Final report

for the CORE Organic Cofund funded project

"Organic and biodynamic vegetable production in low-energy GREENhouses – sustainable, RESILIENT and innovative food production systems - GREENRESILIENT"

Period covered:

2nd April 2018 – 1st October 2021

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Project period: December 2016 - May 2022

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1. General information

1.1 Project information

Project information			
Project acronym	GREENRESILIENT	**Project ID**	1866
Project title	Organic and biodynamic vegetable production in low-energy GREENhouses – sustainable, RESILIENT and innovative food production systems		
Project website	https://www.greenresilient.net/		
Details of the project coordinator			
Name	Tittarelli	**First name**	Fabio
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Institution	CREA – Agriculture and Environment	**Country**	Italy
Start of project	2nd of April 2018	**End date of project**	1st of April 2021
Duration in months	**42**	**New end date in case of a project extension due to COVID-19**	1st of October 2021

1.2 Consortium

Partner no.	Country	Institution/ organisation name	Type of institution/ organisation[1)]	Functions[2)]	Involved in WPs	Contact person[3)]
1	Italy	Council for Agricultural Research and Economics (CREA)	Public Research Centre	PC, WPL	All	Fabio Tittarelli (fabio.tittarelli@crea.gov.it)
2	Sweden	Swedish University of Agricultural Sciences (SLU)	University	WPL	4	Beatrix Alsanius (beatrix.alsanius@slu.se)
3	Belgium	Vegetable Research Centre (PCG)	Public Research Centre	P	All	Stefanie De Groote (stefanie.de.groote@pcgroenteteelt.be)
4	Switzerland	Research Institute of Organic Agriculture (FiBL)	Research institute	WPL, P	5	Kemper Laura (laura.kemper@fibl.org)
5	France	Groupe de Recherche en	Research institute	P, WPCL	All	Jérôme

		Agriculture Biologique (GRAB)				Lambion (jerome.lambion@grab.fr)
6	Belgium	Institute for Agricultural and Fisheries Research (ILVO)	Research institute	WPL, P	3	'Koen Willekens' (koen.willekens@ilvo.vlaanderen.be)
7	Denmark	Aarhus University, Department of Food Science (AU-FOOD)	University	WPL, P		Ivan Paponov (ivpa@food.au.dk)
8	Switzerland	Agroscope	Public research centre	P	All	Cédric Camps (cedric.camps@agroscope.admin.ch)
9	Austria	Federal Ministry of Agriculture, Forestry, Environment and Water Management (HBLFA)	Public research centre	P	2	Wolfgang Palme (wolfgang.palme@gartenbau.at)
10	Netherlands	Institute for Biodiversity and Ecosystem Dynamics (UvA)	Research institute	P	4	'Arne Janssen' (arne.janssen@uva.nl)
11	Netherlands	Wageningen Research, BU Greenhouse Horticulture	Private Research centre	P	4	Gerben Messelink (gerben.messelink@wur.nl)
12	Italy	Società Agricola Semplice LA COLOMBAIA	Farm	P	2; 5	'Enrico Amico' (direzione@amicobio.net)

1) University, Public research centre, Private research centre, Company, Other
2) PC = Project coordinator, WPL = Work package leader, WPCL = Work package co-leader, P = Participant
3) inclusive e-mail address

2. Summary

2.1 Final project summary suitable for web publication for a wider audience

The main objective of the GREENRESILIENT project is to demonstrate that an agroecological approach to greenhouse production is feasible and allows robust agroecosystems to be established in different European areas. The project hypothesis is that the implementation of more resilient production systems, based on low energy consumption, appropriate crop rotation, use of agroecological service crops (ASCs) and local organic amendments, is possible at almost any latitude in Europe. At five experimental sites (Belgium, Denmark, France, Italy, and Switzerland), Greenresilient partners implemented a system approach to compare innovative production systems against more intensive so-called "business as usual" systems to identify which systems were able to maintain high and stable production with low environmental impacts. Innovative systems were based on the agroecological practices usually implemented in open field conditions at the different latitudes where the experimental sites were located (extended crop rotations, intercropping, transfer mulch, short term green manure species, flower strips, etc.). In response to the demand to identify innovative and less energy-intensive production methods, the innovative systems also included leafy vegetables during winter. Many species of winter leafy crops (WLC) are frost resistant and, with appropriate changes to cultivation techniques, they can easily be grown in unheated greenhouses, even in Central and Northern Europe.

The systems were evaluated on the basis of the agronomic results, the availability of nutrients and their synchronization with the plant needs, the microbial biomass and activity, the belowground (nematode and microbial) and aboveground (soil arthropods and spontaneous flora) diversity.

Even though a comprehensive analysis of all the results obtained during Greenresilient project has not been carried out yet, the main hypothesis were verified and the project objective has been met. The main project outputs can be divided according to the different stakeholders target groups as follows:

Farmers/advisors

- The introduction of winter leafy crops in the rotation was successful and can be considered a viable option for frost-free greenhouses in the winter months. However, at different latitudes, it is important that these crops are sown at the right time and that humidity in greenhouses is kept at a low level in order to guarantee an adequate and sustainable yield during winter;
- Crop diversification and alternative fertilization strategies in innovative systems sustained crop productivity without significant yield losses compared to business as usual (BAU) systems. However, they did not consistently result in higher nitrogen utilization in the short-term;
- Agroecological service crops (ASCs) (so-called "short-term green manure crops" in the new Regulation 848/2018) introduced in innovative systems increased plant nitrogen availability in the plant-soil system in all trial locations and cropping systems;
- Higher risk of nitrate leaching was observed in BAU systems (mainly due to solarization and high input of off-farm fertilisers);
- The introduction of ASCs promoted the presence and diversity of spontaneous flora (i.e., weeds) in the rotation, while not presenting an increased risk of competition with crops. Similarly, the introduction of new management systems resulted in a higher diversity of weeds with less dominance of few species.
- A life cycle assessment (LCA) showed mixed environmental performance across cropping strategies and sites, showing potential to modify the design, including combinations of BAU and INN strategies.

Citizens

- Cropping system re-design should be accompanied by a closer relationship between farmers and consumers to increase the awareness of the potential impact of our food choices on the environment (Food Citizenship).

- Tested Winter Leafy Crops (WLC) represented an example of the re-discovery of the "Taste of winter" that their incredible diversity can offer

Scientists

- A comprehensive survey of microbial and nematode biodiversity and community structure showed that functional biodiversity was not affected by the compared production systems during the two-year period of observation. Other factors like local preconditions, crop cultivated at the time of sampling, and time of year had more of an effect on biodiversity
- The introduction of flower strips in greenhouse can promote natural enemies and improve biological pest control in vegetable crops, but a better understanding of the processes that link biodiversity with pest management is needed.

2.2 Process update of the whole project

The project, as a whole, has achieved all its objectives in a framework of strong and effective collaboration among partners. At the beginning of the project, in 2018, the most challenging issue to deal with was the implementation of a multidisciplinary approach and the respect of the timing and of the research needs of partners with different scientific and technical backgrounds. All partners were aware of the potential failure risk of one or more activities in case they had not collaborated from the very beginning of the project. This issue has been discussed since the kick-off meeting and carefully monitored during the first project year, until protocols and timing for sampling soil and plants has become a routinary activity in the five experimental sites. Mutual understanding and full respect of the work done by partners allowed to overcome this challenge. The main activities, performed during the first 18 months of the project, to achieve the objectives were the following:

- the presentation, by the leaders of the experimental sites, during the kick-off meeting, of the experimental design and of the compared systems of production (defined according to local conditions);
- soil and plant sampling protocols have been written by project partners involved in cross-cutting activities and shared for discussion and final approval;
- agronomic activities, soil and plant sampling, samples delivery and laboratory analysis were scheduled and carefully monitored to verify that all partners were able to carry out their activities and to overcome potential communication or logistic problems;
- dissemination activities started immediately after the start of the project with the implementation of the GREENRESILIENT website and logo, creation of Facebook and Twitter accounts, development of a dissemination plan and scheduling of the first farm visits;
- deliverables and milestones were strictly monitored and accomplished according to the scheduled timeline of the project;
- during the second project meeting in Sion (CH), all partners presented the preliminary results of their activities regarding the first growing cycle, showing to be perfectly in-line with the scheduled activities.

In the second half of the project timeline, the main challenge was to re-schedule and to guarantee the agronomic and laboratory activities in the framework of the sanitary and precautionary measures implemented by the different countries for reducing the impact of SARs-CoV-2 pandemic. Despite some delays in laboratory activities were experienced and some dissemination activities in presence were postponed, all scheduled activities and project objectives were accomplished. During the final plenary meeting held in Rome, results obtained were presented and discussed and some of the partners, in collaboration, have already started to write scientific papers as reported below in this report (Section *4.5 Future dissemination actions*).

3. Outcomes of the project

3.1. Main results, discussion, conclusions and fulfilment of objectives

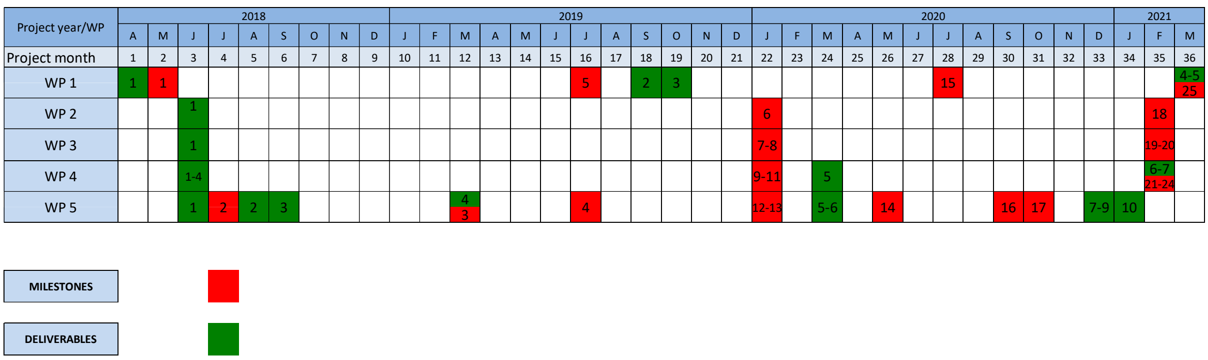
WP1	*Scientific and administrative coordination and quality control*

WP leader: Fabio Tittarelli
Responsible partners: All

Overall summary of main results, discussion and conclusions of WP1

The main objective of WP1 is to assure project coordination and to respect the timetable of the project by monitoring and stimulating planned scientific and dissemination activities.
According to CORE Organic Cofund Call 2016, Greenresilient project should have lasted 36 months, but, due to the sanitary measures imposed to manage the SARs-CoV-2 pandemic, the end of the project was postponed of 6 months when the delay in carrying out the research and the dissemination activities were ascertained.
In order to monitor that initially planned Deliverables were accomplished, and scheduled Milestones were reached, a Timeline for Milestones and Deliverables, along the entire 36 months project, had been prepared and shared with project partners at the beginning of the project (Fig. 1). When the end of the project was postponed, a new Timeline for Milestones and Deliverables was proposed and adopted by the entire Consortium of Greenresilient project taking into account the restrictions to which all partners were subjected (Fig. 2).

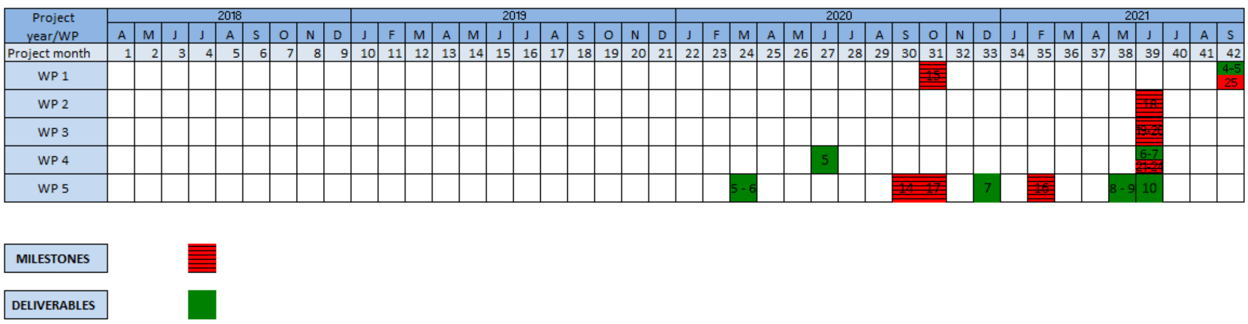
Fig. 1 Greenresilient Milestones and Deliverables



Greenresilient Milestones and Deliverables along 36 months

Start date of the Project: 2nd of April 2018
End date of the Project: 1st of April 2021 1

Fig. 2 Greenresilient Timeline Milestones and Deliverables



Greenresilient Milestones and Deliverables along 42 months

Start date of the Project: 2nd of April 2018
End date of the Project: 1st of October 2021

The results achieved are synthetically reported as follow:

- In April 2018 (within the first month from the beginning of the project) the kick-off meeting has been organised and held in Capua (IT) with the active participation of all the project partners;
- The Consortium Agreement for the Greenresilient project has been finalised and the Steering Committee (SC), has been established.
- A shared Greenresilient folder in Dropbox® web tool has been set up for sharing project documents among partners;
- In June 2019, as scheduled, the 2nd Greenresilient Project Meeting has been held in Sion (CH);
- In March 2020, Milestones and Deliverables were re-scheduled ;
- In October 2020, the 3rd Greenresilient Project Meeting was held virtually ;
- In September 2021, the 4th and last Greenresilient Project Meeting (hybrid conference) was held in Rome (Italy)

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:

- At the project start, it was decided that information exchange among partners should be mainly by e-mail correspondence, but also by the use of Dropbox® web tool as a platform for sharing and saving relevant documents for the project;
- As scheduled, at Month 1 (M1), to diffuse the information among the scientific community and organic farming stakeholders, the Project press release (**D1.1**) was published (file "20180417_GRP_FT_Press-release final" in Annexes to the Final Report). The press release was translated into the mother language of each participating country (Section 4 Publication and dissemination activities);
- At the kick-off meeting, held on the 18-20th April 2018 in Capua (Italy) (**Milestone 1**, file "20180412_GRP_FT_Final Agenda kick-off meeting" in Annexes to the final Report), all scientists involved in Greenresilient project met and actively participated. Project background, main objectives and planned activities were presented and confirmed. As previously requested, all leaders of the experimental sites showed both BAU and INN systems based on local vegetable market demand and needs. Crop rotations and WLCs species were object of discussion and approved with minor changes (file "20180502_GRP_FT_Minute_Greenresilient_kick-off meeting" in Annexes to the final Report);
- Greenresilient Consortium Agreement (CA) has been discussed, revised and finally set up at M5 with the support of all the partners legal offices (file "20180830_GRP_Greenresilient_CA_Signed" in Annexes to the final Report);
- The 2nd Greenresilient plenary meeting (**Milestone 5**) was held at Sion (CH) at M15 (4th – 6th June 2019) (file "20190520_GRP_FT_Agenda 2nd Meeting_Sion" in Annexes to the final Report). During the meeting, all participants presented and shared the preliminary results of their activities in the framework of the project. A minute of the plenary discussion and main achievements of the 2nd plenary meeting in Sion was written in collaboration with the members of the Steering Committee (SC) (file "20190704_GRP_FT_Minute_2nd Meeting_Greenresilient_Sion" in Annexes to the final Report).
- The Coordinator participated to the International Symposium on Advanced Technologies and management for Innovative Greenhouses (GREENSYS2019) organized by the International Society for Horticultural Science (ISHS), held in Angers (France) from the 16th to the 20th June 2019. He presented (oral presentation) a paper titled "GREENRESILIENT - applying agroecology to organic greenhouse production" in the framework of the session Organic Greenhouse Horticulture.
- In September 2019, WP leaders and the experimental sites managers wrote jointly a paper titled "Greenresilient: innovative cropping systems in organic greenhouse production" which has been submitted to the Organic World Congress 2020 which should have been held in Rennes (France)

next 21st - 27th September 2020 (and postponed as hybrid Congress in August 2021 due to SARs-CoV-2pandemic);

- In November 2019, the Mid-term Report was submitted (**Deliverable D1.2**) ("D1.2_20191129_Greenresilient_Mid-term report" in Annexes to the final Report) and relative press release was published ("D1.3_GRP_FT_Press release Mid term-final version" in Annexes to the final Report);
- On 1st December 2019 a joint event of Greenresilient and ProOrg projects called "The Leafeaters" was organized in Capua (IT) (*https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/food-citizenship-in-capua-a-joint-event-by-greenresilient-and-proorg-projects/*)
- On the 20th of April 2020, during a Steering Committee Meeting the scheduled Milestones and Deliverables were revised according to the envisaged new end date of the project ("20200420_GRP_FT_Minute_Steering Committee Conference Call" in Annexes to the final Report)
- The Third Greenresilient plenary meeting (**Milestone 15**) was virtually held on the 12th – 14th of October 2020 ("20201011_GRP_Final Agenda_Greenresilient Meeting" in Annexes to the final Report). During the meeting, all participants presented and shared the results obtained in the framework of the project and discussed about the publication strategy of the project. A minute of the plenary discussion and main achievements of the 3rd plenary meeting was written in collaboration with the members of the SC ("20201120_GRP_FT_Minute_3rd Meeting_Greenresilient_WebConference" in Annexes to the final Report);
- The Fourth Greenresilient plenary meeting was held on 21st - 22nd of September 2021 in Rome (hybrid conference) ("20210920_GRP_Agenda Final Meeting_Hybrid Conference" in Annexes to the final Report). During the meeting all partners have presented the activities carried out and the last results which are detailed in the reports of the other WPs, as follows.

B- fulfilment of objectives:
Apart re-scheduling the timing of Milestones and Deliverables (as described above), no deviations from the original plan have been observed.

At M42, end of Greenresilient project, all the objectives envisaged in the project proposal have been successfully reached.

WP2	*Resilient cropping systems*

WP leader: Karen Koefoed Petersen, AU-FOOD, DK until 31st of March 2020. Fabio Tittarelli (CREA) has taken the *interim* of WP2 since the 1st of April 2020
Responsible partners: ILVO, PCG, AU-FOOD, CREA, La Colombaia (Private farm), AGROSCOPE, GRAB

Overall summary of main results, discussion and conclusions of WP2

Seasonal and sustainable winter vegetable production in Central and Northern European climates appears contradictory and represents formidable challenges regarding increased resource efficiency and reduction in greenhouse gas (GHG) emissions. Europe's 'Roadmap 2050' emphasises the importance of finding new ways to reduce resource inputs and develop new products which will help to support the shift towards a resource-efficient and low-carbon economy. One potential solution could be the cultivation during winter of leafy vegetable crops which are much more frost hardy than they are supposed to be. They can be grown in unheated greenhouses during wintertime.
As described in the Mid-term report, in the Mediterranean countries the more diffused organic greenhouse production system is characterized by short and non-diversified crop rotations and adoption of an input substitution approach to soil fertility management and crop protection. On the other side, in Central and Northern European countries, one of the main challenges in organic greenhouse production

is the high energy input for heating. In addition, crop rotation is often limited. Since so-called « business as usual » (BAU) systems and climatic conditions differ between countries, the experimental designs in Greenresilient are also different and systems are compared rather than individual factors. During the first months of the project, the experimental designs for the individual experimental sites were agreed on thereby fulfilling deliverable **D2.1** (the five files regarding the experimental design in the five experimental sites are in Annexes to the final report). Yield data have been taken for each cultivated crop during the two year rotation and soil samples collected according to specific protocols and guidelines agreed with partners involved in WP3/WP4/WP5 activities, accomplishing and respecting the deadlines for derivables **D3.1, D4.1, D4.2, D4.3, D4.4, D5.1, D5.2, D5.3, D5.4** (as already reported in Mid-term report) (all the files relative to the above mentioned deliverables are in Annexes to the final Report). In order to reduce the level of intensification associated to « Business as usual » systems, cropping systems were re-designed. In Italy, the utilization of off-farm inputs and soil solarization (widely practiced in BAU systems) were replaced by the cultivation of short cycle green manure species while in France pest control and plastic mulch for weed control were compared to mixed cropping (in alternating rows), flower strips and transfer mulch. Winter leafy crops (WLC) frost resistant were cultivated in the five experimental sites. First results showed that some of the WLCs were also well suited for winter cropping in research stations in Switzerland, Belgium and Denmark. Oriental greens, winter purslane and Swiss chard grew well under unheated or frost-free greenhouse conditions. They were able to fill the winter gap in unheated greenhouses. However, it is important that these crops are sown in advance and air humidity is maintained at low levels in order to guarantee an adequate and sustainable yield during winter and protect crops from the occurrence of fungi diseases.

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:

The project started the 2nd April 2018 and during the first three months detailed designs for the five experimental sites were defined. The agronomic trials lasted two years and ended in the fall 2020. The main factors studied in the different countries are shown in table 1.

Table 1 ASC = Agricultural service crop; IC = Intercropping; BAU = Business As Usual; INN = Innovative

Production factor	Italy		France		Belgium		Switzerland		Denmark	
	BAU	INN	BAU	INN	BAU	INN	BAU	INN	BAU	INN
ASC/IC	+	+++	+	+++	+	+++	+	++	+	++
Crop diversity	++	++	+	+++	+	+++	+	+++	+	+++
Soil tillage	++	++	+++	+++	++	++	+++	+++	++	++
Organic matter	+	+++	+	+++	+	+++	+	++	no	+
Pest control	++	+	++	++	++	++	+++	+	++	++
Disease control	++	+	++	++	++	++	+++	+	++	++
Flower strips	no	no	no	yes	no	yes	no	yes	no	yes
Solarization	yes	no	no	no	no	no	no	no	no	no
Biodynamic prep	no	yes/no	no	no	no	no	no	no	no	no
Heating	no	no	no	no	no	no	high	low	high	low

In Italy, a total of nine systems were compared, but in only three, detailed measurements and samples were taken. These three systems were: an intensive organic system (BAU) including soil solarization, commercial organic fertilizers and pesticides; a biodynamic system according to the hosting farm 'La Colombaia' (BIODYN) using biodynamic preparations and on farm compost and green manure; an organic system characterized by using biowaste compost and green manure (AGROEC). A fourth treatment, negative control (CONT), where no fertilisers were broadcasted and no short cycle green manure species were cultivated, was taken into account for monitoring crop yields and nutrients availability.

In France, a total of six systems are compared, but one BAU, one INN and one "Intermediary" system were chosen for detailed measurements and sampling. In BAU, a summer crop (tomato in 2018) and a winter leafy crop is grown using common practise for fertilization and pest control and plastic mulch for weed control. In INN, crops were mixed in alternating rows and flower strips and transfer mulch were introduced.
The Intermediary system follows the same mixed crop rotation of the INN and the same fertilization strategy of the BAU.
In Belgium, the BAU system had bare soil between crops (one WLC and tomato in 2019) and green compost and plastic mulch to reduce weed pressure. The INN system was based on agroecological principles with ASCs, three WLCs, high-quality on-farm compost, straw mulch and flower strips. Winter purslane, Swiss chard and Oriental greens as Mizuna were grown from September to February and yielded 300 to 400 g/m².
In Switzerland, two BAU and two INN systems were compared. In BAU there was low crop diversity, the greenhouse was heated according to organic standards and pest control include sulphur and copper. The other systems were kept frost free throughout the year and the INN systems had higher crop diversity, alternative fertilization and pest management strategies and included ASCs. The systems differed in mulching strategies. Lettuce, Spinach, Lamb's lettuce, Kohlrabi and winter purslane were grown over winter.
In Denmark, the BAU system was heated according to the need of the only crop (tomato). In INN, the greenhouse was kept frost-free, WLCs, IC and a third crop (lettuce)were introduced as well as flower strips. Fertilizer type, pest management and weed protection strategy were not differentiated between the two systems. Lettuce, stem lettuce, spinach, Swiss chard, Oriental greens and cabbage were grown as winter crops. The yield ranged from 400 g/m² (spinach), 500 g/m² (Mustard green) to 140 g/head of lettuce.

B- fulfilment of objectives:
1 – Define final experimental layouts for five experimental sites with tomato as main summer crop and one or more winter leafy crops – **Fulfilled**
2 – Run two experimental cycles of comparison between at least two cropping systems – a Business As Usual (BAU) and an Innovative system (INN) at five experimental sites – **Fulfilled**
3 – Collect and supply WP3, WP4 and WP5 with samples and data from experimental sites - **Fulfilled**

The winter cropping results gained in WP2 can be evaluated as first steps towards a new system of fresh winter vegetable production across Central and Northern Europe. The main obstacles were: too late sowing and planting dates (because of extending late summer crops), infections with fungi diseases (grey mould, rot) because of low ventilation in the greenhouses. So, the yield level across all experimental stations was not satisfying yet. Especially Denmark turned out to lack light for plant growth during the cold season not only because of reduced day length but also because of foggy and wet winter conditions from November to February.

Promising experiences were made with Oriental greens, spinach and winter purslane which can be considered as innovative winter leafy crops for local markets. Preparing plantlets instead of direct sowing helped to prolong the summer season and to delay the start with the winter leafy crops in the greenhouses.

WP3	*Crop yield, nutrients availability and soil fertility assessment*
WP leader: Koen Willekens (ILVO) **Responsible partners:** ILVO, PCG, AU-FOOD, CREA, AGROSCOPE, GRAB	

Overall summary of main results, discussion and conclusions of WP3

Crop diversification and alternative fertilization strategies in innovative (INN) systems, compared to business as usual (BAU) systems did not jeopardize crop productivity, however, did not unambiguously result in higher N utilization on the term of the experiment, i.e., the short term. Curves of plant available N (PAN, i.e., the sum of the amount of soil mineral N in the 0-30 cm soil layer (SMN 0-30 cm) and the crop N uptake) over the experimental period easily visualized differences in N dynamics caused by differences in crop choice and fertilization between the cropping systems. A steady, not excessively high amount of soil mineral N (no occurrence of SMN peaks) in combination with a sufficiently high crop N uptake reflected a better N use efficiency in the INN compared to the BAU systems at the Italian and Swiss trial locations.
A higher C input by alternative fertilization strategies in some of the INN systems, compared to the respective BAU systems, did not result in differences in the C stock evolution over the experimental period between systems.
At four out of five trial locations, N leaching losses appeared under long lasting fruit crops with higher irrigation needs and were related to high N availability caused by either solarization in a BAU system or excessively high external N input by fertilization practices in both BAU and INN systems.
The use of agroecological service crops (ASCs) as a green manure in INN systems clearly sustained N availability and crop productivity.
Compost application had a minor effect on instantaneous N availability, however, presumably sustained soil organic matter content and future N release from SOM.

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:
Minor differences in productivity between BAU and INN systems

Considering N output (kg per ha) as a productivity measure, innovation in protected cultivation by crop diversification, an alternative fertilization and crop protection strategy, does not per se lowers productivity. Respective N output were: Italian trial (26 months) 509 - 412 - 411, for resp. BAU, INN1 (Biodyn) and INN5 (Agroecological), French trial (29 months) 669 - 832 - 795, for resp. BAU, INN and Inter, Swiss trial (26 months) 959 - 1049 - 1170 - 883 for resp. BAU1, BAU2, INN1 and INN2, Belgium trial (32 months) 876 - 883 for resp. BAU and INN and Danish trial (24 months) 1286 - 715 for resp. BAU and INN.
In case of substantial lower productivity in the innovative system in the Danish trial, this was related to a shorter growing period for the tomato crop and failure of winter leafy crops.

No clear differences in N surplus between BAU and INN systems
The N surplus, i.e., the external N input minus the N output, was higher in the BAU compared to the INN systems at the Swiss and Danish trial sites, and also at the Italian trial site. The Italian Biodyn and Swiss INN systems showed even a negative N surplus. The N surplus in the Italian Agroecological system equalled the N surplus in the BAU. The N input from alfalfa hay transfer mulch caused an extremely high N surplus in the French INN system, and so higher than the N surplus in the BAU. The intermediary French INN system showed a lower N surplus than the BAU system. At the Belgian trial site, the higher N surplus in the INN system, compared to the BAU, was caused by the higher N content of the repetitively applied on-farm compost - relative to its organic matter content – compared to the N content of the municipal waste compost applied in the BAU system.

Agroecological service crops (ASCs) increase plant N availability in the plant-soil system
The internal N input from terminated ASCs was substantial, on average 153 kg ha^{-1} over all trial locations and cropping systems. In the Italian innovative systems, internal N input from ASC (305 and 148 kg N ha^{-1} in Agroecological and 245 and 154 kg N ha^{-1} in Biodyn system, first and second year, respectively) increased SMN 0-30 cm at following crop transplanting, compared to SMN 0-30 cm before ASC sowing. The internal

N input from ASC was combined with an external N input from compost, applied after ASC termination in the first year and after ASC termination in the second year (146 and 241 kg N ha^{-1} in Agroecological and 24 and 12 kg N ha^{-1} in Biodyn system, first and second year, respectively). Apparently, the much higher compost dosage in the Agroecological system, compared to the Biodyn one, lowered the N availability from ASC. The Biodyn system showed a relatively high productivity considering its minor yearly external N input (i.e., fertilizers). Productivity seems to be guaranteed by the high internal N input from terminated ASC and crop residues and the N release from soil organic matter (SOM).
The amount of soil mineral N in the 0-30 cm layer (SMN 0-30 cm) showed a minor decrease during the ASC growing period in the INN and INN2 system at the Belgian and Swiss trail sites, despite an N uptake by the ASC of respectively 157 and 168 kg ha^{-1}. The ASC seems to favour plant N availability due to additional N release from SOM. In the Swiss INN 2 system, the productivity level of the melon and tomato crop has been maintained by substitution of (a part of) the silage N input by an ASC N input. However, the internal N input from ASC in the Belgian INN system did not increase N availability to a higher extent than the continued fallow period in the BAU system. The use of ASC in the INN system hardly increased the amount of plant available N (PAN, i.e., the sum of the amount of soil mineral N in the 0-30 cm layer and the crop N uptake) for the succeeding crops.

Low N leaching risk coincides with high N utilization
N leaching risk was assessed by measurement of soil mineral N in the 30-60 cm soil layer (SMN 30-60 cm). For both BAU and INN at the Belgian trial site, a decrease of SMN 30-60 cm in the first half of the tomato crop growing period is probably indicative for leaching of N below the 30-60 cm layer. An increase of SMN 30-60 cm under the winter leafy crops, that followed the tomato crop, showed some N leaching from the 0-30 to 30-60 cm layer, which induces an N leaching risk towards the + 60 cm subsoil. For BAU at the Italian trial site, a steep decrease in SMN 30-60 cm during both tomato crops' growing periods is indicative for substantial N leaching towards the + 60 cm subsoil. The steep decrease of SMN 30-60 cm in the second half of the eggplant (+ pepper) growing period at the French trial site is also indicative for some N leaching. The extremely high SMN 30-60 cm at the start of the tomato crop at the Danish trial site (just one measurement time point for BAU) is also indicative for a downward movement of soil mineral N.
At higher irrigation rates for long lasting fruit crops, N leaching might appear and will be more substantial at excessively high soil mineral N content due to e.g., solarization (IT, BAU, an increase of 259 kg SMN ha^{-1} in both 0-30 and 30-60 cm layers due to solarization), a high N input by alfalfa hay transfer mulch (FR, INN, an additional 65 and 41 kg SMN ha^{-1} in 0-30 and 30-60 cm layers, respectively, at the end of eggplant/pepper cycle, compared to the intermediary system), too high dose of fast N releasing fertilization (DK, BAU) due to underestimation of potential N release from SOM (BE, BAU and INN).

Lower N leaching risk and high N utilization rates might be assumed at high PAN levels combined with low levels of SMN 0-30 cm (i.e., on average a hundred kg per ha). This situation clearly appeared in three of the four Swiss systems (BAU2, INN1 and INN2) and in the Italian Biodyn (INN 1) and Agroecological system (INN 5).

Minor effect of compost application on N output
Relatively large differences in external N input occurred due to differences in N input by compost application between BAU and INN at the Belgian trial site and between the Biodyn (INN 1) and the Agroecological (INN 5) system at the Italian trial site. However, this did not result in differences in N output or overall productivity. Compost application sustains SOM content and potential N release from SOM on the longer term. In the Italian Biodyn and Agroecological systems, PAN is mainly derived from N release out of ASC and crop residues and SOM, whereas in the INN and BAU systems at the Belgian trial site, plant available N is derived from N release out of commercial fertilizers and SOM.

Compost type apparently affects the plant available N amount

At the end of the Belgian trial period, the PAN amount was 109 kg per ha higher in BAU versus INN due to a difference in compost type (green compost in BAU versus on-farm compost in INN), and despite the higher N input by on-farm compost. At the Italian trial site, the Biodyn (INN 1) system showed (a trend of) higher amounts of plant available N compared to the Agroecological (INN 5) system, despite the much lower N input by application of the Biodyn compost compared to the N input by application of the 'agroecological' compost in the INN 5 system.

Mixed cropping does not clearly affect productivity

In the French trial, mixed cropping of tomato and cucumber in the intermediate system apparently enhanced the total N output at same external N input (same fertilization strategy and N doses), compared to BAU. On the contrary, at the Belgian trial site, mixed cropping (tomato + cucumber) did not show a higher total N output in INN compared to the tomato N output in BAU.

Differences in C stock evolution between systems were not possible to assess within the experimental term

Assessing differences in soil fertility evolution between cropping systems based on C content measurements was not possible, even when the differences in C input between systems were rather high in case of the French INN system by the alfalfa hay transfer mulch application and in the Italian system by the biowaste compost application.

B- fulfilment of objectives:

Under the general hypothesis that agroecological approach to the greenhouse cropping system enhance nutrient cycling and soil fertility, the main objectives of the WP3 have been:

i) to measure nutrient availability and to assess potential nitrate leaching in compared treatments, especially in case of high nitrate leaching vulnerability and/or high level of organic fertilisers broadcasted. **Fulfilled**

ii) to assess both short term N dynamics and soil fertility evolution. **Fulfilled.**

N dynamics were assessed by measuring external and internal N input (by fertilization, ASCs, and crop residues) and crop N output, and by simultaneous repetitive measurement of the SMN (NH_4^+-N and NO_3^--N) amounts in the 0-30 cm topsoil layer.

SMN was measured in the 30-60 cm soil layer availability to assess potential nitrate leaching in compared treatments in case of high nitrate leaching vulnerability under long lasting fruit crops with high irrigation needs and high level of organic fertilizers broadcasted.

Soil fertility assessment was performed at the start and at the end of the trial period, by measurement of total organic C (TOC) and/or total N (TN) content, both being a proxy for SOM, and plant nutrients availability.

WP4	*Soil health and functional biodiversity*

WP leader: Beatrix Alsanius (SLU)

Responsible partners: ILVO, PCG, AU-FOOD, CREA, La Colombaia (Private farm), AGROSCOPE, GRAB,

Overall summary of main results, discussion and conclusions of WP4

WP4 addressed the assessment of soil health and functional biodiversity as a function of agricultural practices implemented in BAU and INN cropping systems at all five experimental sites. Soil inherent characteristics (determined by climate, parent rock material and environmental conditions) at the five experimental sites were different and so were crop rotation choices. Therefore, comparisons are only valid among systems at each site.

Task 4.1: Soil borne diseases and biodiversity assessment was conducted on the basis of soil microbial activity and biomass as well as community composition of soil microorganisms and nematodes in BAU and INN systems at the five experimental sites (WP2). Samples were taken thrice during the crop rotation.

Specific soil suppressiveness was determined at the end of the crop rotation experiments using *Fusarium oxysporum* f.sp. *lycopersici* (FOL) as a target organism. *Soil nematode communities* were used to assess soil biodiversity based on abundances and species richness and food web analysis based on nematode (functional) guilds and nematode specific indices (Enrichment Index EI and Structure Index SI).

SLU and ILVO analysed soil samples submitted from the partners managing the experimental sites with respect to soil microbial and nematode community features as well as functional diversity.
Interestingly, there was a boost in microbial activity at almost all sites (exception: Italy) after the first experimental year. Dynamics of certain microbial groups with members of function interest were observed. Microbial and nematode community structure and functional biodiversity was overruled by unknown dominant factors, leaving crop rotations without significant impact after two years. Phyla hosting plant pathogenic fungi were abundant in all crop rotations. No difference in specific soil suppressiveness was found between BAU and INN systems. There was indication that INN systems, compared to BAU, can score worse in terms of control of such plant pathogenic nematodes.
Task 4.2 considered *arthropod diversity and pest control* in the tomato crop in BAU and INN systems at the five experimental sites. Arthropods have been sampled with respect to ground-dwelling (pitfall traps) and flying arthropods (pan traps) and by direct observation of pests and natural enemies on the crop plants in WP2. Among ground-dwelling arthropods the proportion of detritivores was higher in Northern European sites than in more Southern sites and correlated with a lower functional diversity, but without consistent differences between BAU and INN systems. With respect to herbivores feeding on tomato (such as Tuta moths, aphids, leafhoppers, thrips, and spider mites) were always below damaging levels. At BE, CH and FR the most important pests were more abundant in the BAU systems, whereas natural enemies, especially parasitoids and mirid predators, were generally more abundant in the INN systems.

Soil samples from BAU and INN systems were collected by WP2 following standard protocols Deliverable **D4.2** (D4.2 file in Annexes to the final report) and sent to WUR in the Netherlands for assessing the presence and abundance of entomopathogenic fungi. WUR succeeded to isolate several strains of entomopathogenic fungi from the 5 experimental sites. Out of 920 bait larvae, entomopathogenic fungi infected 252. The highest diversity was found in the soil samples from IT and FR, followed by CH, BE and DK. Strains were identified with PCR and at least 14 genetically different strains were identified. The endophytic capacity of these strains was evaluated using the South American tomato pinworm *Tuta absoluta* (model for tomato crop). So far, two strains are found to shorten and one strain to prolong developmental time of this pest.

Task 4.3: At the three experimental sites *weed biodiversity* was evaluated at three mandatory times during the two growing cycles (prior to start, end of the first year and end of the second experimental year) through identification of main species and groups of species (density and/or cover). Additional (not mandatory) samplings were performed at species level over the rotation in Belgium, Italy, and Switzerland. The diversity of weeds was slightly affected by the BAU and INN systems, and effects in weed density depended on site and management strategy. On the one hand, obtained results put in evidence the effect of INN systems in promoting the weed presence, related to the ASCs presence in the systems based on their introduction. On the other hand, introduction of new management drove to higher diversity (R) and lower dominance.

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:
Local preconditions in the five countries hosting the experimental sites: Belgium (BE), Switzerland (CH), Denmark (DK), France (FR) and Italy (IT) varied and the choice and order of crops within the various BAU and INN systems differed between countries. Therefore, as expected and envisaged from the beginning of the project, a comparison can only be performed between systems at the same site.

Task 4.1: Soil borne diseases and soil biodiversity assessment:
Samples were taken at three incidents (start, mid-term and end) during the two-year rotations. Specific disease suppressiveness was evaluated with respect to *Fusarium oxysporum* f.sp. *lycopersici* (FOL). There was no general trend with respect to microbial activity for the different cropping systems. Interestingly, the microbial activity initially rose in many of the systems (mid-term) but decreased to a lower level mostly similar or insignificantly higher to the starting point. A general significant decrease in microbial activity was found at all cropping systems in IT from the start to the end of the experiment. Likewise, soil bacterial and fungal alpha diversity varied between the different sampling incidents with respect to both species richness and evenness (Chao1 index, Shannon diversity index). Interestingly, a strong shift towards richer fungal community was found for the CH-BAU systems as compared to the CH-INN systems over time (based on % change from initial sample). CH-INN systems displayed a richer bacterial community than CH-BAU systems. Similar observations were found sporadically in other systems, displaying changes in beta-diversity between systems over time. Shifts in relative abundance was found for some phyla over time within systems, but no general trend applying to all BAU or INN was registered. Diversity of soil bacteria and fungi was affected by local preconditions, crop produced at the time of sampling, and time of year, more than the production system itself.
A presence of several types of fungal pathogens were observed in all countries, independent of production system. Microbial activity did not conclusively explain variations in microbial diversity for fungi or bacteria. No differences were found in plant performance when assessing specific suppressiveness towards FOL. As plant performance in control samples was much better than those detected in fresh soil samples, with or without amendment of FOL, the general build-up of pathogenic organisms during the crop rotations might mask direct effects (**Deliverable D4.1**) ("D4.1 20180625_GRP_AR_Final version_D4_1" file in Annexes to the final Report and Deliverable D4.6 in Organic e-prints).
Soil nematode communities were used to analyse biodiversity indexes (nematode abundances and species richness) and for food web analysis based on nematode (functional) guilds and nematode specific indices (Enrichment Index EI and Structure Index SI), (**Deliverable D4.1**) (file "D4.1_20180607_GRP_NV_finalversion_D_4_1_nematodes" in Annexes to the final Report). After two years of experiments, the biological and/or functional diversity followed the same evolution in BAU and INN systems. It seems that a common, more dominant factor impacted the nematode biodiversity and overrules the differences between both systems. What exactly this factor might be (crop, meteorological condition, population dynamics, etc) remained unclear. Thus, as a general conclusion it can be stated that after two years (only), the INN agricultural practices do not alter the nematode community in comparison to the BAU and thus do not make protected organic production more or less resilient, more or less sustainable as assessed by nematode communities.
Also, plant-parasitic nematodes were present and could potentially cause crop yield and quality reductions. It was demonstrated that INN systems, compared to BAU, can score worse in terms of control of such nematodes. Growing ASC instead of fallow and mixed cropping most probably plays an important role. It is recommended that the host status of the extra crops implemented during more complex rotational crop systems is determined. Data on host status, plant resistance and/or tolerance of ASC, WLC and other (newly introduced) crops, as well as population dynamics of plant pathogen nematodes (PPN) in mixed cropping systems could present a subject for future projects.
Task 4.2: Pest management and soil arthropods/microbial biodiversity
Arthropods were sampled regularly in periods that tomato was grown in both BAU and INN treatments, which were different for different experimental sites. Arthropod samples were collected in three different ways following standard protocols (**Deliverable D4.2**)("D4.2 20180531_GRP_PR_Arthropods assessment for task 4.2" file in Annexes to the final Report): (1) pitfall traps, sampling ground-dwelling arthropods, (2) pan traps, sampling flying arthropods and (3) direct observation of pests and natural enemies on the tomato plants. All samples were sent to UvA, where the arthropods were identified and counted.
All specimens were identified at least up to order, but for some insect orders up to family or even species level. All taxa were classified in 6 feeding guilds. The combination of phylogeny (mainly orders) and feeding guilds resulted in 26 different functional groups represented within the combined dataset. The

representation of these groups within the individual samples was used to define functional diversity (using the inverse Simpson index).
Based on pitfall samples the soil-dwelling arthropods showed the highest functional diversity on the IT site (ca 5.5), which gradually decreased with increasing latitude of field station locations, resulting in the lowest values (ca 2.0) for the DK site. At sites that were sampled in more than one year (DK and FR) the functional diversity was higher in 2020 than in 2019. Within the experimental sites in CH and FR the functional diversity was higher in the INN than in the BAU systems, whereas at the other sites no differences between systems were observed. The functional diversity strongly correlated negatively with the percentage detritivores and positively with the percentage ants, carnivores, and omnivores, leaving the percentage herbivores unaffected. The percentage ants, carnivores and omnivores are observed to be higher in the energy saving INN systems compared to the BAU systems in Denmark and Switzerland, but seemed unaffected by innovations in Belgium, France, and Italy 2019.
Based on pan trap samples the functional diversity of aerial insects and spiders did not change systematically with latitude, given that Italy was not represented in this dataset. As for the soil-dwelling-arthropods the functional diversity correlated negatively with the percentage detritivores, mainly represented by Diptera (flies and mosquitoes). In contrast, no correlations with the % carnivores or herbivores were observed. No differences between BAU and INN systems were apparent for any functional group.
Based on direct observations, herbivores feeding on tomato never reached damaging levels. In DK the main pests were aphids, Tuta and thrips. In 2020 their numbers were even lower than in 2019 when a higher number of natural enemies were observed, especially parasitoid wasps and spiders, and especially in the INN2 system. In BE 2019 less whiteflies were present in the INN system, where parasitoid wasps and parasitoid flies were more abundant. In CH 2019 lower number of aphids and whiteflies were observed in the INN systems compared to the BAU1 system. While the number of parasitoids was initially much higher in the BAU1 compartment due to their inundative release, other natural enemies, especially mirid bugs (Macrolophus), were much more abundant in the INN systems throughout the summer. In FR 2018 more homopterans (leafhoppers, aphids and whiteflies) were recovered from the pan traps in the mixed-crop INN system than in the BAU system, however on the tomato plants no differences were observed, since the higher number resulted from the intercropped cucumber plants that are better hosts for these species. Tuta moths that only occur on tomato were less abundant in the INN system with flower strips. In FR 2019 (with aubergine as main crop) homopterans were again more abundant in the INN system, however thrips were less abundant. On the plants much less spider mites were observed in the INN system with mixed-crops and flower strips.

Task 4.3 Weed biodiversity assessment
The evaluation of the weed communities over the two-year rotations was used to compare systems impact on: i) weed spread (density and cover estimation), ii) weed diversity (diversity indices computing), iii) on weed functional diversity (trait analysis) (**Deliverable D4.4**) (“D4.4_20180406_GRP_CC_task 4.3_detail protocol for weed biodiversity” file in Annexes to the final Report). After two years, the datasets were analysed site by site, allowing the weed diversity and functional diversity assessment in BE, IT and CH. Results put in evidence the impact over time of the compared systems on the weed communities, despite the closed environments represented by greenhouse. The INN systems, characterized by higher planned diversity (wider rotation, intercropping, ASC) were characterized by higher weed presence whereas the traits distribution in the community was influenced by rotation and management with strong differences between BAU and INN systems in all the sites. Moreover, the ASCs introduction showed a strong impact on the weed development during their cycles, otherwise controlled in the systems without their cropping. This potential drawback was at the same time counterbalanced by the reduced number of weed control strategies foreseen in these systems. As general consideration, the introduction of new management (INN in CH and BE, BAU in IT) drives to higher diversity (R) and lower dominance.

B- fulfilment of objectives:

All objectives relative to Soil health and functional biodiversity assessment were fulfilled despite Covid-19 pandemic affected the laboratory work. There was a global competition for labware, chemicals and DNA/RNA extract kits as a result of the pandemic, leading to delays in delivery during a long period for non-human health service purposes. Some delays were observed in the submission of Deliverable 4.6 and Deliverable 4.7 as a result of the pandemic.

WP5	*Communication, actors' involvement and sustainability assessment*
WP leader: Laura Kemper **Responsible partners: All**	
Overall summary of main results, discussion and conclusions of WP5 The project was able to successfully communicate project information and outcomes to actors through the project website, flyers, and social media. 13 experiment site visits, more than 50 articles in farmers' and specialised press, as well as several dissemination tools (six factsheets, two practice abstracts and four videos) were key to disseminating information regarding innovative and more environmentally sustainable agricultural practices to farmers, advisors and scientists. Consumers were specifically addressed and involved in the project through a series of targeted events (Food Citizenship in Capua, Food Festival in Aarhaus, Denmark, and the FiBL Open House, among others), two factsheets providing information about growing, harvesting and using winter vegetables as well as articles in relevant specialised press. Results from the life cycle analysis (LCA) showed mixed performance across cropping strategies and sites. In Belgium and France, impacts associated with the BAU fertilization strategies were not resolved with use of transfer mulches in INN system. In Denmark, energy input reductions lowered global warming potential impacts in INN systems, and yet this took place at a cost to total yields. For Italy, the substitution of commercially-made fertilizers with a locally sourced strategy led to overall lower impacts. Lastly, in Switzerland, the innovative practices of ASC and transfer mulch also led to higher impacts relative to BAU in nutrient management impact categories, yet with lower impacts in global warming and energy use due to a reduction in heating energy. To assess the economic sustainability of the systems tested in Switzerland, profitability calculations were made for each crop in the crop rotations, taking into account the different heating, fertilisation and crop protection methods. All approaches tested in the different crop rotations have potential. Diversified crop rotations in greenhouses are economically interesting, provided that there is a market for the different crops. While there are many opportunities for diversification in the winter half of the year, it is difficult to find good alternative crops in the summer that can be grown economically and bring diversity into the crop rotation. The INN1 system is the most profitable per area in the trial while the INN2 system performed worst from an economic point of view. This is partially due to the yield losses caused by the cultivation of ASC.	
Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal **A- results obtained and structured in relation to the user groups they are relevant for:** *All end-users* Together with the project partners, FiBL prepared a detailed dissemination plan (**D5.1**) ("20190531_GRP_LK_Greenresilient-dissemination-plan"in Annexes to the final Report) and produced and published a flyer with a short description of the entire project (**D5.2**) - ("D5.2_greenresilient_leaflet web" in Annexes to the final Report). FiBL also built and has maintained a project website (**D5.3**) (https://www.greenresilient.net/), with over 1,600 views. It includes information about the project, the partners, the experimental sites and events as well as news items. Associated to the homepage, FiBL is managing the social media accounts (Twitter, Facebook and YouTube), which have been widely used for the communication of the project. All project publications are archived on Organic E-prints and made accessible via the project website. At least two rounds of experimental site visits took place at all	

experimental sites (BE, CH, FR, DK, IT). These were advertised beforehand through media in the respective countries as well as on the project website afterwards.

Farmers, advisors and scientists
FiBL and selected partners (CREA, FiBL, GRAB, HBLFA, ILVO, UvA) published a total of six factsheets and two practice abstracts (**D5.5** and **D5.8**), which have over 2700 views on organic eprints. The factsheets have also been translated into other project languages and used by partners in their work. All factsheets and practice abstracts are also available on the organic farm knowledge platform. Four videos were produced (**D5.6** and **D5.7**) covering the following topics: How to assess weed biodiversity: exploiting weeds' functionality in greenhouses (CREA), How to monitor soil health with DNA-metabarcoding of Nematode communities (ILVO), Innovative production in the greenhouse: flower strips, mixed crops, plant mulch (FiBL and GRAB), and How to set a pitfall trap to assess spiders and predatory beetles (CREA and FiBL). The videos are available in English with subtitles in Dutch, French, German, Italian and Swedish. All videos are available on the project YouTube channel, where they have a total of 808 views. More than 50 articles published in the local language in the farmers' and specialised press. For more details, see the "publication and dissemination activities".

As part of task 5.3, the environmental sustainability of contrasting cropping strategies, BAU and INN, was assessed using the Life Cycle Assessment (LCA) approach. In a first step, this work saw to the systematic collection of relevant primary production data from each project partner **(D5.4)** (file "D5.4 20190505_GRP_MM_LCA_inventory protocol" in Annexes to the final Report). Use of ISO-conform life cycle inventory databases then served to characterize material and energy flows of all notable upstream inputs and emissions associated with the final product, up to the point of harvest. In total, 75 unique cropping cultivation inventories, belonging to 13 unique strategies, were modelled in detail. These inventories formed the basis for carrying out environmental impact assessment calculations and subsequent analyses at both crop and cropping system levels. The observation of multiple metrics allowed for a more comprehensive assessment of environmental sustainability and included global warming potential, energy demand, waterbody eutrophication (resulting from N and P nutrient loading), water scarcity and ecotoxicity. Results were compared between the two cropping strategies and at varying levels of details via contribution analysis. Results showed mixed performance across cropping strategies and sites. In Belgium and France, impacts associated with the BAU fertilization strategies were not resolved with use of transfer mulches in INN system. In Denmark, energy input reductions lowered global warming potential impacts in INN systems, and yet this took place at a cost to total yields. For Italy, the substitution of commercially-made fertilizers with a locally sourced strategy led to overall lower impacts. Lastly, in Switzerland, the innovative practices of ASC and transfer mulch also led to higher impacts relative to BAU in nutrient management impact categories, yet with lower impacts in global warming and energy use due to a reduction in heating energy. More information is available in the LCA report **(D5.9).** To assess the economic sustainability of the systems tested in Switzerland, profitability calculations were made for each crop in the crop rotations, taking into account the different heating, fertilisation and crop protection methods. The results showed that one of the innovative systems was the most profitable and the second innovative systems was the least profitable. However, many caveats are highlighted in the report (**D5.10**). Furthermore, all approaches tested in the different crop rotations do have potential. Diversified crop rotations in greenhouses are economically interesting, provided that there is a market for the different crops. While there are many opportunities for diversification in winter, it is difficult to find good alternative crops in the summer that can be grown economically and bring diversity into the crop rotation.

Citizens
Consumers were invited to the experimental site visits in BE, CH, FR, DK, IT. Furthermore, additional events with a special focus on food citizens were organised in several various countries. For example, CREA and La Colombaia organised the "Food Citizenship in Capua" event, which gave citizens the opportunity to taste different leafy vegetables and learn more about them. At the Food Festival in Aarhaus, Denmark, AU asked citizens to taste six different winter leafy crops suitable for growing in unheated greenhouses. 112 visitors

also filled in a survey about their knowledge and opinions of the vegetables. Similarly, at the FiBL Open House, visitors were invited to learn about plant breeds, which can have longer growing seasons through cultivation in unheated greenhouses. Participants took part in a quiz about when certain plants are grown and how diverse growing seasons can be.
Two of the Greenresilient leaflets are targeted toward consumers: Wintamines and Taste of Winter. In addition to the Greenresilient dissemination channels, they have been published in relevant outlets, such as the FAO Family Farming Knowledge Platform.
Some of the articles in the specialised press also contain information for citizens about how their food is grown. Notably, Greenresilient is mentioned in a book about harvesting your own vegetables in winter.

B- fulfilment of objectives:
Project communication and information for growers and policy makers – **Fulfilled**
- Detailed dissemination plan (**D5.1**) and project flyer **(D5.2)**
- Project website (**D5.3**) (https://www.greenresilient.net/),
- Social media accounts (Twitter, Facebook and YouTube)
- At least two rounds of experimental site visits at all experimental sites (BE, CH, FR, DK, IT).
- Six factsheets and two practice abstracts (**D5.5** and **D5.8**)
- Four videos (**D5.6** and **D5.7**)
- Several articles in the farmers' and specialised press

Interaction and involvement of consumers – **Fulfilled**
- Consumers invited to the experimental site visits in BE, CH, FR, DK, IT.
- Additional events with a special focus on food citizens, e.g., Food Citizenship in Capua, Food Festival in Aarhaus, Denmark, and the FiBL Open House.
- Two factsheets about growing, harvesting and using winter vegetables
- Articles in the specialised press containing information for citizens about how their food is grown

Sustainability assessment – **Fulfilled**
- LCA report published on organic eprints (**D5.4** and **5.9**)
- Swiss economic assessment published on organic eprints **(D5.10)**

3.2 Deliverables and milestones status

Deliverable No.	Deliverable name	Link to the document[2]	Planned delivery month[1)]	Actual delivery month[1)]	Reasons for changes/delay and explanation of consequences
D1.1.	Project start press release	"20180417_GRP_FT_Press-release final"	M1	M1	
D2.1	Definite Experimental designs	Different files in Greenresilient/ WP2/detailed experimental plans	M3	M1	
D3.1	Soil and plant sampling	'20180629_GRP_KW_Final	M3	M2	

CORE organic

	procedure and analysis	version D3_1', '20180628_Greenresilient_WP3_summary of soil and vegetables analysis and sampling' and '20181024_GRP_KW_Leafy vegetables sampling and analysis'			
D4.1	Soil sampling procedures for soil health assessment	'Task 4 wp 1 labelling.xlsx', '20180625_GRP_AR_Final_version_D4_1.docx', '20180607_GRP_NV_finalversion_D4_1_nematodes.docx'	M3	M1	
D4.2	Soil sampling procedures for pest management	"20180531_GRP_PR_Arthopod assesments for task 4.2"	M3	M2	
D4.3	Pitfall trap and plant assessment procedures for arthropods biodiversity assessment	"20180531_GRP_PR_Arthopod assesments for task 4.2"	M3	M2	
D4.4	Guideline for weed community assessment	"20180406_GRP_CC_task 4.3_detailed protocol for weed biodiversity"; '20180406_GRP_CC_task 4.3_short protocol for weed biodiversity'	M3	M3	
D5.1	Dissemination plan	"20190531_GRP_LK_Greenresilient-dissemination-plan"	M3	M3	
D5.2	Project flyer	greenresilient_leaflet_web	M5	M5	

D5.3	Project homepage	https://www.greenresilient.net/	M6	M6	
D5.4	Template of inventory sheet for LCA	"20190505_GRP_MM_LCA_inventory protocol"	M12	M13	A slight delay due to final feedback from partners and revisions.
D1.2	Mid-term report	"20191129_Greenresilient_Mid-term report"	M18	M18	
D1.3	Project Mid-term press release	"GRP_FT_Press release Mid term_final version"	M19	M18	
D4.5	List of endophytes and arthropod predators with potential to increase pest resilience	"20200331_GRP_PR_D4_5_Arthropods for resilience"	M27	M24	
D5.5	First leaflet on promising techniques	{Tool} ***Nematodes as suitable indicators for soil health (Greenresilient Factsheet).***	M24	M24	
D5.6	First short video	{Tool} ***How to set a pitfall trap to assess spiders and predatory beetles (Greenresilient video).***	M24	M20	
D5.7	Second short video	**Blühstreifen, Mischkulturen und Pflanzenmulch im Gewächshaus (Video).**	M33	M24	
D5.8	Leaflets on promising techniques and consumer awareness (n. 6)	Listed in next paragraph **4.1 List extracted from Organic Eprints** (among sub-paragraph Practice tool)	M38	M38	
D5.9	Environmental assessment (LCA)	**Environmental assessment: LCA of innovative agroecological**	M38	M38	

		protected vegetable cropping systems.			
D5.10	Case study of economic performance	**Greenresilient case study of Economic Performance: Deliverable 5.10.**	M39	M39	
D4.6	Insights in interactions between biodiversity and root disease suppression in innovative organic production systems	**Insights in interaction between soil biodiversity and root disease suppression in organic production systems - preliminary results.**	M39	M43	The fulfilment of D4.6 was late as a result of the pandemic. There was a global competition for labware, chemicals and DNA/RNA extract kits as a result of the pandemic, leading to delays in delivery during a long period for non-human health service purposes.
D4.7	Insights in the role of fungal endophytes present in organic soils in above ground pest suppression	"GRP_GM_Fungal endophytes"	M39	M43	Delay in the work of molecular identification of the last sampling of autumn 2020 in spring 2021.
D1.4	Final report	"Greenresilient_Final Report"	3rd January 2022	31st of December 2021	
D1.5	Project end press release	**Innovative systems for organic greenhouse production: transnational European Project just ended (press release).**	M42	M43	In Italy, project end was postponed to 31st of December 2021 to carry out planned dissemination activities

Milestone No.	Milestone name	Planned delivery month[1)]	Actual delivery month[1)]	Reasons for changes/delay and explanation of consequences
M1	Kick off Meeting	M2	M1	
M2	Project homepage design	M4	M1	
M3	Video clips: topics selected	M12	M12	

M4	I Round of farm visit	M16	M17	For some sites, it was more appropriate to have the site visit in August rather than July.
M5	II Project Meeting	M16	M15	
M6	I cycle crop data collected and evaluated	M22	M22	
M7	I cycle nutrients availability and nitrate leaching data collected and evaluated	M22	M22	
M8	I cycle surface Nitrogen input/output balance data collected and evaluated	M22	M22	
M9	I cycle soil biodiversity, microbial biomass and microbial activity assessment data collected and evaluated	M22	M22	
M10	Project pest management and soil arthropods biodiversity assessment data collected and evaluated	M22	M22	
M11	I cycle weed composition data collected and evaluated	M22	M22	
M12	1st Video draft version	M22	M22	
M13	Draft of first leaflets on new techniques	M22	M22	
M14	II Round of farm visit	M30	M30	
M15	III Project Meeting	M31	M31	
M16	Draft of all (six) leaflets on promising techniques and consumer awareness	M35	M35	
M17	Draft version of second Video	M31	M31	
M18	II cycle crop data collected and evaluated	M39	M39	
M19	II cycle nutrients availability and nitrate leaching data collected and evaluated	M39	M39	
M20	II cycle surface Nitrogen input/output balance data collected and evaluated	M39	M39	
M21	II cycle soil biodiversity, microbial biomass and microbial activity assessment data collected and evaluated	M39	M42	The delay was a result of the pandemic. There was a global competition for labware, chemicals and DNA/RNA extract kits as a result of the pandemic, leading to delays in delivery during a long period for non-human health service purposes.
M22	Project end suppressiveness assay	M39	M39	
M23	Project pest management and soil arthropods biodiversity assessment data collected and evaluated	M39	M39	

M24	II cycle weed composition data collected and evaluated	M39	M39	
M25	Final Meeting	M42	M42	

1) Measured in months from the project start date (month 1)

2) Link to Organic eprints or to files in Annexes to the final Report

4. Publications and dissemination activities

4.1 List extracted from Organic Eprints

(Publications affiliated to European Union > CORE Organic Cofund > "project acronym", grouped by Eprint type, with date of extraction)

ISI Journal papers

Messelink, Gerben; Lambion, Jérôme and Paul, van Rijn (2021) **Biodiversity in and around Greenhouses: Benefits and Potential Risks for Pest Management**. *Insects*, 12 (10), p. 933.

Tittarelli, Fabio (2020) **Organic Greenhouse Production: Towards an Agroecological Approach in the Framework of the New European Regulation—A Review.** *Agronomy*, 10 (72), pp. 1-12.

Tittarelli, Fabio; Alsanius, Beatrix W.; Kemper, Laura; Petersen, Karen Koefoed and Willekens, Koen (2020) **GREENRESILIENT – applying agroecology to organic greenhouse production.** *ISHS Acta Horticulturae*, 1296, p. 139.

Newspaper or magazine articles

Brandt-Møller, Irene (2019) **Endnu mere fokus på alternative gødningsformer.** *Økologisk Landbrug*, 30 August 2019, 647, pp. 10-11.

Brandt-Møller, Irene (2019) **Projekt udvikler robuste systemer til væksthuse.** *Økologisk Landbrug*, 30 August 2019 (647), p. 15.

De Groote, Stefanie (2019) **Variety trial of organic radish in tunnel.** [Rassenproef bio radijs in tunnel.] *Proeftuinnieuws*, 7 June 2019, p. 36.

De Groote, Stefanie; Willekens, Koen and Waeyenberge, Lieven (2019) **Towards a more agroecological cultivation technique in tunnels.** [Naar een meer agro ecologische teelttechniek in koepels.] *BioPraktijk*, 6 September 2019, p. 1.

De Groote, Stefanie; Willekens, Koen and Waeyenberge, Lieven (2019) **Towards a more agroecological cultivation technique in tunnels.** [Naar een meer agro ecologische teelttechniek in koepels.] *Proeftuinnieuws*, 6 September 2019, 15, pp. 26-28.

Forslund, Elisabeth (2020) **SLU deltar i EU-projekt för robustare växthusodling.** *Viola*, 2020 (8), pp. 30-31.

Hauenstein, Samuel; Rochat, Armelle and Schwitter, Patricia (2021) **Transfer mulch in organic greenhouses.** *The Organic Grower*, 2021 (55), pp. 32-34.

Hauenstein, Samuel (2020) **Nachhaltigkeit im Gewächshaus - das Forschungsprojekt Greenresilient.** *Bioland Fachmagazin*, 1 October 2020, p. 18.

Hauenstein, Samuel (2019) **Fruchtfolgeoptimierung im Biogewächshausanbau.** *Schweizer Bauer*, 27 July 2019, xx.

Hauenstein, Samuel (2019) **Vielfältige Fruchtfolge.** *BauernZeitung*, 5 July 2019, p. 31.

Kemper, Laura (2020) **Organic Greenhouse Production: Towards an Agroecological Approach in the Framework of the New European Regulation.** *Core Organic Cofund Newsletter*, February 2020, pp. 1-2.

Koefoed Petersen, Karen (2019) **Greenresilient at the Food Festival in Aarhus.** *Core Organic Cofund Newsletter*, October 2019, pp. 1-2.

Kristensen, Helene (2018) **Designing resilient organic greenhouse production systems for Europe.** *Core Organic Cofund Newsletter*, November 2018, pp. 1-3.

Lambion, Jérôme; Dietemann, Lauren and Willer, Helga (2020) **Greenresilient experimental site visit: Innovative greenhouse practices in France.** *Core Organic Cofund Newsletter*, September 2020, pp. 1-2.

Lambion, Jérôme and VEDIE, Hélène (2020) **Video from Greenresilient.** *Core Organic Cofund Newsletter*, February 2020, p. 1.

Lippens, Louis (2018) **European project aims to make organic horticulture more agro-ecological.** [Europees project wil bioglastuinbouw agro-ecologischer.] *VILT*, 2018, pp. 1-2.

Lippens, Louis; Barbry, Joran and Willekens, Koen (2018) **Biologische teeltsystemen herbekeken.** [Organic cultivation systems reconsidered.] *Proeftuinnieuws*, June 2018, 11 (11), p. 19.

Messelink, Gerben (2019) **Greenresilient: Functional biodiversity with soil borne fungi to suppress greenhouse pests.** *Core Organic Cofund Newsletter*, June 2019, pp. 1-2.

Palme, Wolfgang (2021) **Gemüse für den Winter.** *bioprofi*, 2021 (1), pp. 28-30.

Palme, Wolfgang (2020) **Reiche Winterernte - Frisches Gemüse aus dem Kalthaus.** *Bioland*, 2020, 10, pp. 20-21.

Paponov, Ivan Alekseevic and Dietemann, Lauren (2020) **Optimising organic vegetable greenhouse production in Denmark.** *Core Organic Cofund Newsletter*, September 2020, pp. 1-2.

Petersen, Karen Koefoed (2019) **Tomater i et agroøkologisk system.** *Gartner Tidende*, 19 September 2019, 135 (11), pp. 16-17.

Petersen, Karen Koefoed (2019) **Agroøkologiske principper til tomater.** *Gartnertidende*, 25 June 2019, 135 (8), p. 31.

Rose, Frédérique (2019) **Concevoir des systèmes sous abris résilients**. *BIOFIL*, November 2019, 126, pp. 53-54.

Sommer, Lea and Hauenstein, Samuel (2019) **Greenresilient experimental site visit: Optimizing Crop rotation in organic greenhouse cultivation in Switzerland.** *Core Organic Cofund Newsletter*, October 2019, p. 1.

Tittarelli, Fabio (2020) **Designing resilient organic greenhouse production systems for Europe.** *Core Organic Cofund Newsletter*, February 2020, pp. 1-3.

Tittarelli, Fabio (2020) **Food Citizenship in Capua – a joint event by Greenresilient and ProOrg projects.** *Core Organic Cofund Newsletter*, February 2020, pp. 1-2.

Vedie, Hélène (2018) **Concevoir des systèmes de production résilients. [Designing resilient production systems.]** *Maraîchage Bio Infos*, 7 September 2018, 95, p. 12.

Vedie, Hélène and Lambion, Jérôme (2019) **Vers un système de production de légumes bio plus écologique sous serre : résultats 2018 de l'essai du GRAB dans le projet GREENRESILIENT**. *MARAICHAGE BIO INFOS*, 2019, 99, pp. 1-8.

Viaene, Nicole (2019) **Nematodes as indicators of soil biodiversity in Greenresilient.** *Core Organic Cofund Newsletter*, October 2019, p. 1.

Waeyenberge, Lieven (2020) **Leaflet on nematodes as suitable indicators for soil health.** *Core Organic Cofund Newsletter*, May 2020, pp. 1-2.

Conference paper, poster, etc.

Petersen, Karen Koefoed (2019) **Greenresilient - innovativ og robust produktion i lavenergivæksthuse.** Poster at: Food Festival, Aarhus, 05 - 07 September 2019.

Takacs, J; Messelink, Gerben and Woelke, J (2019) **Effect of entomopathogenic fungi as root endophyte on the development of a specialist & generalist herbivore**. Poster at: Dutch Entomology Day, December 13, 2019. [Unpublished]

Tittarelli, Fabio; Alsanius, Beatrix; De Groote, Stefanie; Fleury, Yannick; Kemper, Laura; Koefoed Petersen, Karen; Lambion, Jerome; Morra, Luigi and Willekens, Koen (2021) **Greenresilient: Innovative Cropping Systems In Organic Greenhouse Production.** Paper at: Organic World Congress 2021, Science Forum: 6th ISOFAR Conference co-organised with INRA, FiBL, Agroecology Europe, TP Organics and ITAB, Rennes, France, 8 - 10 September, 2021. [Completed]

Tittarelli, Fabio; Baiano, Salvatore; Trotta, Stefano; Bilotto, Maurizio; Ciaccia, Corrado; Testani, Elena and Morra, Luigi (2021) **Agronomic performances of organic rocket cultivation in greenhouse: a comparison among intensive (Business as Usual), biodynamic and agroecological systems of production.** In: Bautze, Lin; Brock, Christopher; Code, Jonathan; Derkzen, Petra; Fritz, Jürgen; Hach, André; Peschke, Jasmin; Ravenscroft, Neil; Sharmila Dass, Regina; Spengler-Neff, Anet; Swann, Richard; Von Diest, Saskia; Wahl, Verena; Wirz, Johannes; Wright, Julia and Florin, Jean-Michel (Eds.) *Growing beyond resilience: 2nd International Conference on Biodynamic Research*, Section for Agriculture at the Goetheanum, Dornach, Switzerland (online).

Tittarelli, Fabio; Morra, Luigi; Testani, Elena and Ciaccia, Corrado (2018) **Greenrelisient: Agroecological approach to organic greenhouse production in Europe.** Poster at: 2nd International GRAB-IT Workshop "Organic farming and agroecology as a response to global challenges", Capri Island (Naples), Italy, 27-29 June, 2018.

Report

De Groote, Stefanie (2018) **Visitor guide field visit organic covered crops 2018.** [Bezoekersgids proefveldbezoek bio beschutte teelten 2018.] , Kruishoutem.

De Groote, Stefanie (2019) **Visitor guide field visit organic covered crops 2019.** [Bezoekersgids proefveldbezoek bio beschutte teelten 2019.] , Kruishoutem.

De Groote, Stefanie (2020) **Visitor guide field visit organic covered crops 2020.** [Bezoekersgids proefveldbezoek bio beschutte teelten 2020.] , Kruishoutem.

De Groote, Stefanie; Willekens, Koen and Viaene, Nicole (2019) **Agro-ecological production systems for organic greenhouses.** .

Hansen, Janne (2019) **Organic greenhouse vegetables can become sustainable and resilient.** Aarhus University, Aarhus.

Hauenstein, Samuel; Hofer, Sheila and Kemper, Laura (2021) **Greenresilient case study of Economic Performance: Deliverable 5.10.** Research Institute of Organic Agriculture FiBL, Frick, Switzerland.

Rosberg, Anna Karin; Will, Lena and Alsanius, Beatrix W. (2021) **Insights in interaction between soil biodiversity and root disease suppression in organic production systems - preliminary results.** Reports from Landscape Architecture, Horticulture and Crop Production Science, no. 2021:6. Swedish University of Agricultural Sciences, Alnarp.

Thompson, Michael and Moakes, Simon (2021) **Environmental assessment: LCA of innovative agroecological protected vegetable cropping systems.** GreenResilient Deliverable 5.9.. Research Institute of Organic Agriculture FiBL , CH-Frick.

Thesis

Affrait, Laura (2020) **Amélioration de la durabilité des systèmes maraîchers biologiques sous abris : le projet Greenresilient**. Thesis, Groupe de Recherche en Agriculture Biologique(GRAB) . HAL.

Practice tool

{Tool} ***Agroecological service crops in Southern European greenhouse (Greenresilient Factsheet).*** Creator(s): Ciaccia, Corrado; Testani, Elena; Morra, Luigi and Tittarelli, Fabio. Issuing Organisation(s): CREA - Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria. Greenreslient Factsheet. (2021)

➔ Available in English and Italian

{Tool} ***Transfer mulch in organic greenhouse crops (Greenresilient Practice abstract).*** Creator(s): Hauenstein, Samuel and Rochat, Armelle. Issuing Organisation(s): FiBL - Research Institute of Organic Agriculture. Greenresilient Practice Abstracts. (2021)

{Tool} ***Transfer mulch in organic greenhouses (Greenresilient Factsheet).*** [Transfermulch in Bio-Gewächshäusern.] Creator(s): Hauenstein, Samuel; Rochat, Armelle and Schwitter, Patricia. Issuing Organisation(s): FiBL - Research Institute of Organic Agriculture. Greenresilient Factsheet. (2021)

➔ Available in English, French and German

{Tool} ***Flower strips: a tool for pest control in greenhouses (Greenresilient Practice abstract).*** Creator(s): Lambion, Jérôme. Issuing Organisation(s): GRAB - Groupe de Recherche en Agriculture Biologique. Greenresilient Practice abstract. (2021)

{Tool} ***Flower strips: a tool for pest control in greenhouses (Greenresilient Factsheet).*** [Les bandes fleuries : un outil de lutte contre les ravageurs dans les serres.] Creator(s): Lambion, Jérôme and van Rijn, Paul. Issuing Organisation(s): GRAB - Groupe de Recherche en Agriculture Biologique. Greenresilient Factsheet. (2021)

➔ Available in English, Dutch, French and German

{Tool} ***Taste of Winter (Greenresilient Factsheet).*** Creator(s): Palme, Wolfgang. Issuing Organisation(s): Horticultural College and Research Institute. Greenresilient Factsheet. (2021)

➔ Available in English and Dutch

{Tool} ***Wintamines (Greenresilient Factsheet).*** Creator(s): Palme, Wolfgang. Issuing Organisation(s): Horticultural College and Research Institute. Greenresilient Factsheet. (2021)

{Tool} ***How to assess weed biodiversity: exploiting weeds' functionality in greenhouses (GreenResilient video).*** Creator(s): Testani, Elena and Tittarelli, Fabio. Issuing Organisation(s): CREA - Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria. GreenResilient video. (2021)

➔ Available in English, Danish, Dutch, French, German, Italian and Swedish.

{Tool} ***How to set a pitfall trap to assess spiders and predatory beetles (Greenresilient video).*** Creator(s): Tittarelli, Fabio and Kemper, Laura. Issuing Organisation(s): CREA - Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria. GreenResilient video (2019)

➔ Available in English, Danish, Dutch, French, German, Italian and Swedish.

{Tool} ***Nematodes as suitable indicators for soil health (Greenresilient Factsheet).*** Creator(s): Waeyenberge, Lieven; Viaene, Nicole and Willekens, Koen. Issuing Organisation(s): ILVO - Flanders Research Institute for Agriculture, Fisheries and Food. Greenresilient Factsheet. (2020)

➔ Available in English and Dutch.

Web product

Brandt-Møller, Irene (2019) **Projekt udvikler robuste systemer til væksthuse.** . Online at **https://nyheder.okologi.dk/mark-og-stald/projekt-udvikler-robuste-systemer-til-vaeksthuse**, accessed on: 2019.

Brusco, Maria Luigia (2019) **Agricoltura biodinamica: alla ricerca di conferme scientifiche.** FreshPlaza . Online at **https://www.freshplaza.it/article/9091991/agricoltura-biodinamica-alla-ricerca-di-conferme-scientifiche/**, accessed on: 5 October 2021.

Cinquemani, Tommaso (2018) **Con GreenResilient il biologico in serra diventa più sostenibile.** AgroNotizie – riproduzione riservata. Online at **https://agronotizie.imagelinenetwork.com/vivaismo-e-sementi/2018/06/04/con-greenresilient-il-biologico-in-serra-diventa-piu-sostenibile/58897**, accessed on: 5 October 2021.

Hauenstein, Samuel (2019) **Biogewächshausanbau nachhaltiger gestalten.** Online at **https://www.bioaktuell.ch/aktuell/meldung/biogewaechshausanbau-nachhaltiger-gestalten-7-2019.html**, accessed on: 11 October 2021.

House of, Switzerland (2019) **Switzerland participates in international efforts to promote sustainable agriculture.** House of Switzerland. Online at **https://houseofswitzerland.org/headlines/switzerland-participates-international-efforts-promote-sustainable-agriculture**, accessed on: 11 October 2021.

Iarrapino, Carlotta (2021) **Greenresilient, la bioagricoltura in serra per la sostenibilità. A colloquio con Fabio Tittarelli.** Online at **https://www.agricolturabio.info/protagonisti/greenresilient-la-bioagricoltura-in-serra-per-la-sostenibilita-a-colloquio-con-fabio-tittarelli/**, accessed on: 17 May 2021.

Lebleu, Flore (2019) **Rendre la culture biologique sous serre plus durable.** Institut de recherche de l'agriculture biologique FiBL, CH-Frick . Online at **https://www.bioactualites.ch/actualites/nouvelle/rendre-la-culture-biologique-sous-serre-plus-durable-7-20190.html**, accessed on: 6 March 2020.

Mathiesen, C. (2020) **Potentiale i nye gødskningsstrategier i økogrøntsager.** [Potential of new fertilization strategies regarding organic vegetables.] DCA. Online at **https://dca.au.dk/aktuelt/nyheder/vis/artikel/potentiale-i-nye-goedskningsstrategier-til-oekogroentsager/**, accessed on: 10 September 2021.

Messelink, Gerben (2019) **Functional biodiversity with soilborne fungi to suppress greenhouse pests.** Wageningen University and Research. Online at **https://www.wur.nl/en/newsarticle/Functional-biodiversity-with-soilborne-fungi-to-suppress-greenhouse-pests.htm**, accessed on: 30 January 2019.

Ökolandbau, NRW (2018) **Europäisches Projekt zur Entwicklung resilienter Produktionssysteme für Bio-Gewächshäuser.** Online at **https://www.oekolandbau.nrw.de/fachinfo/pflanzenbau/gemuesebau/2018/europaeisches-projekt-zur-entwicklung-resilienter-produktionssysteme-fuer-bio-gewaechshaeuser**, accessed on: 11 October 2021.

Pergamo, R.; Coppola, R. and Morra, L. (2018) **Amico Bio, con la biodinamica più qualità e competitività.** Terra e vita . Online at **https://terraevita.edagricole.it/biologico/amico-bio-la-biodinamica-piu-qualita-competitivita/?utm_term=305834+-+https%3A%2F%2Fterraevita.edagricole.it%2Fbiologico%2Famico-bio-la-biodinamica-piu-qualita-competitivita%2F&utm_campaign=Campagne+B-NBM+Biodinamica+News&utm_medium=email&utm_source=MagNews&utm_content=64676+-+30662+%282018-05-15%29**, accessed on: 5 October 2021.

Piccione, Gaetano (2019) **Incontro fra ricercatori e consumatori per aumentare la consapevolezza alimentare.** FreshPlaza . Online at **https://www.freshplaza.it/article/9170648/incontro-fra-ricercatori-e-consumatori-per-aumentare-la-consapevolezza-alimentare/**, accessed on: 5 October 2021.

Serventi, Marco (2018) **Greenresilient: un approccio agroecologico alla produzione bio e biodinamica in ambiente protetto in Europa.** Biodinamica - Associazione per l'agricoltura . Online at **https://www.biodinamica.org/greenresilient-un-approccio-agroecologico-alla-produzione-bio-e-biodinamica-in-ambiente-protetto-in-europa/**, accessed on: 5 October 2021.

Tittarelli, Fabio (2021) **Greenresilient, a Capua il 19 maggio.** Agricolurabio.info . Online at **https://www.agricolturabio.info/notizie/greenresilient/**, accessed on: 5 October 2021.

Tittarelli, Fabio (2018) **Greenresilient: sistemi biologici resilienti in ambiente protetto.** FreshPlaza . Online at **https://www.freshplaza.it/article/98599/Greenresilient-sistemi-biologici-resilienti-in-ambiente-protetto/**, accessed on: 5 October 2021.

Tittarelli, Fabio (2018) **Sistemi biologici resilienti in ambiente protetto. Il nuovo progetto europeo Greenresilient.** SINAB Sistema d'informazione Nazionale sull'Agricoltura Biologica . Online at **https://www.sinab.it/bionovita/sistemi-biologici-resilienti-ambiente-protetto-il-nuovo-progetto-europeo-greenresilient**, accessed on: 5 October 2021.

Ullvén, Karin (2018) **GREENRESILIENT will improve organic greenhouse production.** The CORE Organic Cofund Website, Tjele, Denmark. Online at **http://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/greenresilient-will-improve-organic-greenhouse-production/**, accessed on: 5 April 2018.

Willekens, Koen (2018) **European project aims to make organic horticulture more agro-ecological.** [Europees project wil bioglastuinbouw agro-ecologischer.] .

Video

Alföldi, Thomas; Kemper, Laura; Vedie, Hélène and Lambion, Jérôme (2020) **Blühstreifen, Mischkulturen und Pflanzenmulch im Gewächshaus (Video).** Forschungsinstitut für biologischen Landbau FiBL, CH-Frick.

➔ Available in English, Danish, Dutch, French, German, Italian and Swedish.

Vedie, Hélène and Lambion, Jérôme (2021) **Amélioration de la durabilité des systèmes.** Maraîchers biologiques sous-abris.

Waeyenberge, Lieven (2021) **How to monitor soil health with DNA-metabarcoding of Nematode communities.** Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Plant Sciences Unit.

➔ Available in English, Danish, Dutch, French, German, Italian and Swedish.

Other

Tittarelli, Fabio (2021) **I risultati e le prospettive future della ricerca in agricoltura biologica e biodinamica. Il progetto Greenresilient e la Food Citizenship**.

Tittarelli, Fabio (2021) **Innovative systems for organic greenhouse production: transnational European Project just ended (press release)**.

Tittarelli, Fabio (2021) **Vivere il green europeo: Agricoltura e allevamenti sostenibili**

Tittarelli, Fabio (2021) **Confronto tra sistemi di produzione: risultati e prospettive.** , Roma.

Tittarelli, Fabio (2020) **Designing resilient organic greenhouse production systems for Europe: updates from the first half of the Greenresilient project (Press release).**

Petersen, Karen Koefoed (2019) **Greenresilient flyer.** Aarhus University, Food Science.

Tittarelli, Fabio (2018) **Designing resilient organic greenhouse production systems for Europe – New project started (Press release).**

Tittarelli, Fabio (2018) **Greenresilient: How to implement agroecological practices in organic greenhouse production in Europe.** CREA, Rome.

4.2 Stakeholders oriented articles in the CORE Organic newsletter

All target groups

- *Greenresilient experimental site visit: Innovative greenhouse practices in France: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/greenresilient-experimental-site-visit-innovative-greenhouse-practices-in-france/*
- *Designing resilient organic greenhouse production systems for Europe: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/designing-resilient-organic-greenhouse-production-systems-for-europe-1/*
- *Greenresilient experimental site visit: Optimizing Crop rotation in organic greenhouse cultivation in Switzerland: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/greenresilient-experimental-site-visit-optimizing-crop-rotation-in-organic-greenhouse-cultivation-i/*

- *Designing resilient organic greenhouse production systems for Europe: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/designing-resilient-organic-greenhouse-production-systems-for-europe/*
- *GREENRESILIENT will improve organic greenhouse production: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/greenresilient-will-improve-organic-greenhouse-production/*

Citizens

- *Learn to grow vegetables in the winter: two Greenresilient factsheets published: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/learn-to-grow-vegetables-in-the-winter-two-greenresilient-factsheets-published/*
- *Greenresilient: relevant in Sweden and other partner countries: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/greenresilient-relevant-in-sweden-and-other-partner-countries/*
- *Winter Harvest: the Green Revolution: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/winter-harvest-the-green-revolution/*
- *Food Citizenship in Capua – a joint event by Greenresilient and ProOrg projects: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/food-citizenship-in-capua-a-joint-event-by-greenresilient-and-proorg-projects/*
- *Video from Greenresilient: Innovative production in the greenhouse: flower strips, mixed crops, plant mulch: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/new-greenresilient-video/*
- *Greenresilient at the Food Festival in Aarhus: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/greenresilient-at-the-food-festival-in-aarhus/*

Farmers/advisors

- *New innovative tool for provisioning ecological services in Southern European greenhouses: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/agroecological-service-crops-in-southern-european-greenhouses-factsheet-from-greenresilient-projec/*
- *Transfer mulch in organic greenhouses: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/transfer-mulch-in-organic-greenhouses/*
- *How to use flower strips for pest control in greenhouses: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/how-to-use-flower-strips-for-pest-control-in-greenhouses/*
- *Leaflet on nematodes as suitable indicators for soil health: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/leaflet-on-nematodes-as-suitable-indicators-for-soil-health/*

Scientists

- *How to monitor soil health with DNA-metabarcoding of nematode communities – new video from Greenresilient project: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/how-to-monitor-soil-health-with-dna-metabarcoding-of-nematode-communities-new-video-from-greenresi/*
- *Nematodes as indicators of soil biodiversity in Greenresilient: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/nematodes-as-indicators-of-soil-biodiversity-in-greenresilient/*
- *Greenresilient: Functional biodiversity with soil borne fungi to suppress greenhouse pests: https://projects.au.dk/coreorganiccofund/news-and-events/show/artikel/greenresilient-functional-biodiversity-with-soil-borne-fungi-to-suppress-greenhouse-pests/*

4.3. Practice abstracts

- *Flower strips: a tool for pest control in greenhouses: https://organic-farmknowledge.org/tool/39675*
- *Transfer mulch in organic greenhouse crops: https://organic-farmknowledge.org/tool/39680*

4.4 Other dissemination activities and material

(List other dissemination activities or dissemination material which cannot be uploaded to Organic Eprints. Please sort them by partner countries and indicate activity/material type)

Austria

- Palme, W. (2019). Ernte mich im Winter: *Einfach immer frisches Gemüse. säen, wachsen, glücklich sein*. Löwenzahn Verlag

Belgium: Events

- Experimental site visit (18 August 2020): about 16 producers, technicians and advisors
- Experimental site visit (24 October 2019): about 17 producers, technicians and advisors
- Open companies day (7 October 2019): 500 students (primary and secondary school)
- Open companies day (6 October 2019): 1200 visitors (for all people interested)
- Open house (July 2019): about 15 producers, technicians and advisors
- Experimental site visit (18 October 2018): about 14 producers, technicians and advisors
- Open house (21 June 2018): about 18 producers, technicians and advisors

Denmark: Articles

- Bisgaard A (2018): Mere Bæredygtige øko-tomater. Gartner Tidende 134(8);46

Denmark: Events

- Experimental site visit, August 27, 2020
- First Danish experimental site visit, June, 2019.
- Food Festival in Aarhus, 6-8 September, 2019
- Even for BA students at Aarhus University

France: Events

- Experimental site visit (9/09/2020): about 45 producers, technicians, journalists and advisors
- Experimental site visit (27/06/2019) : about 45 producers, technicians, journalists and advisors
- Experimental site visit (10/07/2018) : about 55 producers, technicians, journalists and advisors

Italy: Events

- Organic products and their taste. November 29, 2019: https://www.greenresilient.net/service/news/event-organic-products-and-their-taste.html
- 35th International Conference: Innovation and research alliances for agroecology, Milan, November 15-17, 2019
- Produzione biologica e biodinamica in serra: l'agroecologia per la progettazione di sistemi sostenibili e resilienti, 18.07.2018. Meeting with farmers, scientists and policy makers
- SOILVEG Meeting, 23.05.2018. Short presentation of Greenresilient and Food Citizenship in the framework of a visit to community vegetable garden
- First Italian experimental site visit, July 18, 2018

Netherlands

- Messelink, G.J. Pham, K., Takacs, J, Altay, G., Woelke, J., Janssen, A. van Rijn, P. 2021. Greenresilient: Organic and bio-dynamic vegetable production in low-energy GREENhouses: Fungal endophytes and pest management. Presentation Biokennis vakbeurs 22 Januari 2021.
- Van leth, P. (interview) 2021. Afwegingen maken bij een biodiversere glastuinbouw. Vakblad voor de Bloemisterij.

Switzerland: Events

- Second experimental site visit, September 23, 2021
- First Swiss experimental site visit, August 7, 2019
- FiBL open doors, 19.08.2018. ~4000 consumers, farmers, scientist and other stakeholders.

Project-level

Social media posts

- Twitter: 104 tweets and 134 followers: https://twitter.com/green_resilient
- Facebook: 106 posts and 110 followers: https://www.facebook.com/greenresilient
- YouTube: 4 videos, 14 subscribers and 808 views: https://www.youtube.com/channel/UC7tLpqZD6qfhoQa8iQ8TnFw

Greenresilient website

- 56 news items: https://www.greenresilient.net/service/news-news-archive.html
- Project information with over 1,600 views in total: https://www.greenresilient.net/index.html

Other news outlets outside of the project

- EIP-Agri: VIDEO CORE Organic Cofund GreenResilient project. https://ec.europa.eu/eip/agriculture/en/news/video-core-organic-cofund-greenresilient-project
- FAO Family farming knowledge platform: Learn to grow vegetables in the winter: two Greenresilient factsheets published. https://www.fao.org/family-farming/detail/en/c/1415241/

4.5 Future dissemination actions

(It is strongly recommended to upload your scientific publications and dissemination material in the Organic Eprints also after the end of the project implementation)

- List publication/deliverables/activities arising from your project that you are planning for the future;
- Ciaccia C., Armengot Martinez L., Testani E., Anselmo S., De Groote S., Morra L., Tittarelli F. "Effects of agroecological intensification on weed dynamics in organic greenhouse vegetable systems. Suggested Journal: "Weed Science"
- Rosberg, A.K. and co-authors: an abstract and poster are planned for the International Horticulture Congress in 2022 in Angers, France. Topic: Soil microbial diversity in organic greenhouse production and an article in the Acta Horticulturae on Organic and biodynamic vegetable production in low energy greenhouses. Sustainable, resilient and innovative food production systems.
- Rosberg AK, Alsanius BW, and co-authors, "Soil health in organic greenhouse crop rotations". Suggested journal**:** "Phytopathology" or "Applied Soil Ecology"
- Rosberg AK, Wayenberge L, Alsanius BW, and co-authors, "Food web and biogeography in organic greenhouse production systems". Suggested journal: "Science of the total environment"

- Tittarelli F., Saba A., Di Pierro M., Ciaccia C. “Food citizenship as an agroecological tool for food system re-design” submitted to journal “Sustainability”
- Tittarelli, F. and co-authors “A multidisciplinary approach to organic methods comparison in protected condition (tentative title). Suggested journal: “Agriculture Ecosystems & Environment” or “European Journal of Agronomy”
-
- Waeyenberge, L. and co-authors “Does an agro-ecological approach alter the nematode structural composition in protected production areas?” Suggested journal: “European Journal of Agronomy” or “Agronomy for sustainable Development”
-
- Willekens, K. and co-authors “Agroecological intensification in organic protected cultivation: advantages and drawbacks regarding nutrient dynamics, carbon sequestration and below and aboveground biodiversity” ” Suggested journal: "European Journal of Agronomy**”**

– List publications/deliverables arising from your project that more specifically Funding Bodies could disseminate in the respective national contexts;
– Indicate publications/deliverables that could be useful to translate (Please indicate targeted language and user groups).

All practice tools could be useful to translate and disseminate in different countries, for the following target groups:
Farmers/advisors:

- {Tool} ***Agroecological service crops in Southern European greenhouse (Greenresilient Factsheet).*** Creator(s): Ciaccia, Corrado; Testani, Elena; Morra, Luigi and Tittarelli, Fabio. Issuing Organisation(s): CREA - Consiglio per la ricerca in agricoltura e l’analisi dell’economia agraria. Greenreslient Factsheet. (2021)
    - Available in English and Italian
- {Tool} ***Transfer mulch in organic greenhouse crops (Greenresilient Practice abstract).*** Creator(s): Hauenstein, Samuel and Rochat, Armelle. Issuing Organisation(s): FiBL - Research Institute of Organic Agriculture. Greenresilient Practice Abstracts. (2021)
- {Tool} ***Transfer mulch in organic greenhouses (Greenresilient Factsheet).*** [Transfermulch in Bio-Gewächshäusern.] Creator(s): Hauenstein, Samuel; Rochat, Armelle and Schwitter, Patricia. Issuing Organisation(s): FiBL - Research Institute of Organic Agriculture. Greenresilient Factsheet. (2021)
    - Available in English, French and German
- {Tool} ***Flower strips: a tool for pest control in greenhouses (Greenresilient Practice abstract).*** Creator(s): Lambion, Jérôme. Issuing Organisation(s): GRAB - Groupe de Recherche en Agriculture Biologique. Greenresilient Practice abstract. (2021)
- {Tool} ***Flower strips: a tool for pest control in greenhouses (Greenresilient Factsheet).*** [Les bandes fleuries : un outil de lutte contre les ravageurs dans les serres.] Creator(s): Lambion, Jérôme and van Rijn, Paul. Issuing Organisation(s): GRAB - Groupe de Recherche en Agriculture Biologique. Greenresilient Factsheet. (2021)
    - Available in English, Dutch, French and German
- {Tool} ***How to assess weed biodiversity: exploiting weeds' functionality in greenhouses (GreenResilient video).*** Creator(s): Testani, Elena and Tittarelli, Fabio. Issuing Organisation(s): CREA - Consiglio per la ricerca in agricoltura e l’analisi dell’economia agraria. GreenResilient video. (2021)
    - Available in English, Danish, Dutch, French, German, Italian and Swedish
- {Tool} ***How to set a pitfall trap to assess spiders and predatory beetles (Greenresilient video).*** Creator(s): Tittarelli, Fabio and Kemper, Laura. Issuing Organisation(s): CREA - Consiglio per la ricerca in agricoltura e l’analisi dell’economia agraria. (2019)

   - Available in English, Danish, Dutch, French, German, Italian and Swedish

Consumers/general public

- {Tool} ***Taste of Winter (Greenresilient Factsheet).*** Creator(s): Palme, Wolfgang. Issuing Organisation(s): Horticultural College and Research Institute. Greenresilient Factsheet. (2021)
   - Available in English and Dutch
- {Tool} ***Wintamines (Greenresilient Factsheet).*** Creator(s): Palme, Wolfgang. Issuing Organisation(s): Horticultural College and Research Institute. Greenresilient Factsheet. (2021)

Scientists

- {Tool} ***Nematodes as suitable indicators for soil health (Greenresilient Factsheet).*** Creator(s): Waeyenberge, Lieven; Viaene, Nicole and Willekens, Koen. Issuing Organisation(s): ILVO - Flanders Research Institute for Agriculture, Fisheries and Food. Greenresilient Factsheet. (2020)
   - Available in English and Dutch
- Waeyenberge, Lieven (2021) **How to monitor soil health with DNA-metabarcoding of Nematode communities.** Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Plant Sciences Unit.
   - Available in English, Danish, Dutch, French, German, Italian and Swedish.

4.6 Specific questions regarding dissemination and publications

Is your CORE Organic Cofund project website up-to-date?
Both the CORE Organic Cofund website as well as the Greenresilient website (https://www.greenresilient.net/index.html) are up-to-date.

List the categories of end users relevant to the research results and how they have been addressed or will be addressed by dissemination activities (Please order them according to the user groups).

How were end-users addressed by dissemination activities?
All target groups
- Greenresilient website: https://www.greenresilient.net/index.html
- CO newsletter articles (see section 4.2)

Farmers/advisors
- Factsheets and practice abstracts: https://www.greenresilient.net/service/factsheets.html
- Videos: https://www.greenresilient.net/service/videos.html
- Articles in specialised/farmer's press (see section 4.1)
- Experimental site visits (see section 4.4)
- Organic farm knowledge: all relevant materials (factsheets, practice abstracts and videos) were added to organic farm knowledge: https://organic-farmknowledge.org/

Citizens
- Factsheets: https://www.greenresilient.net/service/factsheets.html
- Events (see section 4.1)
- Articles in specialised press (see section 4.1)

Scientists

- Journal articles (see section 4.1)
- Videos: https://www.greenresilient.net/service/videos.html
- Factsheets and practice abstracts: https://www.greenresilient.net/service/factsheets.html
- Experimental site visits (see section 4.1)

5. Project impact

In the project proposal, it was stated that the main objective of Greenresilient is to demonstrate that, in Europe, at different latitudes, it is possible to implement systems of organic production in protected conditions which have a more agroecological approach and that are more resilient. The multidisciplinary approach of the project builds up common and detailed knowledge with regard to the main local organic greenhouse production systems in Europe and has the ambition of a comprehensive interpretation of the results obtained at the five experimental sites. The results obtained in terms of feasibility of WLC cultivation, of plant nutrient availability and of potential nitrate leaching in compared systems, of nematode, weeds and arthropods biodiversity are very interesting and demonstrate that an agroecological approach to greenhouse production is feasible and environmentally friendly.. Farmers and policy makers can take profit from the introduction of innovative measures for the greenhouse environment derived from the complete redesign of the cropping systems, while the society as a whole can benefit from consumers awareness of the potentiality of cultivation of many different species of winter leafy crops, in low energy greenhouses. In terms of dissemination, the project was much more successful than envisaged in the project proposal. As example, it is worth of notice the organization of a joint event with consumers of Greenresilient and ProOrg projects. During the event, titled “The LeavesEaters” and organised at La Colombaia on the 1st of December 2019, the diversity of winter leafy vegetables production and of their organoleptic characteristics was shown (Food Citizenship). As described in detail above, all target groups (farmers/advisors, policy makers, citizens and scientists) were reached in all the countries involved by the project.

6. Added value of the transnational cooperation in relation to the subject

Organic greenhouse production systems have been object of debate for more than ten years in Europe and there is no single/unique way to reduce their level of intensification. The transnational research cooperation which has characterised Greenresilient project has provided project partners with five experimental sites at different latitudes and managed with different agronomic practices. Even though the inherent soil characteristics at the five experimental sites were different and did not allow a common assessment of their soil quality, all partners have applied the same methodology for assessing nutrients availability and for biodiversity assessment at the different experimental fields as well as the same agronomic guidelines. In this way, the adoption of common criteria for system assessment has been possible and will allow deeper scientific speculations with the same approach. Moreover, transnational projects respect to national projects, allow an interaction with researchers with different scientific background, experiences and points of view which can be extremely helpful in interpreting the results obtained. A multidisciplinary approach to technical and scientific issues associated to the different partners nationality can be difficult and sometimes extremely challenging, but when the consortium of partners is made of people respectful and open to different opinions, like it happened for Greenresilient project, a successful result can be more easily reached.

7. Suggestions for future research

Greenresilient project is multidisciplinary project which analysed compared systems of production from different viewpoints. Results obtained by partners involved in functional biodiversity assessment seems to indicate the need of implementing the experimental design for a longer period of time to discriminate compared systems of production.

Food citizenship, intended as improvement of consumer awareness of the potential impact on the environment of the different systems of production, is a slow evolving aspect but can play an important role in the future of organic farming in Europe, in the future of research on organic production and, more in general, in redesigning the food systems towards sustainability.
Events on Food Citizenship organised in the framework of Greenresilient project were always successful.

Food represents for urban consumers probably the unique contact with nature and so future research call in organic food and farming sector should also include a topic on urban agriculture/food citizenship.

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