriving from a methodology, based on diachronic visual analysis of aerial photos coupled with a semi-automatic classification through remote sensing analysis and weighted multi regression approach, to map and quantify abandoned olive groves which have the potential to be restored and/or recovered in the study area of Montalbano (Province of Florence, Pistoia and Prato). Results indicate that about 900 ha (out of 4,900 ha currently cultivated as olive orchards in the study area) are shifted to other cultivations and/or to forests and shrublands. Moreover, about 2,500 hectares show a very low plant density (< 210 trees/ha). The methodology, coupled with simulation and/or biogeochemical models has the potential to identify agriculture measures to be promoted and incentive to local farmers under adaptation and GHG mitigation perspectives in abandoned and/or semi-abandoned olive orchards.

Keywords: plant density, NDVI, remote sensing; GIS; modelling.
Parole chiave: densità di impianto, NDVI, telerilevamento, GIS, modelli

Introduction

Olive (*Olea europea*) groves account for a large cultivated areas across the Mediterranean basin (Moriondo et al., 2013) and the Tuscan landscape (Galli et al., 2010). Furthermore, olive farming represents the main and often unique livelihood for rural population, with a notable contribution to raise the financial conditions and to stabilize the populations of otherwise depressed rural regions, historically source of emigration towards urban areas (Greppi, 2007). Over the last decades (from 1960s onward), a particular pattern of rural areas abandonment has taken throughout Italy, as well as Tuscany: plains are increasingly being utilized for human activities, while hilly areas, being abandoned, are facing natural reforestation processes leading to a deterioration of the historic Tuscan agricultural landscape (Agnoletti et al., 2015). In this context, the hilly area of Montalbano, located across the Provinces of Florence, Prato and Pistoia, is experiencing a large olive orchard abandonment mainly concentrated across marginal rural lands. This research, carried out within the project CatchCo2-Live financed by Tuscany Region administration, aims at investigating the olive groves which potentially can be recovered and/or restored in the area of Montalbano so as to promote and incentive local farmers to adopt strategies for their management under a GHG mitigation perspective. To this aim, a diachronic visual analysis of aerial photos from 1954 and 2013 has been performed coupled with a semi-automatic classification of abandoned olive groves through

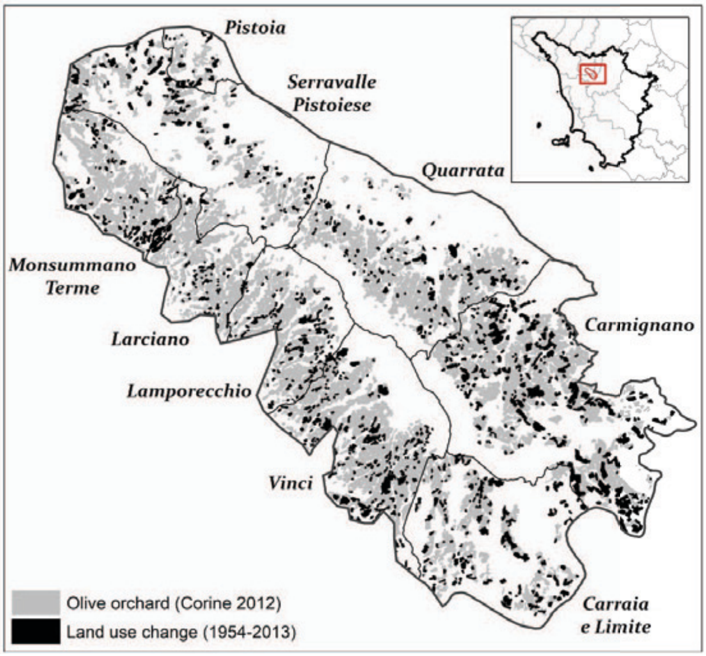


Fig. 1: Study area: Montalbano. In light grey the extent of olive orchards according to CORINE (2012) in dark grey land use changes
Fig. 1: Area di studio: Montalbano. In grigio chiaro le aree ad olivo secondo la carta CORINE (2012) in grigio scuro i cambi di uso del suolo

remote sensing analysis and weighted multi regression approach.

Materials and Methods

The study area (which approximately extends between 43.73°-43.91° Lat N and 10.80°-11.08° Lon E; Fig. 1) occupies about 19,000 hectares with an altitude ranging from 23 to 500 m a.s.l.. First, the current distribution of olive groves was derived extracting the corresponding codes from CORINE Land Cover map database (2006), updated to 2012 by Tuscany Region administration. Second, a set of aerial imageries were collected from the cartographic portal of Tuscany Region on 1954 and 2013 years with a nominal spatial resolution of 0.5 x 0.5 m. Later, the areas currently not covered by olive groves were visually interpreted against the 1954 aerial imageries using on screen digitizing so as to detect olive tree cultivation changes (Fig. 1). Finally, a contingency table was then created in order to map and quantify current lands potentially restorable to olive tree cultivation (i.e. arable lands, forests, shrubs, etc.).

From the visual interpretation, large areas - currently classified as olive groves - resulted with a very low plant density (likely semi-abandoned), thus with a high potential to be restored with additional olive trees plantation. In order to identify these areas and quantify the number of olive trees to be replanted, a geographically weighted regression approach was applied using NDVI and local topography (i.e. elevation and slope) as predictor variables of plant density.

To this aim, a Landsat 8 OLI (Operational Land Imager) multiband scene (30x30 m spatial resolution) was collected on July (the 12th 2016; the 26th 2016) and for each grid, the relevant elevation and slope were extracted from the digital elevation model. The current olive groves map was thus converted onto a grid fishnet dataset with 50 x 50 m spatial resolution and for each grid point (188,868 in total) the NDVI values from each Landsat images were calculated. A set of grid cells, 405 out of 1,143, falling completely inside the olive grove layer feature dataset (CORINE), was extracted and the number of olive plants calculated from visual interpretation on aerial imageries of year 2013. The geographically weighted regression was then applied using NDVI value, elevation and slope as predictors of plant density in a leave-one-out scheme to avoid regression overfitting.

Tab. 1: Olive tree changes from 1954 vs 2013
Tab. 1: Trasformazione degli oliveti dal 1954 al 2013

	Area (ha)	%
Arable lands, grasslands	104.8	11.5
Fruit trees (including vineyards)	328.2	36.2
Olive tree with low density	49.6	5.5
Forests, shrublands	251.7	27.7
Urban	150.5	16.6
Other	22.7	2.5
Total	907.7	100

Results and Discussion

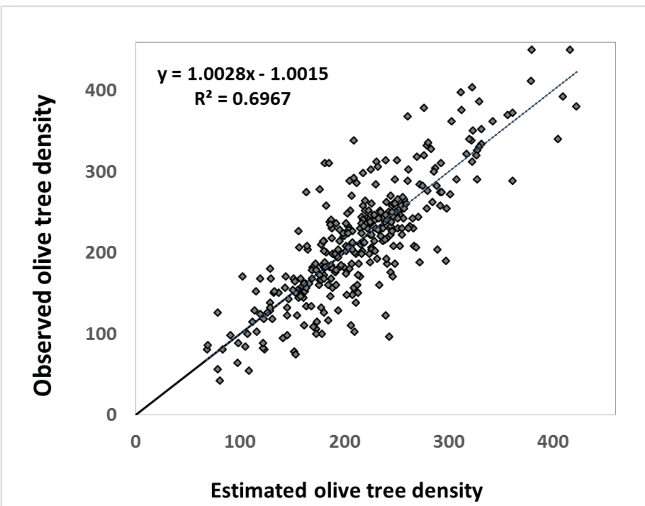


Fig. 2: Regression between observed and estimated olive tree density
Fig. 2: Regressione fra densità di olivi osservati e stimati

According to CORINE land cover 2013, the current olive tree cultivation of the study aera extends about 4,900 ha. From the diachronic analysis (1954 vs 2013) about 907.7 ha of olive orchards in 1954 have been abandoned (Table 1). About 50 ha turned to low-density olive groves while about 860 ha shifted to other land uses; namely arable lands (104.8 ha), tree cultivations (vineyards and fruit trees – 328.2 ha), forest and shrublands (251.7 ha), urban areas (150.5 ha), and other cultivations (22.7 ha). The widest land-use-changes occurred in the southern municipalities (Capraia and Limite, Vinci and Carmignano). Lamporecchio, Larciano, Serravalle Pistoiese and Monsummano Terme faced the widest encroachment of forests-shrublands. Pistoia municipality showed the widest abandonment of intensive olive groves onto low-density cultivations. Building on these results, about 900 ha of lands could be restored as olive groves across the Montalbano area. The weighted multi-regression approach, implemented using remotely sensed data (Landsat 8 OLI) and local topography as predictor of olive planting density, provided optimal performances in predicting olive planting density (r=0.83**, RMSE =41.15 trees/ha; Fig. 2) and was therefore applied over the entire study area.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The results showed that 210 trees/ha is the mean plant density across the study area and the under-utilized lands (i.e. <210 trees/ha) extend about 2,500. This implies that half of Montalbano olive orchards are likely giving small yields and income to farmers. On average, Carmignano, Quarrata and Serravalle Pistoiese are the municipalities resulting with the widest area of low-intensity olive systems, while Pistoia and Vinci with the highest intensive olive groves cultivation (Fig. 3). The latter municipalities are in fact characterized by flatter and more fertile lands with respect to the other municipalities, where intensive productions can be exerted. Conversely, olive orchards located in marginal and hilly areas (Carmignano, Quarrata and Serravalle Pistoiese) show a traditional management which can be economically viable only if most of the labour is done by farmer's family members (Duarte et al., 2008). Results indicate that about 20,000 olive trees, mainly concentrated in areas with low plant density, could be replanted so as to shift the cultivation towards more intensive and profitable farming systems.

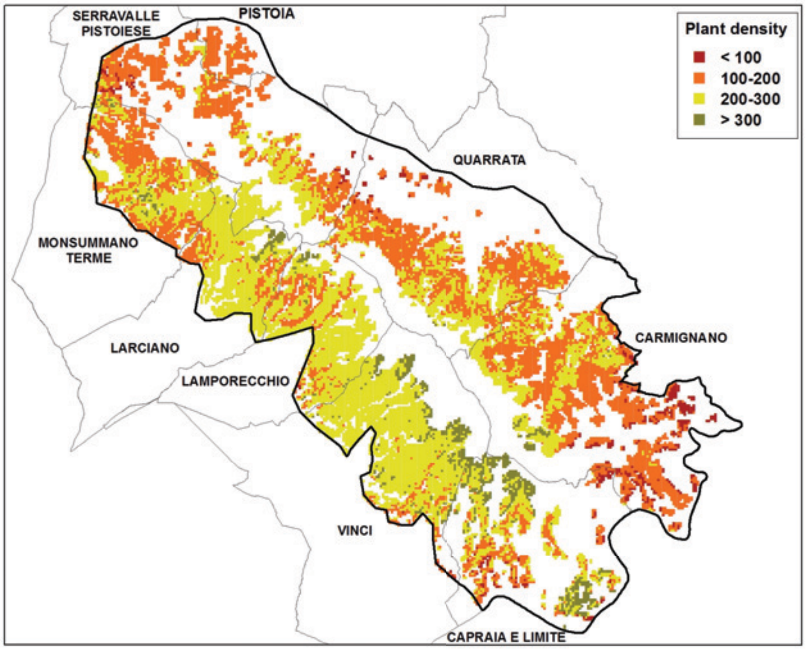


Fig. 3: Plant density of olive orchard in the study area
Fig. 3: Densità d'impianto degli oliveti nell'area di studio

Conclusions

This paper shows preliminary results deriving from a methodology, based on remotely sensed data and weighted multi regression approach combined with a visual diachronic analysis, to quantify and map the level of abandoned olive groves located across a hilly area of Tuscany Region (Montalbano) characterized by low-intensity production systems and low income. Coupling the methodology with crop simulation and biogeochemical modelling will enable the identification of good agriculture practices and options to increase productivity and to face the expected climate scenarios in terms of adaptation but also mitigation, ensuring a profitability and sustainability of olive systems also in the next future.

References

Agnoletti M., Conti L., Frezza L., Santoro A., 2015. Territorial Analysis of the Agricultural Terraced Landscapes of Tuscany (Italy): Preliminary Results. Sustainability, 7(4), 4564-4581.

Duarte F., Jones N., Fleskens L., 2008 Traditional olive orchards on sloping land: Sustainability or abandonment?. Journal of environmental management 89.2: 86-98.

Galli M., Bonari E., Marraccini E., Debolini M., 2010. Characterisation of agri-landscape systems at a regional level: a case study in Northern Tuscany. Italian Journal of Agronomy, 5(3): 285-294.

Greppi C., 2007. Ciglionamenti e terrazzamenti nella Toscana centrale: Dal passato al futuro. In Paesaggi Terrazzati: Culture e Esperienze a Confronto, Proceedings of the Project Alpter—Paesaggi terrazzati Dell'arco Alpino, Venezia, Italia, 22–23 February 2007.

Moriondo, M., Trombi, G., Ferrise, R., Brandani, G., Dibari, C., Ammann, C.M., Lippi, M.M., Bindi, M., 2013. Olive trees as bio-indicators of climate evolution in the Mediterranean Basin. Global Ecology and Biogeography, 22: 818-833.

LINKING SOIL STRUCTURE PROPERTIES UNDER CONSERVATION AGRICULTURE MANAGEMENT IN VENETO REGION SILTY SOILS

STRUTTURA DEL TERRENO IN SUOLI MEDIO LIMOSI VENETI GESTITI CON PRATICHE DI AGRICOLTURA CONSERVATIVA

Ilaria Piccoli[1*], Carlo Camarotto[1], Lorenzo Furlan[2], Antonio Berti[1], Barbara Lazzaro[3], Francesco Morari[1]

[1] Dipartimento DAFNAE, Università di Padova, Via dell'Università 16, 35020, Legnaro PD
[2] Veneto Agricoltura, Settore Ricerca Agraria, Viale dell'Università 14, 35020, Legnaro PD
[3] Regione del Veneto, Direzione Agroambiente, Caccia e Pesca, Via Torino 110, Mestre VE
*ilaria.piccoli@unipd.it

Abstract
Soil structure is one of the most important soil quality indices. Conservation agriculture (CA) has recently been introduced in the Veneto Region as a more sustainable agronomic technique. The aim of this study was to evaluate the effect of CA practices on soil pore network in the silty soils of the Veneto Region in a field experiment where CA practices (no-tillage, cover crop and residues retention) were compared to conventional intensive tillage (IT) system. Almost 100 undisturbed soil samples were collected in 2015 and subjected to porosity characterization coupling mercury intrusion porosimetry and x-ray computed microtomography. Results highlighted no differences between treatments in terms of total porosity while CA was associated with an increase of the pore vertical orientation and ultramicroporosity class. Silty soils of Veneto plain showed a slow reaction to conservation agriculture and more than a 5-yr transition period is probably required to provide a new equilibrium and in turn a better soil structure.

Keywords: conservation agriculture; pore size distribution; pore architecture; pore morphology.
Parole chiave: agricoltura conservativa; distribuzione della dimensione dei pori; architettura dei pori; morfologia dei pori.

Introduction
As in the other European countries, also in Veneto region more sustainable agronomic practices are requested and among these conservation agriculture (CA) (i.e. no-tillage, residues retention and cover-crop usage) has been subsidized during the two last rural development programs of Veneto Government (Regione Veneto, 2016, 2013) to reduce the production costs and to regulate and support several ecosystem services. Soil structure is a key tracer of the changes in soil quality and plays a key role in soil functioning. The aim of this study was to evaluate the effects of CA practices on soil porosity in terms of total porosity, pore size distribution, architecture and morphology in the silty soils of the Veneto region low plain and to compare it with conventional intensive tillage system.

Materials and Methods
A field experiment was set up in 2010 on four farms located in Veneto Region where two treatments, conservation agriculture (CA) and intensive tillage (IT), were compared. IT consisted of 35-cm mouldboard ploughing with crop residues incorporation followed by secondary tillages, while CA included sod seeding, residues retention on soil surface and use of cover crops. In 2015, after 5 years of treatments application, almost 100 undisturbed soil samples were collected from different soil layers (L1: 3-5.5 cm, L2: 12-14.5 cm, L3: 20-22.5 cm and L4: 45-47.5 cm) and analized for pore size distribution (PSD), morphology and architecture coupling mercury intrusion porosimetry ("MIP", in the 0.0074 µm - 100 µm range) (Thermo Finningan, Waltman, USA) and x-ray computed microtomography ("µCT", for pores > 26 µm) (Skyscan 1172, Bruker MicroCT, Kontich, Belgium). MIP-derived pores were then classified as cryptopores (0.0074-0.1 µm), ultramicropores (0.1-5 µm), micropores (5-30 µm), mesopores (30-75 µm) and macropores (75-100 µm) while the µCT-derived ones into five classes: 26-500 (CL1), 500-1000 (CL2), 1000-1500 (CL3), 1500-2000 (CL4) and >2000 µm (CL5). Statistics were based on mixed effect models and principal component analysis on 11 selected variables (Kaiser's measure of sampling adequacy 0.77).

Results and Discussion
No differences between treatments were observed in terms of total porosity which decreased with depth irrespectively of agronomic management (Fig. 1). On the contrary, the PSD in the MIP range (0.0074 µm - 100 µm) highlighted how CA was associated with an increase of ultramicroporosity class (0.1-5 µm) as a result of mesoporosity one (30-75 µm) contraction while no treatment effect was observed in the µCT domain.

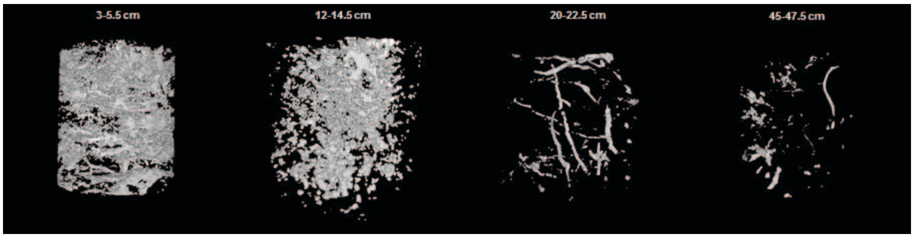


Fig. 1:Total porosity (µCT-derived) distribution in different soil layers.
Fig. 1:Distribuzione della porosità totale (da µCT) lungo il profilo del suolo.

Pore architecture and morphology were positively affected by CA treatment only in terms of pore orientation (76° vs 72°). Indeed, independently of agronomic management, the soil pore network of Veneto region silty soils was less complex and more connected with soil depth increasing (Fig. 1) as revealed by fractal dimension and connectivity density indices decreasing.

The PCA analysis extracted two principal components. The first one (PC1) was representative of the macroscale domain as related to texture- and MIP-derived parameters while the second one (PC2) was related to the macroscale domain as linked to the µCT-derived parameters. In the plain described by PC1 and PC2, PC1 divided farm 3 from the other farms because it was less related with microscale properties (Fig. 2). Inside farm 3, PC2 discriminated the two treatments with CA being less correlated with macroscale properties (Fig. 2). Finally PC1 divided the top layer from the others as more representative of macroscale soil pore characteristics (Fig. 2).

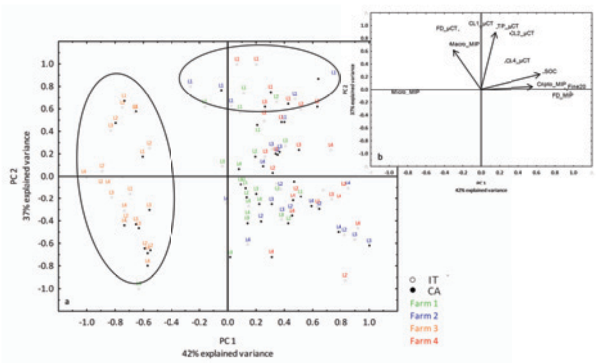


Fig. 2 Principal component analysis. 2-a represents case scores where different colour highlights different experimental farms and different labels correspond to the studied soil layers. 2-b represents factor loadings: Macro_MIP: 75-100 µm, Micro_MIP: 5-30 µm, Crypto_MIP: 0.0074-0.1 µm, FD_MIP: fractal dimension (MIP-derived), Fine20: particles < 20 µm, SOC: soil organic carbon, CL1_µCT: 26-500 µm, CL2_µCT: 500-1000 µm, CL4_µCT: 1500-2000 µm and FD_µCT: fractal dimension (µCT-derived).
Fig. 2 Analisi delle componenti principali. In 2-a vengono rappresentati i casi dove i colori sono associati a diverse aziende e le etichette agli strati studiati. In 2-b vengono riportati i fattori estratti: Macro_MIP: 75-100 µm, Micro_MIP: 5-30 µm, Crypto_MIP: 0.0074-0.1 µm, FD_MIP: dimensione frattale (da MIP), Fine20: particelle < 20 µm, SOC: carbonio organico, CL1_µCT: 26-500 µm, CL2_µCT: 500-1000 µm, CL4_µCT: 1500-2000 µm and FD_µCT: dimensione frattale (da µCT).

Conclusions

In the short term, the implementation of conservation agriculture practices was not able to easily improve soil structure but despite no remarkable differences were observed in terms of total porosity or pore size distribution, CA allowed at least the formation of a more vertical soil pore network which could be seen as the result of a higher biological activity. More than 5-yr transition period is probably required to provide a new equilibrium and in turn a better soil structure.

Acknowledgment

This study was funded by “Helpsoil” life + European project (LIFE12 ENV/IT/000578).

References

Regione Veneto, 2013. URL https://www.regione.veneto.it/web/agricoltura-e-foreste/psr-2007-2013 (accessed 7.12.16).

Regione Veneto, 2016. URL http://www.regione.veneto.it/web/agricoltura-e-foreste/sviluppo-rurale-2020 (accessed 7.13.16).

LOW-COST MULTISPECTRAL CAMERA ON BOARD A UAV: ESTIMATION OF MAIZE NITROGEN-RELATED VARIABLES TO SUPPORT NITROGEN FERTILIZATION

CAMERA MULTISPETTRALE A BASSO COSTO: STIMA DELLE VARIABILI COLTURALI DA DRONE PER IL SUPPORTO ALLA FERTILIZZAZIONE

Martina Corti[1*], Daniele Cavalli[1], Giovanni Cabassi[2], Antonio Vigoni[3], Lamberto Borrelli[2], Luca Bechini[1], Pietro Marino Gallina[1]

[1] Dipartimento di Scienze Agrarie e Ambientali – Produzione, Territorio, Bioenergia – Università degli Studi di Milano, Italia
[2] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria – CREA ZA, Lodi, Italia
[3] Sport Turf Consulting, Rescaldina (MI), Italy
*martina.corti@unimi.it

Abstract

Maize is the main crop in Northern Italy (314000 ha in 2016). Maize cultivation requires high nitrogen (N) loads (up to about 300 kg N ha^{-1}); thus, fertilization must be properly managed in order to reduce environmental pollution, especially in zones vulnerable to nitrate leaching. In this context, matching maize N demands with the correct timing and amount of N fertilizers would be crucial. Nowadays, the development of new technologies allows monitoring in-field crop variability at high spatial and temporal resolution. In particular, small unmanned aerial vehicles (UAVs) coupled with low-cost multi-spectral optical sensors are technologies potentially interesting for agriculture applications. The present work was aimed at testing the ability of this technology to map within-field crop variability and support N fertilization. An experimental field with six different fertilized treatments was monitored with an UAV-mounted imaging sensor in the years 2014 and 2015. Maize was sampled at V6 and V9 development stages. At each sampling date, dry above ground biomass, its N concentration and plant N uptake were determined. At the same time, the UAV mounting a modified consumer digital camera surveyed the field to record multispectral images. The average BNDVI, GNDVI vegetation indices, and the fraction cover were calculated for each experimental plot and regressed against measured variables. Estimation of above ground biomass at V9 was the most satisfactory. The best predictor was found to be the estimated fraction cover: regression equation built using the data recorded at V9 in the two years of experiment resulted in R^2=0.87 and rRMSE of 17%. The low cost imaging system led to good performance in AGB estimation thanks to the high spatial resolution of the imaging sensor that allowed a good estimation of the canopy fraction cover.

Keywords: unmanned aerial vehicle; digital cameras; airborne multispectral sensing; above ground biomass estimation.
Parole chiave: drone; fotocamera digitale; telerilevamento aereo multispettrale; stima della biomassa aerea.

Introduction

An efficient use of agronomic inputs is needed in order to increase the sustainability of agriculture and save the environment from pollution, especially referring to nitrogen (N) fertilization that could cause air and water pollution with drawbacks on human health. A more efficient preservation of environmental resources in agriculture can be gained taking into account field variability when applying external inputs. Between and within-field variability can be both evidenced with maps describing crop status (e.g. above ground biomass or its N concentration) at specific phenological stages. Maps could be obtained as outputs of remote-sensing techniques that involve using optical sensors and calibration procedures that relate signals to the crop status. The adoption of these techniques to interpret in-season dynamics of plant N demand requires they are rapid, accurate and cheap, in comparison to destructive and time-consuming analytical measurements. In recent years, new opportunities for crop monitoring were achieved by the innovative use of unmanned aerial vehicles (UAVs). UAVs, opportunely equipped with multi-spectral digital cameras, can be used to fly over the field periodically to acquire crop spectral information in visible (VIS) and near infrared (NIR) bands in order to calculate vegetation indices. Recent attempts to construct crop-specific calibration between UAV-derived vegetation indices and crop variables are recorded in the literature (Geipel et al., 2016; Huang et al., 2010; Lebourgeois et al., 2008). The increasing interest in precision agriculture for digital camera mounted on UAVs is due to the possibility of collecting images with high spatial and temporal resolution throughout cultivation season, even when the use of tractor-mounted sensors is logistically and economically difficult. Moreover, UAV-based monitoring is a flexible tool in terms of the timing of the surveys. This feature is of interest for monitoring maize crop status to guide side-dress N fertilization as it is applied in the narrow interval from V6 to V9 development stages (Ritchie et al., 1996). Regarding the UAV-based monitoring of maize, different attempts were made to estimate above ground biomass (Osborne et al., 2004), its N concentration (Osborne et al., 2004; Rorie et al., 2011) and N uptake. However, it must be considered that these experiences were carried for one or two years and often, at later development stages than the ones identified as the best time window for side-dress N fertilization. Due to the lack of specific information about maize UAV-

DOI 10.6092/unibo/amsacta/5692

based monitoring at V6-V9, we present a two years-case study where a modified consumer digital camera mounted on board a UAV was used to estimate maize N-related variables (above ground biomass, plant N concentration and plant N uptake). To this end, an experimental field with a gradient of maize nitrogen nutritional status induced by fertilization was used to test the performances of a low-cost technology to map within-field variability.

Materials and Methods

The UAV survey was carried out on an experimental field located at Montanaso Lombardo (Lodi), Italy (45°20'32" N, 9°26'43" E, altitude 80 m asl) during 2014 and 2015 maize growing seasons. The experiment (Cavalli et al., 2016) started during 2011 with the aim of studying livestock manure-N use efficiency in a crop rotation silage-maize and Italian ryegrass (*Lolium perenne*, Lam.). Six treatments (four manures plus an ammonium sulphate and an unfertilized treatment) were arranged in a randomized block design with four replicates. Plots were 15 m long and 7.5 m wide, with ten meters spacing between adjacent blocks. The four manures comprised an unseparated anaerobically-digested dairy cow slurry (co-digested with silage maize), its liquid and solid fractions, and an unseparated anaerobically-stored dairy cow slurry. This on-going experiment provided a wide range of variability in N availability and thus the field (about 1 ha) it was chosen for calibration purposes. In the year 2015 the same experimental design of the previous year was replicated, but no treatments were applied because the aim of the original experiment was to quantify the residual N effects of previous fertilizations. Thus, in order to rise further available plant-N variability, during 2015, four treatments were added to the original experimental design: ammonium sulphate at 35, 70 and 150 kg N ha^{-1}, and calcium nitrate at 150 kg N ha^{-1}. These treatments were applied to small plots (8 m long and 7.5 m wide) in the strips between block (Fig. 1).

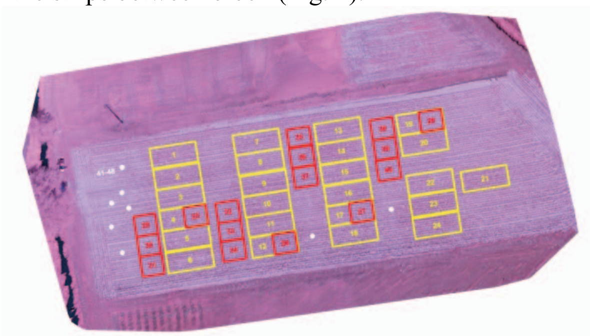


Fig. 1 – Layout of the experimental field. Plots 1-24 belong to the original experiment (Cavalli et al., 2016), while plots 25-40 were added in year 2015 to enhance variability in maize above ground biomass and plant N concentration. Additional points (41-48) were sampled during 2015.
Fig. 1 – Schema del campo sperimentale. Le parcelle 1-24 appartengono all'esperimento originale (Cavalli et al., 2016), mentre le parcelle 25-40 sono state aggiunte nell'anno 2015 per aumentare la variabilità a scopi di calibrazione. I punti di campionamento 41-48, fuori dal disegno sperimentale, sono stati campionati nel 2015.

Crop was sampled at phenological stages V6 and V9 (plants with six and nine fully expanded leaves, respectively), in both years of experiment.
Above ground biomass (AGB, g dry weigth m^{-2}) was estimated after drying at 105°C, while AGB N concentration (Nc, g N 100 g dry weigth^{-1}) was determined on dry samples using an elemental analyzer.
A consumer digital camera Canon® Powershot SX260 HS was manually modified by removing the infrared-blocking filter and adding a Super Blue IR filter to be transformed in VIS-NIR digital camera acquiring 8-bit spectral information in three channels: blue (B), green (G) and NIR. The image acquisition was carried out in the same dates of plant sampling for destructive analysis (before plant collection). The camera was mounted on board a a coaxial octocopter in carbon fiber UAV that surveyed the field at a low flight speed (5 m/s). Images were acquired with the autofocus mode and with 75% forward and sideward overlap, under clear sky conditions, at 35 m altitude, between 11:00 and 13:00 a.m. solar time.
Orthomosaics of the field were built using the software Pix4Dmapper (Pix4D SA, Lausanne, Switzerland). Portions of images belonging to each plot were obtained from the orthomosaics after radiometric and geometric correction. Thereafter, the Blue Normalized Difference Vegetation Index (BNDVI= (NIR – B)/(NIR + B)), the Green Normalized Difference Vegetation Index (GNDVI= (NIR – G)/(NIR + G)), and the canopy fraction cover (i.e. the fraction of pixels that contained vegetation) were calculated separately for each image corresponding to experimental plots. Linear regression models were built to estimate, separately for each sampling date, AGB (g m^{-2}), Nc and N uptake (Nu, g N m^{-2}); the coefficient of determination (R^2) and the relative root mean squared error (rRMSE) were calculated for each model.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Results and Discussion

Table 1 summarizes the variability showed by the measured variables at the two phenological stages of the two years of experimentation.

Tab. 1 – Statistics of the reference variables (AGB, Nc and Nu) measured in the maize field at the different sampling dates.
Tab. 1 – Statistiche descrittive delle variabili misurate su mais (AGB, Nc and Nu) a diversi stadi fenologici divisi per anno.

Statistic[a]	2014						2015					
	V6			V9			V6			V9		
	AGB[b] (g m^{-2})	Nc (%)	Nu (g m^{-2})	AGB (g m^{-2})	Nc (%)	Nu (g m^{-2})	AGB (g m^{-2})	Nc (%)	Nu (g m^{-2})	AGB (g m^{-2})	Nc (%)	Nu (g m^{-2})
Mean	48	3.5	1.7	244	2.4	5.9	42	3.6	2.6	121	1.5	3.3
Std dev	8	0.3	0.3	35	0.3	1.3	8	0.3	0.4	57	0.4	1.8
Min	35	2.8	1.1	171	1.7	2.9	26	3.0	2.0	12	0.9	0.4
Max	70	3.9	2.6	320	2.9	7.9	61	4.1	3.5	297	2.2	9.4
CV (%)	17	9	20	14	13	21	19	7	14	47	23	56

[a]Std dev, standard deviation; Min, minimum; Max, maximum; CV, coefficient of variation.
[b]AGB, above ground biomass (dry weight); Nc, AGB N concentration (dry weight basis); Nu, plant N uptake.

In both years, maize AGB and N uptake increased from V6 to V9, caused by plant N to be diluted during growth. Differences among sampling dates were more relevant at V9, when variables measured in 2015 showed higher variability compared to those measured in 2014. This was expected given the introduction in the year 2015 of additional plots to increase variability in plant available N. Moreover, during 2015, original plots (i.e. those already present in 2014) were not fertilized and thus, difference in residual N effects among fertilizers further enhanced N uptake variability.
The indices BNDVI and GNDVI showed increasing values from V6 to V9 stage, according to the observed increase of AGB. Both the indices showed a narrow range of variability, probably due to the overlapping of the sensed bands that caused similar responses of the three channels (Fig. 2).

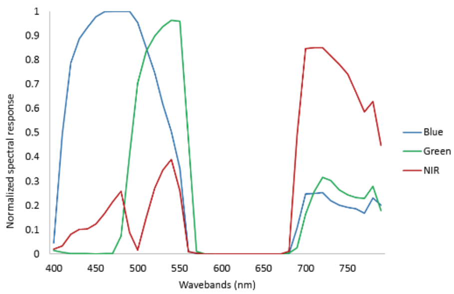


Fig. 2 – Spectral response of the modified Canon tested in the waveband range 400-800 nm using a dispersive monochromator applied to a Xenon lamp.
Fig. 2 – Risposta spettrale della camera Canon modificata, testate nel range di lunghezze d'onda 400-800 nm con un monocromatore applicato ad una lampada Xenon.

The coefficients of determination of linear regression models built at V9 in 2014 were 0.5 and 0.3 for the estimation of AGB and Nu, respectively. Moreover, both indices regressed poorly with Nc in both years and phenological stages (data not shown), with best performance achieved with GNDVI at V9 in 2014 (R^2 of 0.43). This result was expected because the ability of the imaging sensors with low spectral resolution to detect AGB relies on the strong relationship between vegetation indices and the canopy fraction cover (Hunt et al., 2010; Li et al., 2010). Therefore, vegetation indices can only indirectly estimate factors affecting biomass production (*e.g.*, N availability). Thus, the lack of a strong biochemical relationship between the broad bands collected with the modified consumer digital camera and plant-N concentration and the reduced variation range of Nc resulted in poor regressions between the calculated indices and plant-N concentration.
The AGB estimation by the image-derived fraction cover was less satisfactory at V6 than V9 in both the years of experimentation (Fig. 3; R^2=0.58 and rRMSE=11% in the year 2014; R^2=0.33 and rRMSE=24% in the year 2015). These results were probably caused by a low AGB and thus low spectral response of the canopy at this stage. In fact, higher regression performance was reached at V6 in the year 2014 in presence of higher AGB production.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The Fc showed the strongest correlations to AGB (Fig. 3) and pant-N uptake at V9 in 2015. In fact, AGB and Nu were estimated with R^2 of linear regression of 0.73 and 0.63 and with rRMSE of 24% and 36%, for V9. These are quite positive results but their use seems to be limited to a specific phenological stage (V9).

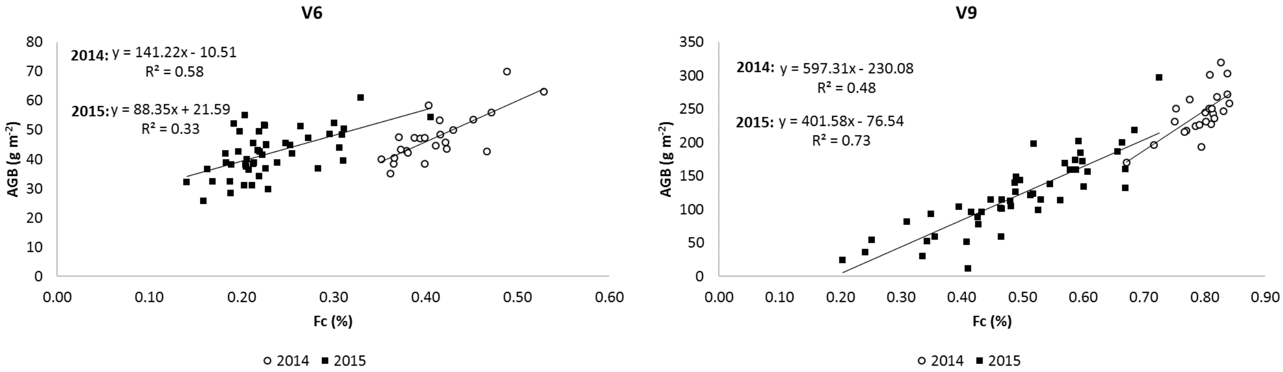


Fig. 3 – Linear regression models between Fc and AGB measured at V6 and V9 in the years 2014 and 2015.
Fig. 3 – Modelli di regressione lineare tra Fc e AGB misurati a stadio V6 e V9 in entrambi gli anni 2014 e 2015.

Since AGB was strongly and positively correlated to Nu (r=0.92 and 0.96 at V6 of 2014 and 2015, respectively and r=0.86 and 0.96 at V9 of 2014 and 2015, respectively), Fc represented a good predictor of crop nitrogen status at maize early stages. Taking into account all the findings, the modified digital camera, even though is characterized by low spectral resolution, could be used for crop monitoring before canopy closure.

Conclusions

Maize above ground biomass and nitrogen uptake were estimated from the average BNDVI and GNDVI of the plots. Fraction cover was also estimated and regressed against the above ground biomass and it was positively and moderately correlated with the AGB. Satisfactory performances in AGB and Nu estimation were found only at the V9 stage of the 2015, when a larger range of variation in the measured variables was explored. The calibration procedures carried out in this work are stage-specific and this represents a limit in the application of the regression equations at different development stages of the time window V6-V9, suitable for side-dress fertilization. However, the low cost imaging system, even with the limitations due to a low dynamic range and JPEG compression (that could cause channels overlap and saturation also at early development stages), led to satisfactory performance in AGB estimation. This was possible thanks to the very high spatial resolution of the imaging sensor that allowed a reliable estimation of AGB through the assessment of the canopy fraction cover.

References

Cavalli, D., Cabassi, G., Borrelli, L., Geromel, G., Bechini, L., Degano, L., Marino, P., 2016. Nitrogen fertilizer replacement value of undigested liquid cattle manure and digestates. European Journal of Agronomy 73, 34–41.

Geipel, J., Link, J., Wirwahn, J.A., Claupein, W., 2016. A Programmable aerial multispectral camera system for in-season crop biomass and nitrogen content estimation. Agriculture 6, 4. doi:10.3390/agriculture6010004

Huang, Y., Thomson, S.J., Lan, Y., Maas, S.J., 2010. Multispectral imaging systems for airborne remote sensing to support agricultural production management. International Journal of Agricultural & Biological Engineering 3.

Hunt, E.R., Hively, W.D., Fujikawa, S.J., Linden, D.S., Daughtry, C.S., McCarty, G.W., 2010. Acquisition of NIR-green-blue digital photographs from unmanned aircraft for crop monitoring. Remote Sensing 2, 290–305.

Lebourgeois, V., Bégué, A., Labbé, S., Mallavan, B., Prévot, L., Roux, B., 2008. Can commercial digital cameras be used as multispectral sensors? A crop monitoring test. Sensors 8, 7300–7322.

Li, Y., Chen, D., Walker, C.N., Angus, J.F., 2010. Estimating the nitrogen status of crops using a digital camera. Field crops research 118, 221–227.

Osborne, S.L., Schepers, J.S., Schlemmer, M.R., 2004. Using multi-spectral imagery to evaluate corn grown under nitrogen and drought stressed conditions. Journal of Plant Nutrition 27, 1917–1929. doi:10.1081/LPLA-200030042

Ritchie, S.W., J.J. Hanway, and G.O. Benson., 1996. How a corn plant develops. Rev. ed. Spec. Rep. 48. Iowa State Univ. Coop. Ext. Serv., Ames.

Rorie, R.L., Purcell, L.C., Karcher, D.E., King, C.A., 2011a. The assessment of leaf nitrogen in corn from digital images. Crop Sci. 51, 2174–2180. doi:10.2135/cropsci2010.12.0699

BIOCHAR APPLICATION TO PEAT-BASED GROWING MEDIA FOR NURSERY PRODUCTION OF BROCCOLI SEEDLINGS

IMPIEGO DEL BIOCHAR IN SUBSTRATI DI CRESCITA A BASE DI TORBA PER LA PRODUZIONE VIVAISTICA DI PIANTINE DI CAVOLO BROCCOLO

Angela Libutti[1*], Teresa Incoronata Tisi[1], Anna Rita Bernadette Cammerino[1], Massimo Monteleone[1]

[1] Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente (SAFE), Università di Foggia, Via Napoli 25, 71122, Foggia
*angela.libutti@unifg.it

Abstract

Peatlands are crucial sinks for carbon in the terrestrial ecosystem, but the massive use of peat as the most common and frequently the sole ingredient in plant growth media is jeopardizing their conservation. Therefore, the present study investigated the feasibility of *biochar* as a partial or total peat substitute in the growing media used for nursery production of broccoli (*Brassica oleracea var. italica*) seedlings. *Biochar* was obtained from residues of fruit-tree pruning. Four growing media were prepared to detect the optimum substrate for broccoli plants: peat 100% weight (P), peat 60% weight + biochar 40% weight (B_{40}), peat 40% weight + biochar 60% weight (B_{60}) and biochar 100% (B_{100}). Substituting biochar at rates of 40 and 60% (w/w) for peat increased substrates pH, electrical conductivity, total porosity, water filled porosity, air space, water retention capacity, while having no effect on bulk density. The growth of roots of broccoli seedling, in terms of length and diameter, was similar in all the four growing media. Dry biomass, root volume, stem height and area of leaf surface of broccoli seedlings were lower when biochar was the only substrate component and higher when biochar was mixed to peat. However, the value of these parameters reached the highest values in peat. These was likely due to the lack of nutrients of biochar in comparison to peat and the difficulties of filling the alveolar trays because the fine and dusty biochar texture. The obtained results suggest the need for an optimization of biochar application in nursery seedling production, such as biochar enrichment with mineral nutrient formulations for the specific seedlings requirements, selection of biochar particle size and/or biochar aggregation into more easily handling grains.

Keywords: peat; biochar; growing media; seedling nursery production; *Brassica oleracea var. italica* L.
Parole chiave: torba; biochar; substrati di crescita; produzione vivaistica di piantine; *Brassica oleracea var. italica* L.

Introduction

Peat has been traditionally used as nursery substrate material due to its well suited properties, such as large water-holding capacity (WHC), high air capacity at 100% WHC, adequate porosity, homogeneity and availability of the product, absence of weed seeds and pathogens, low bulk density, pH, microbiological activity, and nutrient contents (Schmilewski, 2008; Michel, 2010). It is obtained from peatlands that in the world cover an estimated area of 400 million ha and represent the major store of soil carbon (Mendez et al., 2015). As long as peat remains in its natural habitat, its mineralization is slow and peatlands are therefore the main natural sink for carbon dioxide. Conversely, peat decomposes quickly and become a source of greenhouse gases once it is extracted (Cleary et al., 2005). Therefore, increasing ecological concern has developed over peatland destruction due to peat harvest and use. Moreover, peat is a scarce and largely non-renewable natural resource and its diminishing availability is prompting price increases. Massive use of peat as substrate has led to search for alternative materials (Boldrin et al., 2010) in order to obtain "reduced-peat" or "peat-free" growing media. Many studies have shown that several organic residues, after proper composting, can be used with very good results as growth media instead of peat (Benito et al., 2005). Recently, high attention has been focused on *biochar* as renewable alternative to peat in growing media formulation. *Biochar* is the solid, carbon-rich, porous co-product resulting from the pyrolysis of various biomass in the absence of oxygen. Adding biochar to soil has been shown to mitigate global climate change by sequestering atmospheric CO_2 and reducing greenhouse gas emissions, improve physicochemical and microbiological soil properties, enhance plant growth and crop yield. The use of biochar has gained widespread attention as agricultural soil amendment and only recently as additive or substitute of inorganic components, such as vermiculite and perlite, and organic components, such as peat, in growing media for horticultural crop production. Relatively few studies have assessed the potential utilization of biochar in nursery substrates for seedling production. Biochar utilization in the nursery sector may decrease peat usage, enhancing water and nutrient retention and their availability for plants (Di Lonardo et al., 2017). The present study was aimed at evaluating the effect of biochar as partial and total substitute of conventional peat in the composition of a growth media employed in the nursery production of broccoli plants.

Materials and Methods

The experiment was carried out at the "Carpinone" nursery in Castellucio dei Sauri (Foggia district, Apulia region, southern Italy) with broccoli (*Brassica oleracea var. italica*), cultivar "Parthenon F1".

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

Polystyrene trays (60×40 cm), with 240 cells (2.5×2.5×4.0 cm) were used for the experiment. Three replicate trays were filled with each of the following substrates: peat 100% weight (P), peat 60% weight + biochar 40% weight (B_{40}), peat 40% weight + biochar 60% weight (B_{60}) and biochar 100% (B_{100}). P was the control, corresponding to the commercial peat routinely used at nursery (peat Klasmann S3 fine, particle size <5 mm, enriched with: N,14%; P,16%; K,18%; Mg,10% and all the necessary trace elements). Biochar was obtained by pyrolysis of vine pruning residues. The biomass was heated to a maximum temperature of 650°C and the obtained biochar resulted in: pH of 11.3; salinity level of 360 mSm^{-1}; 65.50% by mass C, 1.19% H, 1.21% N, 0.02% S, 18.78% O; H/C_{org} and O/C_{org} of 0.21 and 0.22, respectively (lower values of these ratios are correlated with greater carbon stability). It contained: 69.77% fixed carbon, 16.95% volatile solids and 13.28% ash.
The experiment started in October 2016 by sowing the broccoli seed and placing the trays in the germination room. Here they were kept up to plant emergency under controlled conditions of temperature (22-24°C) ad relative humidity (90-95%), then transferred in greenhouse. The trays were randomly distributed in three blocks each containing all the treatments. They were periodically moistened and fertilized using a mechanic fertirrigation system and following the operations routinely applied in the nursery. The productive cycle of broccoli seedlings ended in December, after a total time of 50 days.
Several parameters were measured on substrates and seedlings in order to assess the effect of biochar on the physical-chemical properties of the growing media and the effect of substrate formulation on the quality of the nursery-produced plants, respectively. Substrate were analyzed for: pH, electrical conductivity (EC, dSm^{-1}), field water capacity (FC, % dw), wilting point (WP, % dw), bulk density (g cm^3), total porosity (%), air space (%), water filled porosity (%). Seedlings were analyzed for: root length (cm), diameter (mm) and volume (cm^3), total dry biomass per seedling and its weight distribution among stem+leaf and roots (g), stem height (mm) and leaf area (cm^2).

Results and Discussion

SUBSTRATES

Biochar addition to peat affected the substrate chemical characteristics, as showed by the significant pH and EC increases observed in B_{40} and B_{60} as compared to P (Table 1). These results are in line with Tian et al. (2012) which reported higher pH and EC values in 50% peat/biochar mixtures than in peat.

Parameters[a]	Growing media			
	P	B_{40}	B_{60}	B_{100}
pH (1:20 w/v)	6.54±0.02 d	9.35±0.14 c	10.13±0.03 b	11.26±0.07 a
EC (1:20 w/v, dSm^{-1})	0.27±0.01 d	1.16±0.02 c	2.03±0.09 b	3.63±0.15 a
FC (% dw)	52.53±0.29 c	143.88±1.39 b	157.37±1.31 a	167.17.14 a
WP (% dw)	37.63±1.03 c	75.31±5.15 b	116.25±1.31 a	104.79±4.12
Bulk density (g cm^3)	0.17 ± 0.01 a	0.16 ± 0.01 a	0.16 ± 0.01 a	0.13 ± 0.01 b
Total porosity (%)	23.18 ± 0.39 c	55.38 ± 0.17	57.41 ± 1.03 a	50.45 ± 1.63
Water filled porosity (%)	22.90 ± 0.30 c	55.07 ± 0.08 a	55.17 ± 1.99 a	41.95 ± 1.49
Air space (%)	0.28 ± 0.09 b	0.311 ± 0.09 b	2.24 ± 0.95 b	8.50 ± 0.13 a

[a] Means followed by same letters in each line are not significantly different (P≤0.05; Tukey test)

Tab. 1: Physical-chemical properties of the growing media.
Tab. 1: Caratteristiche chimico-fisiche dei substrati di crescita.

Biochar influenced also the water retention capacity of substrates. Indeed, B_{100} and B_{60} showed higher FC and WP values than the other two growth media. Biochar is a porous material with a high internal surface area which helps to retain more water. The ability to retain water decreased with decreasing amount of biochar added to peat. Bulk density and porosity of growing media have a high influence on seedlings growth (Bilderback et al., 2005). The optimum density value is <0.40 g cm^{-3} (Abad et al., 2005). The bulk density of the four treatments was always below that limit. The addition of biochar to peat resulted in a slight decrease in this parameter, although the differences between the treatments were not statistically significant. Biochar increased the substrate total porosity, as proven by the higher values in the two peat/biochar mixtures. Likewise, the addition of biochar to peat resulted in a significant increase in the water filled porosity, a very crucial agronomic condition (Lehmann et al., 2009). Biochar addition to peat also increased air spaces, as reported by Nieto et al. (2016). This represents an agronomic benefit since aerobic substrate conditions and physical conditions of seedling grow are both improved.

SEEDLINGS

The dry biomass (total, stem+leaves, roots), the length and volume of the roots were significantly lower when biochar was used as the sole substrate component than it was mixed with peat (Table 2). These results were likely due to nutritive elements more readily available from the peat. Similarly, higher stem height and leaf area were observed in B_{40} and B_{60} than B_{100}, although the highest values were recorded in P. The diameter of the roots was not significantly different among the four treatments that showed an average value of 0.09 mm.
Overall, B_{100} did not have a positive effect on growth parameters of broccoli seedlings. The high pH and the shortage of readily available macro and micronutrients that characterize biochar as compared to peat may be the reasons that presumably led to these results.

Moreover, very likely, biochar did not properly performed as growing media due to its dustiness and its very fine texture that made difficult filling the trays and caused loss of product from the bottom of the cells. Other authors (Dumroese et al., 2011) suggested the application of pelletized biochar to growing media due to its fine and dusty texture that makes this product difficult to manage and incorporate into other materials, especially if it is intended to be used in small containers.

Parameters[a]	Growing media			
	P	B_{40}	B_{60}	B_{100}
Stem height (cm)	18.80±0.57 a	12.36±0.18 b	11.32±0.70 bc	8.81±0.37 c
Leaf area (cm^{-2})	17.36±0.80 a	14.06±0.42 ab	11.21±0.32 b	4.24±0.42 c
Total dry biomass (g)	0.20±0.01 a	0.15±0.01 b	0.10±0.01 c	0.05±0.01 d
Stem+leaves dry biomass (g)	0.16±0.01 a	0.12±0.01 b	0.08±0.01 c	0.04±0.01 d
Root dry biomass (g)	0.04±0.01 a	0.03±0.01 ab	0.02±0.01 bc	0.01±0.01 d
Root lenght (cm)	42.83±1.94 a	33.75±1.10 a	34.17±1.21 a	14.12±0.40 b
Root diameter (mm)	0.09±0.01 a	0.09±0.01 a	0.08±0.01 a	0.10±0.01 a
Root volume (cm^3)	0.28±0.01 a	0.22±0.01 ab	0.16±0.01 b	0.05±0.01 c

[a] Means followed by same letters in each line are not significantly different (P≤0.05; Tukey test)

Tab.2: Growth parameters of broccoli seedlings at the end of the nursery production period.
Tab.2: Caratteristiche di accrescimento delle piantine di cavolo broccolo, al termine della fase di produzione in vivaio.

Conclusions

The experimental results suggest that a biochar selection in particle size and/or an optimization of biochar particle size through a granulation process may allow improving its application as partial or total substitute of conventional peat in nursery growing media. The optimization of biochar particle size should be aimed to obtain a more homogeneous and easily handling material. It could be obtained via: 1) a "mechanical" aggregation - biochar particles adhere one another through a high-pressing compactor roller; 2) a "wet" aggregation – particle adhesion is also favoured by a steam flow or adding a binder (starch, casein, synthetic latex, etc.). Moreover, the addition of a fertilizing formulation during the granulation process could enrich biochar of mineral nutrients able to sustain the growth of nursery seedlings.

References

Abad M., Fornes F., Carrion C., Noguera V., Noguera P., Maquieira A., Puchades R., 2005. Physical properties of various coconut coir dusts compared to peat. HortScience, 40: 2138-2144.
Benito M., Masaguer A., De Antonio R., Moliner A., 2005. Use of pruning waste compost as a component in soil-less growing media. Bioresources Technology, 96: 597-603.
Boldrin A., Hartling K.R., Laugen M., Christensen T.H., 2010. Environmental inventory modelling of the use compost and peat in growth media preparation. Resources, Conservation and Recycling, 54: 1250-1260.
Bilderback T. E., Warren S. L., Owen Jr. J. S., Albano J. P., 2005. Healthy substrates need physicals tool. HortTechnology, 15: 747-751.
Cleary J., Roulet N.T., Moore T.R., 2005. Greenhouse gas emissions from Canadian peat extraction 1990–2000: a life-cycle analysis, Ambio, 34: 456-461.
Di Lonardo S., Baronti S., Vaccari F.P., Albanese L., Battista P., Miglietta F., Bacci L., 2017. Biochar-based nursery substrates: The effect of peat substitution on reduced salinity. Urban Forestry & Urban Greening, 23: 27-34.
Dumroese R. K., Heiskanen J., Englund K., Tervahauta A., 2011. Pelleted biochar: chemical and physical properties show potential use as a substrate in container nurseries. Biomass and Bioenergy, 35: 2018-2027.
Lehmann J., Joseph S. (Eds), 2009. Biochar for environmental management: an introduction. In: Lehmann J. and Joseph S. (Eds) Biochar for environmental management - science and technology. Edited Earthscan, London, 1-12.
Mendez A., Paz-Ferreiro J., Gil E., Gasco G., 2015. The effect of paper sludge and biochar addition on brown peat and coir based growing media properties. Scientia Horticulturae, 193: 225-230.
Michel J.C., 2010. The physical properties of peat: a key factor for modern growing media. Mires Peat, 6, 1-6.
Nieto A., Gascò G., Paz-Ferrero J., Femàndez J.M., Plaza C., Mèndez A., 2016. The effect of pruning waste and biochar addition on brown peat based growing media properties. Scientia Horticulturae, 199: 142-148.
Schmilewski G., 2008. The role of peat in assuring the quality of growing media. Mires Peat, 3: 1-8.
Tian Y., Sun X., Li S., Wang H., Wang L., Cao J., Zhang L., 2012. Biochar made from green waste as peat substitute in growth media for *Calathea rotundifola cv. Fasciata*. Scientia Horticulturae, 143: 15-18.

EFFECTS OF AGRONOMIC MANAGEMENT ON SOYBEAN BRANCHING: VARIATIONS IN CONCENTRATION OF AUXINS AND ISOFLAVONES

EFFETTI DELLA GESTIONE AGRONOMICA SULLA RAMIFICAZIONE IN SOIA: VARIAZIONE DI CONCENTRAZIONE DI AUXINE E ISOFLAVONI

Giuseppe Barion*, Cristian Dal Cortivo, Giuliano Mosca, Teofilo Vamerali

Dipartimento di Agronomia Animali Alimenti Risorse Naturali e Ambiente (DAFNAE) – Università di Padova, Viale dell'Università, 16, 35020 Legnaro (Padova)
*giuseppe.barion@unipd.it

Abstract
Soybean (Glycine max) is one of the most important crop concerning protein production. This plant keeps an essential place in crop rotation in relation to its contribution to soil fertility through nitrogen fixation. In the last decade, nutraceutical approaches in soybean utilisation have been considered following new kinds of market demands. Agronomic management influences the vegetation habitus of soybean, and soil organic matter promotes grain production on lateral stem branches. The higher concentration of auxin-like molecules (tryptophan derivatives) in organic managed soils could have a key role to explain auxin metabolism strengthening on branches and consequently their higher productivity. Seed isoflavone concentration decrease in experimental conditions in which auxin metabolism results stronger suggests an inverse relation between phenylalanine derivatives (isoflavones) and IAA.

Keywords: auxin; isoflavones, branching; indole derivatives; soil organic matter.
Parole chiave: auxina; isoflavoni; ramificazione; derivati indolici; sostanza organica del suolo.

Introduction
The trial, carried out at the experimental farm L. Toniolo at the University of Padua (Padua- NE Italy), had the purpose to evaluate the productive and morphological modifications (branching intensity) induced by agronomic management. (conventional vs. organic). It was also monitored the metabolism of the major plant growth hormone: auxin (IAA, indole acetic acid, in relation to the main nutraceutical molecules (isoflavones).

Materials and Methods
An experimental trial conducted on pots was carried out according to a complete randomised scheme with 3 replicates. Each pot contained four soybean plants; the pot surface was 0.1 m^2. Varieties M35, M22, Demetra and Pedro were cultivated with conventional and organic management. Varieties were chosen for their good attitude to concentrate isoflavones. Pots were placed in a cold tunnel, and irrigation was performed manually. Soil moisture level was checked by TDR (time-domain reflectometer). In the months of higher hot (July, August), soil moisture was keep at 50% of the available water (24% relative humidity). At harvest, the plants were subsequently divided into stems and branches. For each replicate the stem and branching pod yield, grain yield as well as dry matter weight were determined separately. During the cycle, the stem and branching shoots closest to the apex were collected periodically in the stages V3, R1, R4 and R6 for the auxin assay. Shoots were immediately frozen after cutting in liquid nitrogen and stored at -80 °C. Of the four soybean plants in a pot, a different plant was sampled in each stage. Sample preparation and HPLC analysis for auxin determination were performed according to Kim et al., 2006. At the end of vegetative cycle, a soil sample was collected for each pot at a depth of 20 cm and analyzed for indole derivatives concentration, according to Lebhun and Hartman (1993), with appropriate modifications that allowed the shortening of time analysis. Seed isoflavone concentration was determined according to Hubert et al. (2005).

Results and Discussion
Branching coefficient (B/S, branches-to-stem weight ratio) was lower than 1 for Pedro variety (B/S = 0.88) indicating a low ramification attitude. M35 was instead the variety with higher branching coefficient (B/S = 1.73), followed by M22 (B/S = 1.61). Demetra had intermediate branching capacity (B/S = 1.45) (Table 1). The pod branching coefficient (BP/SP, branches-to-stem pod weight ratio followed the same trend, with significant differences among varieties: M35 and M22 had the highest branching productivity (PB/PS = 5.15 and 4.53 for M22 and M35, respectively). Branching pod production was intermediate for Demetra (BP/SP = 3.75), while Pedro produced less pods on branches (PB/PS = 2.25) (Table 1). Pod branching coefficient was 4.17 in organic and 3.41 in conventional management (main effect: +22.3%, $P < 0.05$) (Table 1).
Total grain yield (branches+stem) as well as total pod yield was similar among varieties (data not shown). The yield branching coefficient, calculated as the ratio between the weight of the grain produced by a single plant on branches (BY)

and that produced on the stem (SY) was significantly lower for the Pedro variety only (BY/SY = 2.58) compared to the other varieties (Table 1). The ratio between auxin concentration in the stem shoot and branching shoot was homogeneous among varieties, while the management effect was statistically significant ($P < 0.05$) (Tab.1). In conventional management, the auxinic ratio was higher than 1, while in the organic cultivation it was slightly less than 1 (Fig.1). Indole derivatives (indol lactic acetic acid and 5-hydroxytryptamine) were higher in organic management (Tab. 2).

Table 1: ANOVA for branching coefficients. B: Branching dry matter (d.w.), S: stem dry matter, BP: branching pod yield, SP: stem pod yield, BY: branching grain yield, SY: stem grain yield, TSIC: total seed isoflavone concentration.
Tabella 1: ANOVA dei coefficienti di ramificazione B: peso delle ramificazioni (s.s.), S: peso del fusto (sostanza secca), BP: resa in baccelli delle ramificazioni, SP: resa in baccelli del fusto, BY: resa in granella del fusto, resa in granella delle ramificazioni, SY: resa in granella del fusto, TSIC: concentrazione totale di isoflavoni nel seme.

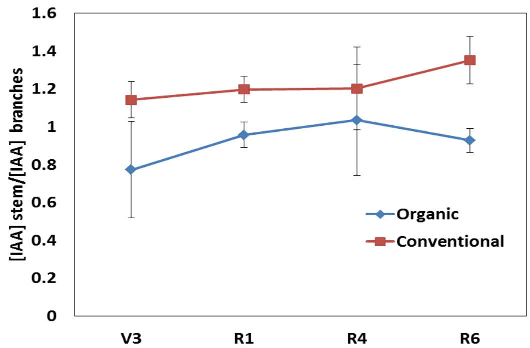
Variables	**B/S**	**BP/SP**	**BY/SY**	**TSIC** (mg/g)
Pedro	0.88 c	2.25 c	2.58 b	1.73a
Demetra	1.45 b	3.75 b	3.90 a	1.51ab
M22	1.61 ab	5.15 a	4.65 a	1.80a
M35	1.73 a	4.53 ab	4.38 a	1.42b
Conventional	1.28 a	3.68 a	3.52 b	1.73a
Organic	1.57 b	4.17a	4.24 a	1.50b

Table 2: Soil indole derivatives concentration (indol lactic acetic acid (ILA), 5-hydroxytryptamine) (ng g^{-1}) and their summation (total), and organic matter (%) in two management.
Tabella 2: Concentrazione di derivati indolici (acido indol lattico acetico ILA, e 5-idrossitriptamina) (ng g^{-1}) e contenuto sostanza organica (%) nel terreno dei due sistemi di conduzione (convenzionale e biologico).

Management	ILA	5-hydroxytryptamine	Total	Organic matter
Conventional	2.81 a	14.4 b	17.2 b	1.64 b
Organic	3.25 a	17.2 a	20.5 a	1.97 a

Fig.1: Ratio between stem-to-branching shoot IAA concentration at different soybean stages.

Figura 1: Rapporto tra la concentrazione di auxina del germoglio principale e delle ramificazioni in vari stati di sviluppo.



Conclusions

Soil organic matter concentration seems to affect the hormonal balance of soybean by modifying its branching attitude, at the same sowing density. A high organic matter content increases branching production probably through its auxin-like activity. Total seed isoflavone concentration varies with soil organic content, by decreasing in experimental conditions where the auxin synthesis was higher. This evidence suggests that a relationship between plant shoots auxinic balance and isoflavone metabolism. In fact, it is known that isoflavones participate in a plant self-regulating mechanism to limit the effects of auxin-like molecules (e.g., soil indole derivatives) on apical dominance (Balla et al. 2016).

References

Hubert J., Berger M., J. Dayde, 2005. Use of a simplified HPLC-UV Analysis for soyasaponin B determination: Study of saponin and isoflavone variability in soybean cultivars and soy-based health food products. Journal of Agricultural and Food Chemisiry, 53, 10: 3923-3930.

Kim Y.J., Oh Y.J., Park W.J., 2006. HPLC-based quantification of indole-3-acetic acid in the primary root tip of maize. Journal of Nano & Biotech, 3 (1), 40-45.

Lebuhn M. and Hartmann A., 1993. Method for the determination of indole-3-acetic acid and related compounds of L-tryptophan catabolism in soils. Journal of Chromatography A, 629(2), 255-266.

Balla, J., Medveďová, Z., Kalousek, P., Matiješčuková, N., Friml, J., Reinöhl, V., & Procházka, S., 2016. Auxin flow-mediated competition between axillary buds to restore apical dominance. Scientific Reports, 6.

INFLUENCE OF PLANT DENSITY AND NITROGEN APPLICATION ON GROWTH, YIELD AND QUALITY OF RADISH (Raphanus sativus L.)
INFLUENZA DELLA DENSITÀ DI TRAPIANTO E DELLA CONCIMAZIONE AZOTATA SULLA CRESCITA, PRODUZIONE E QUALITÀ DEL RAVANELLO (RAPHANUS SATIVUS L.)

Sara D'Egidio[1], Giancarlo Pagnani[1], Fabio Stagnari[1]*, Angelica Galieni[1,2]

[1]Faculty of Bioscience and Technologies for Food, Agriculture and Environment, Univ. Teramo, IT,
[2]Council for Agricultural Research and Economics, Vegetable and Ornamental Crops Research Centre, Monsampolo del Tronto, IT,
*fstagnari@unite.it

Abstract
The effects of nitrogen (N) supply and plant density on biomass accumulation and quality traits of radish plants were assessed with a greenhouse experiment, where N rates (0, 100, 200 kg N ha^{-1}) represented the main factor and plant densities (1, 2, 3, 4 plants pot^{-1}) the secondary one. Storage roots were harvested at 25 days after transplanting (DAT).
The highest root and leaves dry weights were achieved with 100 kg N ha^{-1}. Besides, plant density significantly affected biomass accumulation with the highest values obtained at higher inter-plant distance (i.e.: 1 or 2 plants plot^{-1}). The concentrations of total polyphenols content (TPC) in storage roots were significantly increased under 0 kg N ha^{-1} regardless of plant density; however, the best combination was obtained with 3 plants plot^{-1}.
The modulation of fertilizer inputs as well as of plant density (i.e.: abiotic stressful conditions) could enhance the concentration of some important phytochemicals, providing higher nutritionally improved vegetables, without affecting yield.

Keywords: *Raphanus sativus*, nitrogen fertilization, plant density, total phenolic content.
Parole chiave: *Raphanus sativus*, nutrizione azotata, densità, contenuto in polifenoli totali.

Introduction
Radish (*Raphanus sativus* L.) belongs to the cruciferous vegetable family. It is grown extensively in subtropical regions throughout the world and gives many health and nutritional benefits. Among the various factors influencing yield, inadequate nutrition and plant spacing play a main role. Considering mineral nutrition, N availability significantly increases growth, development, yield and yield components of radish (Pervez *et al*., 2004; Jilani *et al*., 2010). Besides, the effect of plant density on radish growth and yield has been discussed in literature (El-Desuki et al., 2005), principally in relation to the optimal growth of storage organs (Chatterjee and Som, 1991).
Also the synthesis of secondary metabolites in plant tissue is strongly influenced by environmental factors, and it could be enhanced by abiotic stress condition (Goyeneche et al., 2015).
In radish the combined effect of plant density and N availability on biomass accumulation as well as on phytochemicals concentration in edible organs has not been studied so far. Therefore, we investigated such effects on growth and accumulations of important plant-based compounds in storage roots which could improve the health-promoting value of radish plants.

Materials and Methods
The experiment was carried out at the greenhouse of Agronomy and Crop Sciences Research and Education Center, University of Teramo (altitude 15 m a.s.l.; 42° 53 N, 13° 55 E) fr°om 23 September to 30 October 2015. Starting from transplanting the environmental conditions were constantly monitored with temperature and humidity sensors connected to a data logger (EM50 Data Collection System, Decagon Devices, Pullman, WA, USA).
Seeds of radish (*Raphanus sativus* L. cv. Suprella, Vilmorin Italia S.r.l., Argelato (BO), Italy) were sown in a nursery potting soil; 14 days after sowing plants were transplanted into plastic pots (9 x 9 cm). Following a split-plot design with three replications, the effects of two factors were investigated: N fertilization rates as main factor (0, 100 and 200 kg N ha^{-1}) and plant densities as secondary factor (1, 2, 3 and 4 plants plot^{-1}), for a total of 12 experimental treatments. Each experimental unit consisted of 20 pots.
At 25 days after transplanting (DAT), 9 plants per treatment were sampled, separated into leaves and storage roots and dried in an oven untill constant weight to determine organs dry weights (DW). In addition, 3 plants per experimental unit were harvested and frozen at -40 °C until analysis. The total polyphenol content (TPC) was determined by the Folin-Ciocalteu reagent method (Singleton and Rossi, 1965); TPC was expressed as mg of gallic acid equivalent (GAE) on 100 g^{-1} fresh weight (FW).

Results and Discussion

The effects of N rates and plant density interaction were significant for all the investigated variables (Table 1). Leaf DW per plant was significantly enhanced by N treatments, with the highest values reached at 100 kg N ha^{-1}. Conversely, higher plant density reduced biomass accumulation in leaves by 39% and 24% at 0 and 200 Kg N ha^{-1}, respectively.

Root DW was positively related to N fertilization rate in accordance with El-Desuki et al. (2005), while plant density had a significantly negative effect with the highest values achieved at the lowest plant density, regardless of N availability.

Figure 1 shows the amount of total phenolic compounds found in radish storage roots at harvest time.

The highest TPC concentrations were observed in absence of N fertilization, in accordance with literature results. Several authors demonstrated that the content of polyphenols in *Brassicaceae* plants may increase under abiotic stress, like nutrient deficiency during crop growing cycle (Podsedek, 2007; Aires et al., 2006). The higher TPC values were generally observed at the highest plant densities (i.e. 3 or 4 plant pot^{-1}), regardless of N fertilization rate. This is

Table 1: Leaves dry weight (DW, g $plant^{-1}$) and storage roots DW (g $plant^{-1}$) of radish plants subjected to 3 different nitrogen rates (0, 100 and 200 kg N ha^{-1}, principal factor) and 4 different cultivation densities (1, 2, 3 and 4 plants pot^{-1}, secondary factor) at 25 Days After Transplanting (DAT). Data are the average of n=3 independent replicates; different letters stand for statistically significant differences at p<0.05 (Tukey's HSD test).

Tabella 1: Peso secco delle foglie (DW, g $pianta^{-1}$) e stoccaggio radici DW (g $pianta^{-1}$) di piante ravanello sottoposte a 3 diversi trattamenti con N (0, 100 e 200 kg N ha-1, fattore principale) e 4 diverse densità di coltivazione (1, 2, 3 e 4 piante pot^{-1}, fattore secondario) a 25 giorni dal trapianto (DAT). I dati sono la media di n = 3 repliche indipendenti; Diverse lettere presentano differenze statisticamente significative a p <0,05 (test HSD di Tukey).

Nitrogen rate (kg N ha^{-1})	***Plants pot^{-1} (number)***	***Leaves DW (g $plant^{-1}$)***	***Storage roots DW (g $plant^{-1}$)***
0	***1***	0.363 d	1.134 a
	2	0.296 e	0.738 c
	3	0.289 e	0.694 cd
	4	0.220 f	0.639 d
	Overall mean	*0.292*	*0.801*
100	***1***	0.516 a	1.119 a
	2	0.504 ab	0.959 b
	3	0.434 c	0.751 c
	4	0.356 d	0.716 cd
	Overall mean	*0.452*	*0.886*
200	***1***	0.502 ab	1.192 a
	2	0.478 b	0.912 b
	3	0.385 d	0.718 cd
	4	0.380 d	0.693 cd
	Overall mean	*0.436*	*0.879*
Overall mean	***1***	*0.460*	*1.148*
	2	*0.426*	*0.869*
	3	*0.369*	*0.721*
	4	*0.318*	*0.683*
	Nitrogen	**	**
	Plants pot^{-1}	**	**
	N x P	**	**

n.s.= not significant
** = significant at p < 0.05*
*** = significant at p < 0.01*

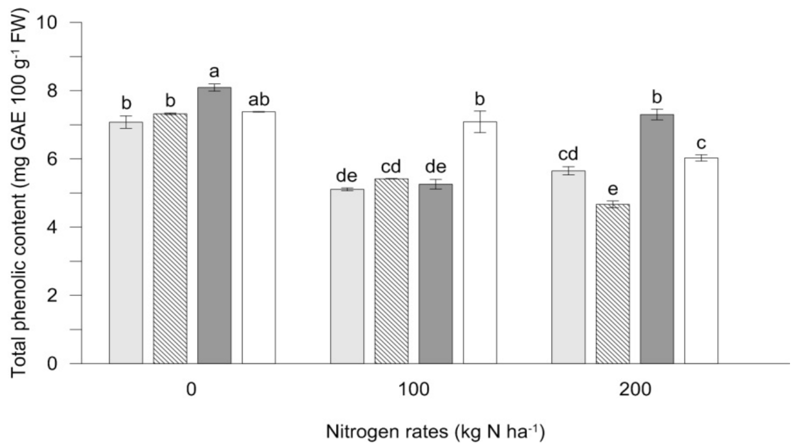


Figure 1: Total phenolic content (mg GAE 100 g^{-1} FW) of radish plants subjected to 3 different nitrogen rates (0, 100 and 200 kg N ha^{-1}, principal factor) and 4 different cultivation densities (1, 2, 3 and 4 plants pot^{-1}, secondary factor) at 25 Days After Transplanting (DAT). Data are the average of n=3 independent replicates; different letters stand for statistically significant differences at p<0.05 (Tukey's HSD test). Grey chart: 1 plant pot^{-1}; Diagonal black line chart: 2 plants pot^{-1}; black chart: 3 plats pot^{-1}; white chart: 4 plants pot^{-1}.

Figura 1: Contenuto totale fenolico (mg GAE 100 g^{-1} FW) di piante di ravanello soggette a tre differenti tassi di azoto (0, 100 e 200 kg N ha^{-1}, fattore principale) e 4 diverse densità di coltivazione (1, 2, 3 E 4 piante $vaso^{-1}$, fattore secondario) a 25 giorni dal trapianto (DAT). I dati sono la media di n = 3 repliche indipendenti; lettere diverse presentano differenze statisticamente significative a p <0,05 (il test HSD di Tukey). grigio: 1 pianta $vaso^{-1}$; linee diagonali: 2 piante $vaso^{-1}$; nero: 3 piante $vaso^{-1}$; bianco: 4 piante $vaso^{-1}$

DOI 10.6092/unibo/amsacta/5692

probably attributable to the intra-specific competition for nutrients in the growing substrate. However, further investigations are needed to individuate which factor mostly affects the synthesis of secondary metabolites.

Conclusions

These preliminary results suggest that in radish the modulation of N inputs in combination with plant density could enhance the concentration of some important phytochemicals, providing higher nutritionally improved vegetables, slightly affecting yield.

References

Aires A., Rosa E., and Carvalho, R. (2006). Effect of nitrogen and sulphur fertilization on glucosinolates in the leaves and roots of broccoli sprouts (*Brassica oleracea* var. italica). Journal of the Science of Food and Agriculture, 86:1512-1516.

Chatterjee, R., and Som, M.G. (1991). Response of radish to various levels of nitrogen, potassium and plant spacing. Indian Journal of Horticulture, 48:145-147.

El-Desuki, M., Salman, S., El-Nemr, M.A., and Abdel-Awgoud, A.M.R. (2005). Effect of Plant Density and Nitrogen Application on the Growth, Yield and Quality of Radish (*Raphanus sativus* L.). Journal of Agronomy, 4:225-229.

Goyeneche, R., Roura, S., Ponce, A., Vega-Gálvez, A., Quispe-Fuentes, I., Uribe, E., and Di Scala, K. (2015). Chemical characterization and antioxidant capacity of red radish (*Raphanus sativus* L.) leaves and roots. Journal of Functional Foods, 16:256-264.

Jilani, M.S., Burki, T., and Waseem, K. (2010). Effect of nitrogen on growth and yield of radish. Journal of Agricultural Research, 48:219-225.

Pervez, M.A., Ayub, C.M., Basharat, A.S., Anwar, N.V., and Nasir, M. (2004). Effect of nitrogen levels and spacing on growth and yield of radish (*Raphanus sativus* L.). International Journal of Agriculture and Biology, 6: 504-506.

Podsędek, A. (2007). Natural antioxidants and antioxidant capacity of Brassica vegetables: A review. LWT-Food Science and Technology, 40:1-11.

Singleton, V.L., and Rossi, J.A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture, 16:144-158.

ASSESSMENT OF WATER STRESS TOLERANCE IN TOMATO: PHYSIOLOGICAL AND YIELD RESPONSE
VALUTAZIONE DELLA TOLLERANZA DEL POMODORO ALLO STRESS IDRICO: ASPETTI PRODUTTIVI E FISIOLOGICI

Federica Carucci, Giuseppe Gatta, Eugenio Nardella, Concetta Lotti, Marcella Michela Giuliani*

Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente, Università di Foggia, Via Napoli 25, 71121 Foggia
*marcella.giuliani@unifg.it

Abstract

In Mediterranean regions, the adoption of water saving strategies may result in significant savings of irrigation water. The aim of this research was to evaluate strategies that allow the reduction of the water used during the tomato crop cycle preserving, at the same time, the yield response. Two tomato genotypes, IT-22/025 and Ikram, were grown under controlled condition using three water regimes: $WR_{100\%}$, as control, in which plants were watered at 100% of their consumption; $WR_{50\%}$, giving 50% of the water supplied in the control; $WR_{0\%}$, watering only at transplanting, during fertigation and as supplementary irrigation. Moreover, azoxystrobin treatment was evaluated by comparing: AT_0 (no agrochemical added) and AT_{az}, (azoxystrobin added) treatments. During the flowering stage the main physiological parameters were measured, and at the end of the experiment aerial plant dry weight, total fruit yield and WUE were determined. Under water stress condition IT-22/025 showed higher stomatal conductance, transpiration and assimilation rate than Ikram. The physiological plant response corresponded to a higher total fresh fruit yield, WUE and TYWUE for IT-22/025 with respect to Ikram. The azoxystrobin treatment determined a lower stomata conductance maintaining a higher *A* respect to the thesis without treatment. Moreover, under water stress condition the azoxystrobin has led to an increase in WUE.

Keywords: deficit irrigation; strobilurin; water use efficiency
Parole chiave: irrigazione deficitaria; strobilurine; efficienza dell'uso dell'acqua

Introduction

Water is the major factor limiting plant productivity in agriculture in many regions of the world, especially in the arid and semi-arid zones (Tahi *et al*., 2007). Tomato is one of the most demanding in water, in Mediterranean area requires about 5000-6000 m^3 ha^{-1} (Giuliani *et al*., 2016), and the adoption of water saving strategies may result in significant savings of irrigation water. The general purpose of this research study was to evaluate strategies that allow the reduction of the water used during the tomato crop cycle preserving, at the same time, the yield and quality response.

Materials and Methods

Two tomato genotypes, Ikram (Syngenta Seeds Spa) and IT-22/025 (selected by Department of Soil Sciences, Plants and Food of University of Bari "A. Moro"), were grown under controlled condition from April 26th to August 3th 2016 (day/night temperatures 22-26°C/18°C; relative humidity 60%; PAR 500 µmol $m^{-2}s^{-1}$ plant height with a 16h/8 photoperiod). The two genotypes were grown using three water regimes: $WR_{100\%}$, considered as control, in which plant were watered at 100% of plant transpiration rate; $WR_{50\%}$, in which 50% of the amount of water given to the control plants was supplied; $WR_{0\%}$, watering only at transplanting, during fertigation and as supplementary irrigation. Moreover, two agrochemical treatments were compared: AT_0, no agrochemical added; AT_{az}, azoxystrobin treatment. The experiment was arranged in a complete randomized design with four replicates and three factors (genotype, G; water regime, WR; agrochemical treatment, AT). During the flowering stage, considered the most sensible to water stress in tomato, the stomatal conductance (g_s), assimilation rate (A) and transpiration rate (E) were measured using the LI-6400XT portable gas exchange system (LiCor Inc., Lincoln, NE, USA). At the end of the experiment aerial plant dry weight and total fruit yield, were determined. Finally, the intrinsic water use efficiency (WUE*i*; A/g_s) WUE (plant dry matter/plant water used; g l^{-1}) and total yield water use efficiency (total fruit yield/plant water used; TYWUE, g l^{-1}) were calculated. The ANOVA procedure was adopted according to randomized complete design with four replicates. The differences in the means were determined using Tukey's test. Statistical analyses were performed using the JMP software package, version 8.1 (SAS Institute Inc., Cary, NC, USA).

DOI 10.6092/unibo/amsacta/5692

Results and Discussion

Water Regime. Both genotypes showed a decrement of g_s values from $WR_{100\%}$ to $WR_{50\%}$ that were equal to 29% and 39% for IT-22/025 and Ikram respectively, showed that IT-22/025 closed less its stomata under water stress condition with respect to Ikram (Table 1). The lower g_s values obtained for $WR_{50\%}$ with respect to $WR_{100\%}$ in both genotypes confirmed that stomatal closure process is one of the first events in the plant response to water stress. Also the *E* decrease from the optimal to the $WR_{50\%}$ regime was different for the two genotypes being 16% and 35% for IT-22/025 and Ikram respectively, showing that IT-22/025 reduced less the transpiration process by reducing the stomatal closure compared to Ikram (Table 1). On the contrary, the percentage *A* decrease observed from $WR_{100\%}$ to $WR_{50\%}$ was higher for IT-22/025 than for Ikram which maintained CO_2 assimilation rate at levels comparable to the optimal irrigation. Finally, as for the WUE*i*, the two genotypes showed a different behaviour in relation to the water stress. The intrinsic WUE increase with the increase in water stress observed especially in Ikram, was due to a different sensitivity of *A* and g_s parameters to water deficit condition. Both genotypes showed similar significant aerial plant dry biomass decrease with the increase in water stress applied (Table 2). The total fresh fruit yield trend was similar to that of the total dry biomass. The genotype IT-22/025 showed higher yield value than Ikram also in the optimal regime. On the other hand, IT-22/025 showed also a higher assimilation rate than Ikram under $WR_{100\%}$. Moreover, the two genotypes showed different yield decrease from the $WR_{100\%}$ to the $WR_{50\%}$ being equal to 43% for IT-22/025 and 51% for Ikram. While the two genotypes showed a slightly increase in WUE calculated on total dry biomass basis, under water stress, they showed a different behaviour in relation to WUE calculated on total fruit yield basis. Under water stress, the TYWUE of the genotype IT-22/025 slightly increased, while a significant decrease was reported for Ikram.

	g_s ($mol\ H_2O\ m^{-2}s^{-1}$)	***E*** ($mmol\ H_2O\ m^{-2}s^{-1}$)	***A*** ($\mu mol\ CO_2\ m^{-2}s^{-1}$)	**WUE*i*** ($\mu mol\ CO_2\ mol\ H_2O^{-1}$)
Ikram				
WR_{100}	0.28 A	4.87 B	5.93 B	21.06 C
WR_{50}	0.17 B	3.17 C	5.26 B	32.1 B
WR_0	0.06 C	0.89 D	2.26 C	49.1 A
IT-22/025				
WR_{100}	0.31 A	5.34 A	7.93 A	25.4 BC
WR_{50}	0.22 B	4.47 B	6.3 B	29.67 B
WR_0	0.03 C	0.34 D	0.41 D	20.55 C

Table 1. Effect of the interaction genotype x water regime on the physiological parameters. In each column, mean values followed by different letters are significantly different (P<0.01) according to Tukey test.

Tabella 1. Effetto dell'interazione genotipo x regime idrico sui parametri fisiologici. Per ogni colonna i valori medi seguiti da lettere diverse sono significativamente diversi (P<0.01) secondo il test di Tuckey.

	Plant Water use ($l\ plant^{-1}$)	Plant dry matter ($g\ plant^{-1}$)	Total fruit yield ($g\ plant^{-1}$)	WUE ($g\ l^{-1}$)	TYWUE ($g\ l^{-1}$)
Ikram					
WR_{100}	28.8 a	115.17 b	629.57 b	4.0	21.85 b
WR_{50}	14.4 b	75.07 c	307.28 d	4.57	18.73 c
WR_0	5.3 c	29.45 d	97.82 e	5.55	18.47 c
IT-22/025					
WR_{100}	33.2 a	162.17 a	814.8 a	4.88	24.55 a
WR_{50}	18.6 b	100.95 b	463.73 c	5.42	24.92 a
WR_0	5.0 c	31.33 d	98.67 e	6.27	19.73 c

Table 2. Effect of the interaction genotype x water regime on plant dry weight, fruit yield and water use efficiency. In each column, mean values followed by different letters are significantly different (P<0.05) according to Tukey test.

Tabella 2. Effetto dell'interazione genotipo x regime idrico su peso secco della pianta, produzione di bacche ed efficienza d'uso dell'acqua. Per ogni colonna i valori medi seguiti da lettere diverse sono significativamente diversi (P<0.05) secondo il test di Tuckey.

Azoxystrobin. In figure 1 the azoxystrobin effect on the physiological parameters is shown. The stomatal conductance was significantly reduced by azoxystrobin treatment (Fig 1a), indicating a higher stomatal closure under this treatment. Moreover, the reduced stomatal aperture appeared not be limiting for the CO_2 income being *A* values higher in the plants treated with azoxystrobin

(Fig. 1b). The reducing in stomatal opening but not in photosynthetic rate determined an increase in WUE*i* with the azoxystrobin application. In our experiment, the azoxystrobin treatment caused also an increment in transpiration rate (*E*) more evident for Ikram. The effect of the azoxystrobin treatment on the yield and quality parameter was less evident. In particular, the effect of the treatment was significant only for the water use efficiency (both WUE and TYWUE) under extreme water stress level with AT_{az} showing higher value with respect to AT_0 (WUE: 5.17 *vs* 6.65 g l^{-1} for AT_0 and AT_{az}, respectively; TYWUE 17 *vs* 21.2 g l^{-1} for AT_0 and AT_{az}, respectively. P<0.05)

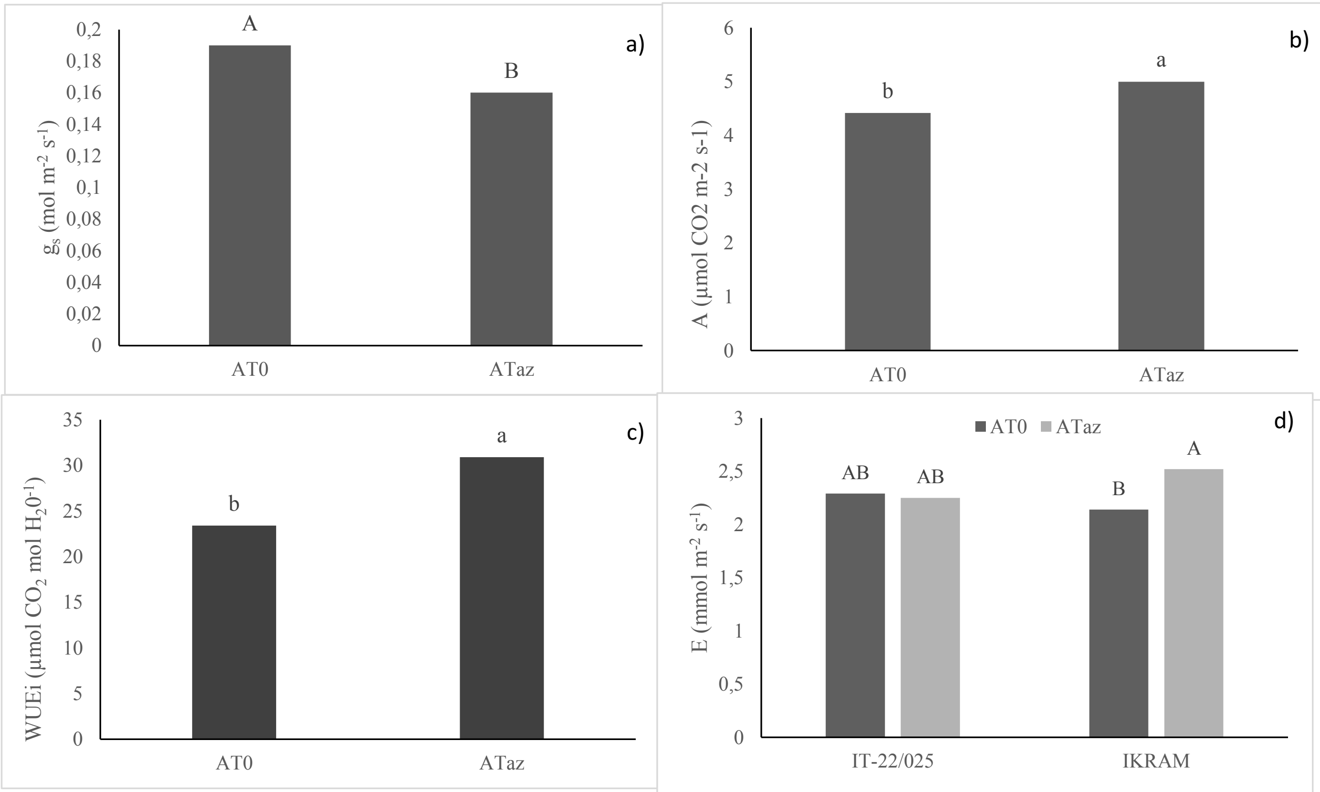


Fig. 1. Effect of the azoxystrobin treatment on stomatal conductance (a), assimilation rate (b), intrinsic water use efficiency (c) and the interaction genotype x azoxystrobin treatment on the transpiration rate (d). Different letters indicate values significantly different (P<0.05 small letters, P<0.01 capital letters) according to Tukey test.

Fig. 1 Effetto dell'azoxystrobin su conduttanza stomatica (a) assimilazione (b) e efficienza d'uso dell'acqua intrinseca (c) e dell'interazione genotipo x azoxystrobin sulla traspirazione (d). Lettere diverse indicano valori significativamente diversi (P<0.05 lettere minuscole; P<0.01 lettere maiuscole) secondo il test di Tukey

Conclusions

In conclusion, in our experimental conditions the two genotypes showed a different behaviour in response to water stress.

In particular, under water stress condition IT-22/025 showed higher stomatal conductance, transpiration and assimilation rate than Ikram. The physiological plant response corresponded to a higher total fresh fruit yield, WUE and TYWUE for IT-22/025 with respect to Ikram. Concerning the azoxystrobin, the treatment determined a lower stomata conductance maintaining a higher *A* respect to the thesis without treatment. Moreover, under water stress condition the azoxystrobin has led to an increase both in WUE and TYWUE.

References

Giuliani M.M., Gatta G., Nardella E., Tarantino E. (2016). Water saving strategies assessment on processing tomato cultivated in Mediterranean region. Italian Journal of Agronomy, 11(1): 69-76.

Tahi H., Wahbi S., Wakrim R., Aganchich B., Serraj R., Centritto M. (2007). Water relations, photosynthesis, growth and water use efficiency in tomato plants subjected to partial rootzone drying and regulated deficit irrigation. Plant Biosystems, 141, 265-274

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

QUANTITATIVE REVIEW OF ANIMAL MANURE DECOMPOSITION IN SOIL
SINTESI QUANTITATIVA DELLA DECOMPOSIZIONE DEGLI EFFLUENTI ZOOTECNICI NEL SUOLO

Daniele Cavalli[1*], Martina Corti[1], Pietro Marino Gallina[1], Luca Bechini[1]

[1] Dipartimento di Scienze Agrarie ed Ambientali, Università degli Studi di Milano, Via Celoria 2, 20133, Milano

[*]daniele.cavalli@unimi.it

Abstract

Animal manures have variable physical-chemical composition and show different decomposition dynamics in soil. Manure composition and decomposition strongly depend on animal feed, manure storage and manure treatments. Optimal manure management can be achieved if their decomposition in soil is well understood and predictable. In this work, we summarized a large body of published literature of incubation experiments, to provide the range of variation of net CO_2 emissions and net N mineralization (NNM) in manure-amended soils, and measurable model parameters. The innovative approach adopted in this work (collection of individual data and fitting of empirical models) provides a new, quantitative view of the manure decomposition processes.

Keywords: CO_2; mineralization; immobilization; incubation; nitrogen.
Parole chiave: CO_2; mineralizzazione; immobilizzazione; incubazione; azoto.

Introduction

Animal manures have variable physical-chemical composition, related to animal species and diet (Kyvsgaard et al., 2000; Powell et al., 2006; Sørensen and Fernández, 2003; Sørensen et al., 2003), type of husbandry, and to biotic or abiotic processes, such as anaerobic storage and digestion, composting, physical-chemical separation, that further modify manure characteristics (Morvan et al., 2006; Peters and Jensen, 2011). Differences in manure composition are often reflected in different decomposition dynamics in soil, both in the short and in the long term (Morvan et al., 2006). Understanding factors affecting manure decomposition allows better predicting manure nutrients (mainly N) availability for crops, and estimating CO_2 emissions connected to fertilization practice.
Soil organic matter (SOM) simulation models can be useful tools to gain insights into manure, and in general SOM, decomposition in soil (Petersen et al., 2005). Indeed, they are of interest to forecast manure-N fate in soil and manure-derived CO_2 emissions from soil, even under climate-change or different management scenarios (Brilli et al., 2017). Models usually represent SOM heterogeneity through different pools connected each other by a net of decomposition fluxes; further differences among models regard decomposition kinetics, and the effects of N shortage on SOM decomposition (Manzoni and Porporato, 2009; Cavalli et al., 2016).
Successful adoption of models necessitate that some parameters are calibrated in order to achieve a good agreement between measured and simulated model outputs. Unluckily, parameter calibration can be a difficult task, because complexity of SOM models can give rise to unsatisfactory calibrations due to trade-offs (*i.e.* compensations) between errors of multiple model outputs (Cavalli and Bechini, 2012) or to identifiability and overfitting issues (Sierra et al., 2015). Indeed, reducing number of models parameters subjected to calibration is of pivotal importance.
The objective of this work was the joint analysis of the results (net CO_2 emissions and net N mineralization) of many published aerobic manure decomposition experiments conducted under controlled conditions. On the one hand, the summary of these experiments provides the statistical properties of quantities that are relevant also for field-scale manure management, as for example the percentage of manure C respired after a given time, the days to reach the peak of microbial immobilization, and the net N mineralization in the long term. On the other hand, the extensive collection of literature data allows estimating the range of variation of measurable model parameters, like the C/N of microbial biomass, and the percentage of C and N contained in the labile and resistant manure fractions.

Materials and Methods

REFERENCE DATASETS

First step - Collection of measured data. Experimental data were collected from tables and figures of published aerobic manure incubation experiments. Different manure types were considered (feces, solid manures, liquid manures), with respect both to species (bovine, pig, sheep and poultry) and to manure storage and treatment (fresh, anaerobically stored, anerobically digested, separated fractions). The variables of interest were accumulated net CO_2 emissions (*i.e.* after subtracting CO_2 measured in unamended soil) and net N mineralization (NNM), expressed as mg C 100 mg^{-1} manure C or mg N 100 mg^{-1} manure C, for consistency with published data. The NNM represents the variation of net soil mineral N (*i.e.*

after subtracting N measured in unamended soil) compared to day 0 (Bechini and Marino, 2009); positive NNM indicates net mineralization of organic N (ON), while negative values indicate net N immobilization of soil mineral N.
Treatments belonging to compost-amended soils were excluded from datasets. A total of 17 experiments were reviewed (Alburquerque et al., 2012; Atallah et al., 1995; Bechini and Marino, 2009; Calderón et al., 2005; Cavalli et al., 2012, 2014; Delin et al., 2012; Kirchmann, 1991; Kirchmann and Lundval, 1993; Kyvsgaard et al., 2000; Morvan and Nicolardot, 2009; Peters and Jensen, 2011; Sørensen and Fernández, 2003; Sørensen et al., 2003; Thomsen and Olesen, 2000; Thomsen et al., 2003, 2013), providing 732 and 674 data points for net CO_2 and NNM, respectively.

Second step - Fitting of empirical models to measured data. Differences in sampling dates among experiments made it impossible to compare experiments. For this reason, empirical models were fitted to measured net CO_2 and NNM, and then used to estimate the two variables at fixed dates. A double exponential model (Bechini and Marino, 2009) was fitted to net CO_2 measurements at time t:

$$\text{Net } CO_{2t} \text{ (mg C 100 mg}^{-1}\text{ manure C)} = C_L(1-e^{-kLt})+C_R(1-e^{-kRt}), \text{ where } C_R=100-C_L \quad \text{[Eq. 1]}$$

Instead, a Monod-type three-parameter model (Peters and Jensen, 2011) was used for NNM at time t:

$$NNM_t \text{ (mg N 100 mg}^{-1}\text{ manure C)} = (at/(t_h+t))(1-b(1-(at/(t_h+t)))) \quad \text{[Eq. 2]}$$

Model parameters C_L, k_L and k_R, for net CO_2, and a, b, and t_h, for NNM were optimized separately for each manure × soil combination, in order to obtain the best fit of experimental data (R^2 0.99 and 0.94 for all data of net CO_2 and NNM, respectively). Calibration was carried out with Solver GRG procedure of MS Excel (Microsoft Professional Plus 2010).

Third step - Construction of the datasets. After parameter estimation, the two models were used to build two datasets, that is to obtain, for all treatments and for both variables, a measured or at least a simulated value at days 3, 7, 14, 28, 42, 84, 120, and 180. The dataset of net CO_2 emissions was built selecting simulated values corresponding to the eight desired dates, irrespective from the duration of the experiment (*i.e.* for experiments that lasted less than 180 days some points were predicted with Eq. 1 even after the end of the experiment; this is adequate given that accumuated net CO_2 emissions have a clear pattern over time; Figure 1a). Conversely, reference points of NNM were preferentially selected from experimental measurements, and in no case the model (Eq. 2) was used to predicted NNM beyond the duration of the experiment (due to less predictable patern of NNM over time). Thus, if a NNM measurement falled within ±10% of a desired sampling date, it was selected, otherwise the simulated value was taken (Figure 1b). After having built the two datasets, relative frequencies of net CO_2 and NNM for each of the eight dates were calculated, selecting the number of classes according to the formula of Sturges (number of classes=1+(10/3)+$\log_{10}$(number of data)).

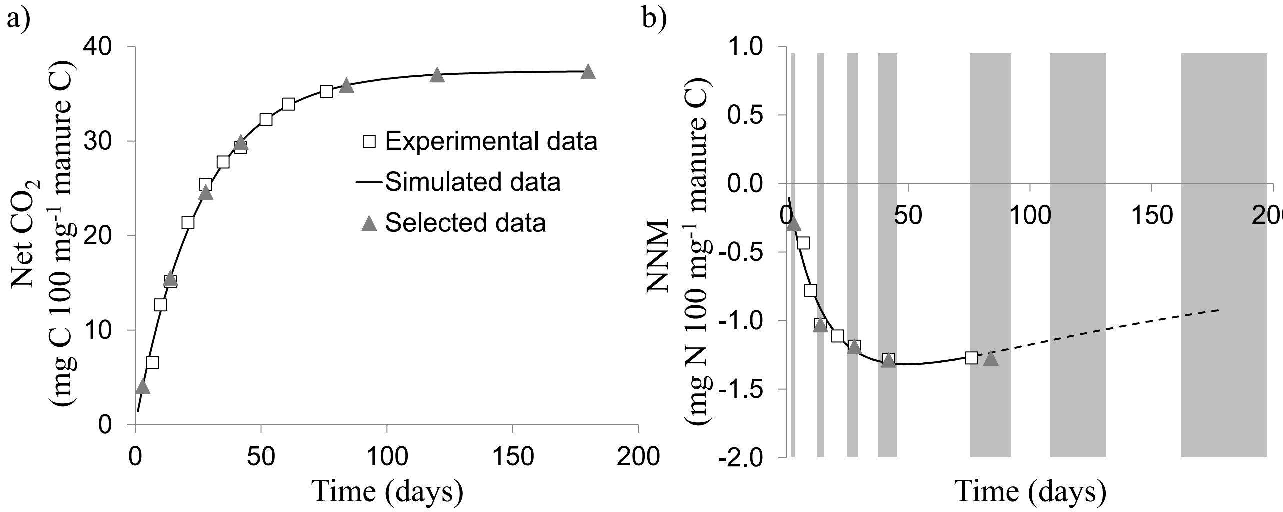


Figure 1. Methodology used to build reference datasets of net CO_2 emissions and net N mineralization (NNM). Gray areas represent time-tolerance for sampling date of NNM (±10%).
Figura 1. Metodologia utilizzata per costruire i dataset di riferimento delle emissioni nette di CO_2 e della mineralizzazione netta di N (NNM). In grigio la tolleranza per ogni data di riferimento di NNM.

PARAMETERS DISTRIBUTIONS

Experimental data related to model parameters were collected from literature regarding manure composition and soil and microbial biomass properties. Thereafter, for each parameter, uniform or normal distribution were considered, choosing the one that better approximated data distribution. While some model parameters were directly taken from measured variables (*e.g.* microbial biomass or soil C/N), others were estimated from measurements (*e.g.* the labile and resistant fractions of manures). At last, some model parameters can not be measured, and are not directly associated to measurements (*e.g.* first-order decomposition constants). Therefore, distributions of such parameters were defined according to the reference values (often resulting from optimization procedures) reported in the literature. Even if models represent SOM and fresh organic inputs to soil (such as manures), as well as their decomposition in different ways, many parameters are often common to (all) models. Therefore, our review did not focuse on specific model formulations and can be useful for many of the SOM models commonly embedded in larger croppying systems models.

Results and Discussion

Net CO_2 emissions from soil (Figure 2) occurred at exponentially decreasing rates over time, due to the mineralization of manure fractions characterized by different decomposability and decomposition velocity (soluble organic matter, holocellulose and lignin). After six months, net CO_2 losses averaged 55±2% of manure C. However, overall variability among treatments was high throughout the considered period (Morvan et al., 2006), with C respiration ranging from less than 20% to as high as 100% of manure C (probably due to priming effects). Manures promoted on average marked net N immobilization in the first week following their addition to soil (Figure 2), accounting for 41±4% of manure ON, considering a C/ON of 17 (average C/ON based on our review). Rapid and marked soil mineral N immobilization was reported during decomposition of volatile fatty acids (Kirchmann and Lundvall, 1993) and of low-N fibrous fractions (Morvan et al., 2006; Morvan and Nicolardot, 2009; Peters and Jensen, 2011). After initial N immobilization, net mineral N concentration in soil started to rise and, after six months, average NNM was positive (9±4% of manure ON). Also in the case of NNM, variability among treatments was very high (Morvan et al., 2006), with some showing long-term net N immobilization, opposite to few others showing net N release already from first days of decomposition (probably due to a low C/ON).

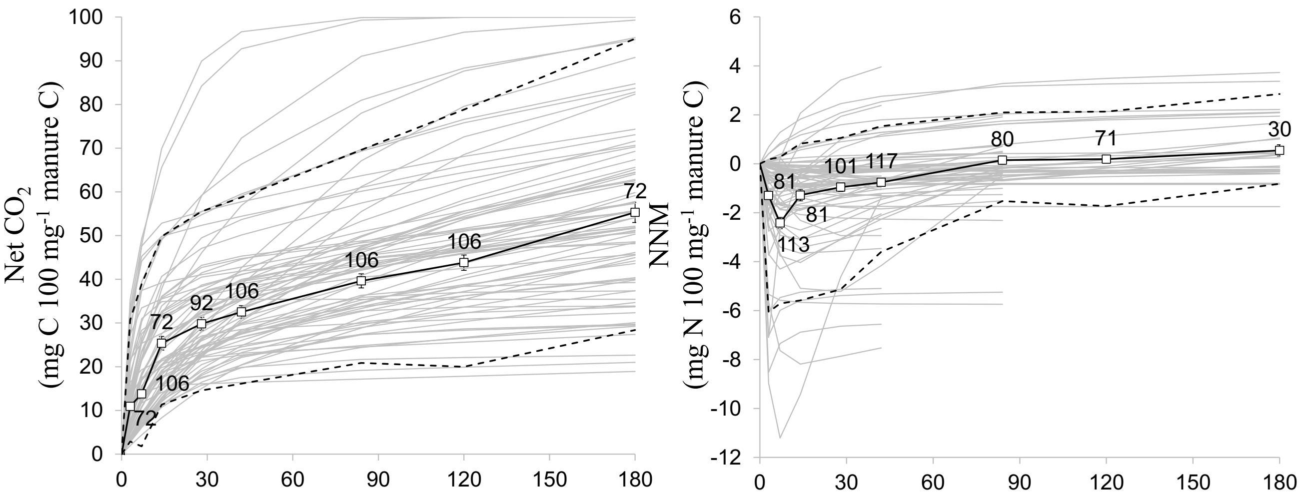


Figure 2. Reference datasets for net CO_2 and NNM variability assessment. Continuous black line and symbols: average of all treatments (labels indicate the number of data used to estimate means); dashed black lines: 5th and 95th percentiles; continuous gray lines: individual treatments. Error bars: standard error of the mean.

Figura 2. Dataset di riferimento per la stima della variabilità delle emissioni nette di CO_2 e NNM. Linea nera continua e simboli: media dei trattamenti (le etichette indicano il numero dei dati utilizzati per stimare le medie); linee nere tratteggiate: 5° e 95° percentile; line grigie continue: singoli trattamenti. Barre di errore: errore standard della media.

Conclusions

The two datasets confirmed the variability of manure decomposition in soil, both concerning net CO_2 emissions and N availability. The two datasets will provide reference distributions useful to test models uncertainty in prediction of net CO_2 and NNM. Moreover, obtained distribution of model parameters can be useful in selecting ranges of model parameters (and their sampling distributions) during sensitivity analysis and model calibration.

Acknowledgements

Work carried out in the project CN-MIP, co-funded by The Italian Ministry of Agriculture (Mipaaf) within the Multi-partner Call on Agricultural Greenhouse Gas Research (FACCE-JPI).

References

Alburquerque J.A., de la Fuente C., Bernal M.P., 2012. Chemical properties of anaerobic digestates affecting C and N dynamics in amended soils. Agriculture, Ecosystems and Environment 160: 15-22.

Atallah T., Andreux F., Choné T., Gras F., 1995. Effect of storage and composting on the properties and degradability of cattle manure. Agriculture, Ecosystems and Environment 54: 203-213.

Bechini L., Marino P., 2009. Short-term nitrogen fertilizing value of liquid dairy manures is mainly due to ammonium. Soil Science Society of America Journal 73: 2159-2169.
Brilli L., Bechini L., Bindi M., Carozzi C., Cavalli D., Conant R., Dorich C.D., Doro L., Ehrhardt F., Farina R., Ferrise R., Fittonh N., Francaviglia R., Grace P., Iocola I., Klumpp K., Léonard J., Martin R., Massad R.S., Recous S., Seddaiu G., Sharp J., Smith P., Smith W.N., Soussana J., Bellocchi G., 2017. Review and analysis of strengths and weaknesses of agro-ecosystem models for simulating C and N fluxes. Science of the Total Environment 598: 445-470.
Calderón F.J., McCarty G.W., Reeves III J.B., 2005. Analysis of manure and soil nitrogen mineralization during incubation. Biology and Fertility of Soils 4: 328-336.
Cavalli D., Bechini L., 2012. Multi-objective optimisation of a model of the decomposition of animal slurry in soil: tradeoffs between simulated C and N dynamics. Soil Biology & Biochemistry 48: 113-24.
Cavalli D., Marino P., Bechini L., Borrelli L., Cabassi G., Degano L., Ronchi N., 2012. Mineralizzazione del carbonio e dell'azoto di un liquame bovino tal quale, digerito e sue frazioni. Proceedings of the XLI Congress of the Italian Society for Agronomy, September 2012, Bari, Italy, pp. 153-155.
Cavalli D., Cabassi G., Bechini L., Ditto D., Marino P., 2014. Release of plant available nitrogen from the solid fraction of two digestates. Proceedings of the 18th Nitrogen Workshop, June-July 2014, Lisbon, Portugal, pp. 55-56.
Cavalli D., Marino P., Bechini L., 2016. Sensitivity analysis of six soil organic matter models applied to the decomposition of animal manures and crop residues. Italian Journal of Agronomy 11: 217-236.
Delin S., Stenberg B., Nyberg A., Brohede L., 2012. Potential methods for estimating nitrogen fertilizer value of organic residues. Soil Use and Management 28: 283-91.
Kirchmann H., 1991. Carbon and nitrogen mineralization of fresh, aerobic and anaerobic animal manures during incubation with soil. Swedish Journal of Agricultural Research 21: 165-173.
Kirchmann H., Lundvall A., 1993. Relationship between N immobilization and volatile fatty acids in soil after application of pig and cattle slurry. Biology and Fertility of Soils 15: 161-164.
Kyvsgaard P., Sørensen P., Møller E., Magid J., 2000. Nitrogen mineralization from sheep faeces can be predicted from the apparent digestibility of the feed. Nutrient Cycling in Agroecosysem 57: 207-214.
Manzoni S., Porporato A., 2009. Soil carbon and nitrogen mineralization: theory and models across scales. Soil Biology & Biochemistry 41: 1355-1379.
Morvan T., Nicolardot B., Péan L., 2006. Biochemical composition and kinetics of C and N mineralization of animal wastes: a typological approach. Biology and Fertility of Soils 42: 513-22.
Morvan T., Nicolardot B., 2009. Role of organic fractions on C decomposition and N mineralization of animal waste in soil. Biology and Fertility of Soils 45: 477-486.
Peters K., Jensen L.S., 2011. Biochemical characteristics of solid fractions from animal slurry separation and their effects on C and N mineralization in soil. Biology and Fertility of Soils 47: 447-455.
Petersen B.M., Jensen L.S., Hansen S., Pedersen A., Henriksen T.M., Sørensen P., Trinsoutrot-Gattin I., Berntsen S., 2005. CN-SIM: a model for the turnover of soil organic matter. II. Short-term carbon and nitrogen development. Soil Biology & Biochemistry 37: 375-393.
Powell J.M., Wattiaux M.A., Broderick G.A., Moreira V.R., Casler M.D., 2006. Dairy diet impacts on fecal chemical properties and nitrogen cycling in soils. Soil Science Society of America Journal 70: 786-794.
Probert M.E., Delve R.J., Kimani S.K., Dimes J.P., 2005. Modelling nitrogen mineralization from manures: representing quality aspects by varying C: N ratio of sub-pools. Soil Biology & Biochemistry 37: 279-287.
Sierra C.A., Malghani S., Müller M., 2015. Model structure and parameter identification of soil organic matter models. Soil Biology & Biochemistry 90: 197-203.
Sørensen P., Fernández J.A., 2003. Dietary effects on the composition of pig slurry and on the plant utilization of pig slurry nitrogen. Journal of Agricultural Science 140: 343-55.
Sørensen P., Weisbjerg M.R., Lund P., 2003. Dietary effects on the composition and plant utilization of nitrogen in dairy cattle manure. Journal of Agricultural Science 141: 79-91.
Thomsen I.K., Olesen J.E., 2000. C and N mineralization of composted and anaerobically stored ruminant manure in differently textured soils. Journal of Agricultural Sciences 135: 151-159.
Thomsen I.K., Schjønning P., Olesen J.E., Christensen B.T., 2003. C and N turnover in structurally intact soils of different texture. Soil Biology & Biochemistry 35: 765-774.
Thomsen I.K., Olesen J.E., Møller H.B., Sørensen P., Christensen B.T., 2013. Carbon dynamics and retention in soil after anaerobic digestion of dairy cattle feed and feces. Soil Biology & Biochemistry 58: 82-87.