SIGMA

Stimulating Innovation for
Global Monitoring of Agriculture

ENVIRONMENTAL IMPACT ASSESSMENT OF AGRICULTURAL LAND USE CHANGES

SIGMA Report WP5.1

ENVIRONMENTAL IMPACT ASSESSMENT OF AGRICULTURAL LAND USE CHANGES

SIGMA – Stimulating Innovation for Global Monitoring of Agriculture

Reference: ***SIGMA D5.1 Local Environmental Impact Analysis***

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EXECUTIVE SUMMARY

Within the overall SIGMA project, work package (WP5.1) focuses on a local and regional environmental impact analysis. In order to meet the world wide increase in food demand, additional agricultural areas have to be reclaimed and existing areas need to intensify. Consequently, this land use change and intensification may have strong environmental impacts. In this work package impacts were analysed addressing the following issues:

- Application of simulation models at the local scale of JECAM sites to investigate and assess eventual impacts and to compare model results with remote sensing results (WP3);
- At representative local (JECAM) sites within the Global Agro-Environmental Stratification (WP3.1), analyses was carried out of the impact of land use and management changes on soil hydrology, groundwater recharge leaching of nitrates and crop growth;
- Quantification of stress factors of the yield gap analyses (WP4.3);
- Upscaling results from analyses at JECAM sites to regional and global analyses (WP5.2 and WP5.3).

In carrying out this work package, a structured analyses of local environmental issues at each JECAM site proved to be instrumental in defining a logical and workable work sequence for each site. In addition, the definition and use of a protocol increases transparency and reproducibility of the work process. As such this contributes to the quality assurance (transparency, reproducibility) of the results obtained.

By following this approach for each JECAM site it was revealed which data were available and which data were still missing and therefore should have been collected. Following the same protocol for each JECAM site had the clear advantage that sites became inter-comparable and enabled the highlighting of similarities as well as differences between sites.

Existing models have been innovated and extended to enable Environmental Impact Analyses for different JECAM sites. Innovated models were tested with different datasets and applied at JECAM sites. A summary of the innovation is given in this report, while a separate report describes the process descriptions, technical details and user's instructions of the innovated models.

During the execution of this work package, participants have been familiarized with existing and innovated models. The training provided the participants with the required background

information on the simulation of water and nutrients in the soil. It provided them also with hands-on experiences in operating simulation models which is helpful when continuing this work in their home countries.

Once the innovated tools were implemented and tested, training was provided to start running applications for JECAM sites. It was decided to focus on JECAM sites where innovations could be tested and implemented thus leading to new insights in environmental issues. The Argentina and Russian JECAM sites were such cases.

The Local Environmental Impact Assessment (EiA) in Argentina was based on items discussed during the development of the protocols and the training sessions held in previous workshops. Based on several modelling exercises these findings can be summarized as follows:

- Timing of planting and fertilizer applications are important issues for environmental impacts such as leaching losses to groundwater;
- Rising groundwater in regions with vulnerable aquifers that contains salts may limit future agricultural production;
- Comparison of no-tillage for soybean and for crop rotations did not support the original idea of soil degradation as an important environmental issue for soybean production. Not all aspects could be analysed and further analyses are required;
- Optimize management : crop rotations may dampen risks emerging from meteorological variation, but may increase risk of leaching of nitrogen when compared to monoculture of soybean;
- Analysis and monitoring of the environmental impacts of land use practices and crop rotation impacts is facilitated by a combination of remote sensing and applying process oriented simulation models.

Similar the SRI JECAM site was another case where an EiA was carried out. Major findings were:

- Moderate resolution remote sensing data are proven to be helpful in environmental problems assessment in Stavropol region;
- Arable land area and winter crop area both experience substantial increase throughout last decade at rayon and krai levels, inducing both positive and negative changes in farmer's agricultural practices;
- Major land use changes occur in the eastern part of Stavropol SRIA JECAM site, while crop rotation intensification occurs in central parts;

- Regression models linking EO-based indicators related to yield and crop acreage is shown to be significant enough to explain most of the yield decrease by ineffective management such as crops area increase with no significant support through fertilisers and herbicides.

A procedure for upscaling was developed, tested and successfully applied in the form of a metamodel focusing on leaching of nitrate (Nitrate Leaching Transfer Function).

About seven International presentations were held, highlighting the promising results of this work package.

In the future outlook promising items are identified which need to be addressed in future work on this item. Agreement was achieved with leaders of other Work Packages about training (WP4), upscaling (WP5) and dissemination (WP6) of results.

1. General introduction

Objectives

This work package (WP5.1) has a focus on local and regional environmental impact analysis. Agricultural areas will need to significantly extend and intensify agricultural production to meet food demand. This will have strong environmental effects of which the impact will be analyzed during this WP with the following objectives:

- To apply environmental models at the local scale of JECAM sites and compare model results with remote sensing results (WP3)
- At representative local (JECAM) sites within the Global Agro-Environmental Stratification (WP3.1), analyses will be carried out after impact of land use and management changes on soil hydrology, groundwater recharge, leaching of nitrates and crop growth.
- To quantify stress factors of the yield gap analyses (WP4.3)
- To upscale results from analyses at JECAM sites to regional and global analyses (WP5.2 and WP5.3)

Tasks

At the local scale this WP will examine the link and feedback between on the one hand crop growth and agro-management, and on the other hand soil hydrology, groundwater recharge and leaching of nitrates. This WP will produce relations between land use changes and nitrate leaching that can be applied at the regional and global scale (WP 5.2 and WP 5.3). This WP will start with the development of a protocol to carry out analyses at local (JECAM) and regional scales (Task 5.1.1.) and then continue with the local JECAM site analyses (Task 5.1.2):

- Task 5.1.1: Develop protocols for Environmental Impact Analyses
  Leader: Steffen Fritz (IIASA); Deputy Leader: Joop Kroes (Alterra)
  Partners: Alterra, INTA, RADI, SRI NASU-NSAU
- Task 5.1.2: Environmental impact analyses of land use and management changes at JECAM/Study sites
  Leader: Joop Kroes (Alterra); Deputy Leader: Steffen Fritz (IIASA)
  Partners: INTA, IKI RAN, RADI, SRI NASU-NSAU,

Table 1: Partners involved in WP5.1

Partner (nr)	Key contact persons	Contact details
DLO	Joop Kroes Piet Groenendijk	joop.kroes@wur.nl piet.groenendijk@wur.nl
IIASA	Steffen Fritz	fritz@iiasa.ac.at
IKI RAN	Sergey Bartalev	bartalev@d902.iki.rssi.ru
INTA	Santiago Veron Diego de Abelleyra	veron.santiago@inta.gob.ar deabelleyra.diego@inta.gob.ar
RADI	Wu Bingfang	wubf@radi.ac.cn
SRI NASU-NSAU	Nataliia Kussul	nataliia.kussul@gmail.com

2. Task 1: Develop protocols for Environmental Impact Analyses

2.1. Introduction

2.1.1. Protocol Framework: general concept

Activities within WP5 imply modelling exercises with a large variation in environmental issues, spatial and temporal scales and data availability. The linkages to other spatial scales and the synthesis of results require a well-structured approach for conducting modelling studies.

For WP5.1 we suggest to adopt the general methodology for multidisciplinary model based research in the field of water management. The FP5-HarmoniQua project has delivered a strategy and tools for quality assurance. One of the key principles is to distinguish some phases and to describe the activities a priori to performing the modelling tasks (Figure 1). Based on the deliverables of FP5-HarmoniQua, we propose to describe a step-wise approach of the modelling process for each WP5.1 pilot areas (JECAM sites):

- Model study plan
- Data and conceptualization
- Model setup
- Calibration and validation
- Simulation
- Evaluation and Dissemination

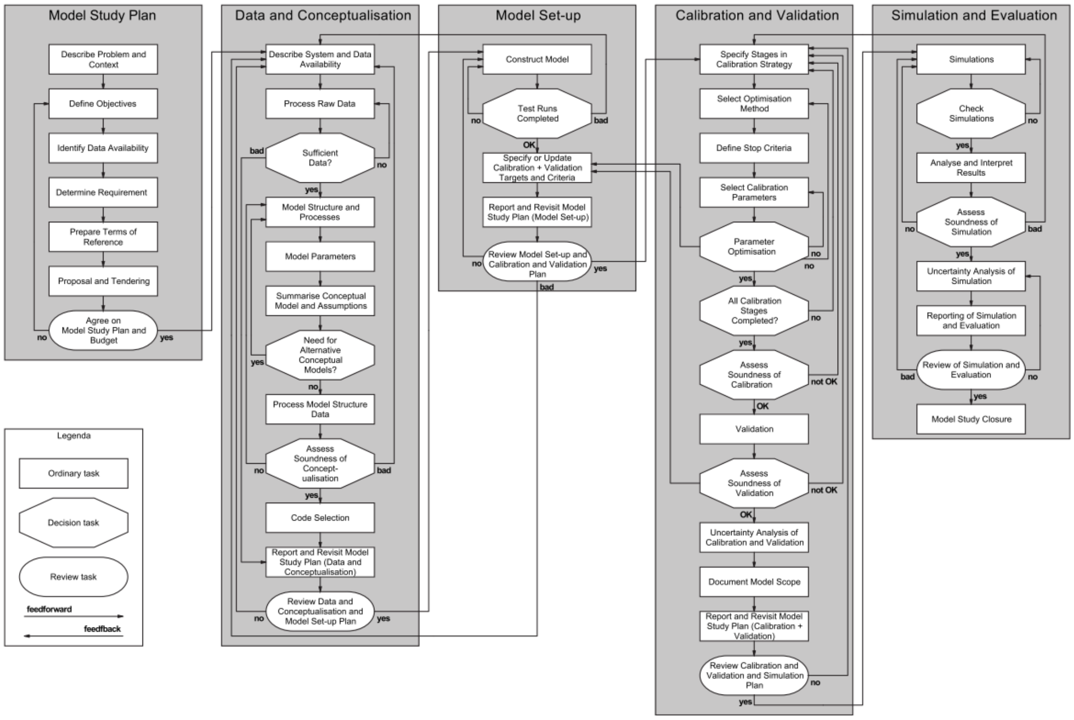


Figure 1: Steps and tasks of the modelling process (figure taken from Scholten et al., 2007)

During this initial phase protocols are worked out for Environmental Impact Analyses at different scales (local, regional and global scale). This protocol will include:

- Definition of JECAM site responsibilities
- Definition of inputs and outputs and selection of algorithms
- Fine tuning of protocols to availability of data at JECAM sites and regions
- Define downscaling and upscaling procedures
- Define training activities
- Define a task group to maintain quality control throughout all tasks of this WP. This task group may adjust protocols.
- Define (representative) local JECAM sites within the Global Agro-Environmental Stratification (WP3.1). These sites will be analysed within WP 5.1.2.

Proposed representative local JECAM sites to be studied in detail with an Environmental Impact Analysis are:

- Europe:
    - Russia
    - Ukraine
- South America:
    - Argentina
- Asia:
    - China: Shandong

An additional JECAM site in The Netherlands (Flevopolder) has been under construction and might be added in a later stage.

The task group responsible for quality control of all tasks of this WP and which may adjust protocols consists of:
- Steffen Fritz (IIASA
- Joop Kroes (Alterra)
- Diego de Abelleyra (INTA)
- Wu Bingfang (RADI)
- Nataliia Kussul (SRI NASU-NSAU)

This task group had skype sessions as often as required for quality control.

The partners involved in this WP have been contacted via email regarding the protocols suggested for Environmental Impact Analysis of the selected JECAM sites.

A mobile app has been developed by IIASA for WP3 and may be used to collect in-situ data as required for the SIGMA project, potentially of value to GLOBIOM and other crop modelling activities.

2.1.2. Example of a Protocol for Flevopolder potential JECAM site

This paragraph gives tables to apply the general concept of the protocol given in paragraph 2.1.1. The tables are given in annex A and filled in using the Flevopolder potential JECAM site in The Netherlands as an example.
One table (table 1) defines Model study plan conceptualization and setup. It summarizes the intentions for model calibration, validation, evaluation and dissemination or results.

Other tables (Tables 2 and 3) summarize available data and possible use of remote sensing data for environmental impact analyses. Doubling of information should be avoided and reference is made to other overviews and tables generated or used in other WP's of SIGMA.
The final protocols that resulted from interactive sessions with participants, are given in Annexes B-E.

2.2. Results

2.2.1. Introduction

At representative local JECAM sites within the Global Agro-Environmental Stratification (WP3.1), Environmental impact Analyses (EiA) will be carried out of local land use and management changes on soil hydrology, groundwater recharge, leaching of nitrates and crop growth. The analyses will quantify:

- Biophysical stresses on the conditions of yields;
- Changes of groundwater recharge under different land use and management strategies
- The impact of agro-management on nitrate leaching to the environment

Observation-gaps will be filled using local expertise and knowledge. The work will be carried using state of the art versions of models Swap, Animo and Wofost for respectively soil hydrology, nitrogen and crop growth. If local conditions require, other models may be applied following an open source philosophy. Training activities will be organized to support model use.

The integrated approach will be beneficiary for analysis of yield gaps (WP4.3, yield gap analyses). Probability density functions will be used to analyse extremes. Metamodels will be derived to allow upscaling to close the yield gap and support water and nutrient limited yield estimates. A comparison will be made with results from empirical models applied at selected JECAM sites.

This task will not begin until all partners have agreed what their role is for the JECAM sites and the protocols have been agreed and filled out.

Table 2: Responsibilities and activities per partner

Partner	Responsibilities and activities
DLO	Leader, oordinator and support partners New JECAM site Flevopolder
IIASA	Deputy leader, support
INTA	JECAM siteINTA San Antonio
IKI RAN	JECAM site IKI-RAN SRIA
RADI	JECAM site- RADI Shandong Yucheng
SRI NASU-NSAU	JECAM site SRI-NASU-NSAU

Specification of activities of partners is given in the next paragraphs.

Relevant additional info about JECAM site in Study is given. General information about JECAM sites is given in “Study and JECAM sites Fact Sheets - DoW.pdf” (version20131216)

2.2.2. JECAM site INTA San Antonio

General Description:

On one hand the area sown with soybeans in the Pampas has been increasing at an unprecedented rate which has altered the once typical agriculture/pasture rotation to one of continuous agriculture dominated by soybeans. On the other hand, genetic and technological improvements together with new management practices and tax policies are opening the door to inclusion of new crops (e.g. beans) or typical crops but managed differently (e.g. second season maize). We lack an adequate knowledge of the impacts these changes may have on the environment. Base information like crop type maps generated yearly are also scarce and need to be generated to perform such analysis. We defined two environmental problems to analyse: 1) land degradation associated to monoculture and 2) changes in the energy budget due to new crop management practices.

1. Land degradation associated to monoculture

This task consists on the generation of base information (crop type, crop rotation and yield maps) for the analysis of the environmental impact that soybean monoculture could generate. Recent ground truth measurements will be used for training and validation of yearly crop type maps that allow the generation of crop rotation maps. Yield estimations will be performed from Earth Observation (EO) sources and meteorological data. Satellite derived yield will be evaluated vs. crop simulation models yield over different crop rotation scenarios. Analysis relating the degree of soybean monoculture and estimated biomass and yield will be performed.

2. Changes in the energy budget

Crop identity together with crop management practices –in particular those that modify crop phenology- can affect the surface water and energy balance. Changes in the moment and duration of the explosion of vegetated vs bare soil surfaces can alter the surface albedo, the longwave radiation budget, and the partitioning of net radiation into sensible and latent heat fluxes with important regional climate consequences. Thus, knowledge of how new management practices may alter fluxes of water and energy can help us improve our abilities to anticipate changes in the Pampas climate.

2.2.3. JECAM site IKI-RAN SRIA

General Description:

During last decades local farmers of Stavropol region were modifying crop rotation technique to maximize their income. Winter crops (mainly wheat, but barley and rapeseed is also present) fields provide high quality grain of high market demand. Thus, winter wheat area in the region was subjected to a gradual increase. Due to peculiarities of local crop rotation technique (80% of arable area has 2-annual cycle of winter crop – clean fallow) this intensification may cause soil degradation, lack of soil moisture, spread of pests and weeds and eventual crop yield decrease.

Though hundreds of thousands ha of cropland were abandoned in 1990-s due to substantial agricultural sector decrease, these areas are being intensively returned to arable lands nowadays. Overall cropland area expansion is up to 15-20% during last 10 years touching mainly eastern part of the region and being major relevant impact on the environment.

Objective

The objective is to quantify the impacts of crop rotation intensification on crop yield. In order to do so data are available on:

- Produced by IKI MODIS-based crop type maps for several crop types
- Crop calendar for specific fields (crop is winter wheat)
- Ground data: LAI, soil chemical composition
- In-situ measured yield information at specific fields
- Regional soil map
- Crop statistical data on yields and sown areas

2.2.4. JECAM site RADI Shandong

General Description:

Location of the site: Top-Left: Latitude: 37.331°N Longitude: 116.319°E. Bottom-Right: Latitude: 36.331°N Longitude: 116.819°E

Typical field size is 2000 - 8000 m^2. Crop types are winter wheat, corn, cotton, vegetables, etc. Typical crop rotation is winter wheat and corn. The crop calendar for winter wheat is early October – end of May of the next year, and for corn is middle of June – end of September. The climatic zone is temperate, semi-arid, monsoon climate. The annual mean temperature is about 13.1℃. The annual mean precipitation is about 582 mm, concentrated from late June to September. The soil texture is calcaric fluvisols (Hou et al., 2011). The landscape topology is plains. The soil drainage class is unknown. The irrigation infrastructure is well drained aqueducts.

Environmental issues:

- Shangdong: Cropping pattern is changing from previous major crops to cash crops, which needs more fertilizer and pesticides, on top of this, cash crops are planted all year around with green houses. The green house's impact to environment is quite significant, but the scale not well known.

Data availability-In situ data:

We carried out six field experiments during April to September every year since 2009 and acquired some valuable in situ data including canopy structure variables (crop height, crop density, etc), leaf area index, fractional of absorbed photo-synthetically active radiation (FAPAR), chlorophyll content of crop leaf, biomass and yield of winter wheat and corn and etc. We also acquired crop distribution map twice a year for different cropping season.

Field experiments were carried out synchronous with some satellite through the study site in 2014. Collection of observed variables continued from 2014 onward with measurements of air temperature, land surface temperature, soil water content, leaf water content and nitrogen content of crop canopy.

*Data availability – ancillary***:**

Land-use and land-cover map of year 2000, 2005, and 2010 at 30m resolution derived from Landsat TM, and China Environmental Satellite (HJ-1) CCD images were used.

Data from the meteorological station including temperature, sunshine time, wind speed, precipitation and etc in the site were also collected and used.

2.2.5. JECAM site SRI-NASU-NSAU Kyiv

General Description:
Prediction of land use change on soil fertility and degradation
Studying relationship between nitrogen and soil degradation

Select data sets for calibration and data sets for validation (e.g. through cross-validation).
Objective function: optimization of prediction performance of evapotranspiration and crop yields
Performance indicators:

- at field scale: coefficient of determination, RMSE, Mean Absolute Error (MAE)
- at regional scale: coefficient of determination, RSME

2.3. Summary

A structured analyses of local environmental issues at each JECAM site proved to be instrumental in defining a logical and workable work sequence for each site. In addition, the definition and use of a protocol increases transparency and reproducibility of the work process. As such this contributes to the quality assurance of the results obtained.

By following this approach for each JECAM site it reveals which data are available and which data are still missing and therefore still need collection. Following the same protocol for each JECAM site has also the clear advantage that sites become inter-comparable thereby highlighting the similarities as well as differences between sites.

3. Task 2: Environmental impact analyses of land use and management changes at JECAM sites

3.1. Introduction

At representative local JECAM sites within the Global Agro-Environmental Stratification (WP3.1), environmental impact analyses were carried out of local land use and management changes on soil hydrology, groundwater recharge, leaching of nitrates and crop growth. The analyses aimed to quantify:

- Biophysical stresses on yield conditions;
- Changes of groundwater recharge under different land use and management strategies
- The impact of agro-management on nitrate leaching to the environment

Observation-gaps had to be filled using local expertise and knowledge.

The activities were carried using state of the art versions of models Swap, modules of the Animo model and Wofost for respectively soil hydrology, nitrogen and crop growth (Van Dam et al., 2008; Rijtema et al., 1999; Boogaard et al., 1998; websites_WUR-Alterra). If local conditions required, other models were applied. Training activities were organized to support model use. The integrated approach was beneficiary for analysis of yield gaps (WP4.3, yield gap analyses). Probability density functions were used to analyse extremes. Metamodels were derived to allow upscaling to close the yield gap and support water and nutrient limited yield estimates (Heuvelmans, 2010). A comparison was be made with results from empirical models applied at selected JECAM sites.

3.2. Tailor made programming for JECAM sites

3.2.1. Introduction

The development of the protocols made clarified the need for the development of tailor made tools to allow environmental impact analyses of land use and management changes at JECAM sites. The original proposal to apply a combination of detailed process-oriented models like Swap-Animo-Wofost was considered as too complex and too demanding of input requirements.

It was therefore decided to develop innovative simplified model-tools. Available tools were simplified and combined in an innovative way and made suitable for applications at the JECAM sites. Important issues in this respect was the integration of soil hydrology and crop growth modeling with an customized version of the ROTH-C model for mineralisation and organic matter degradation in soil and the leaching of nitrate. More detail is given in a separate report (Groenendijk et al., 2016); first results of applications are decribed (par. 3.4) and more will follow as given in the future outlook (par. 4.2). This chapter provides a summary of the innovations that were introduced.

3.2.2. Model Innovation

In the past 40 years, a series of simulation models was developed and applied for simulation of crop growth dependent on water and nutrient availability. Most models are suitable for the climatic zone and soil conditions for which the data that are used for parameter population and validation have been collected. The model structure is usually tailored to the specific area of interest of the developers. Model developers with botanical and agronomic background describe the crop development usually in detail and approach soil water flow with less detail. On the other hand, modellers with a soil science background treat the crop development in a simple way and pay more attention to the description of the organic matter cycle and mineralization processes. We believe that for the description of water and nitrogen limitation of crop growth a detailed description of the soil water flow and crop development is a prerequisite and the nitrogen availability in the soil should be addressed by taking account of to the organic matter cycle and the dynamics of nitrogen mineralisation.

The computational sequence and information exchange between modules implemented in the innovated model is depicted in the figure 2.

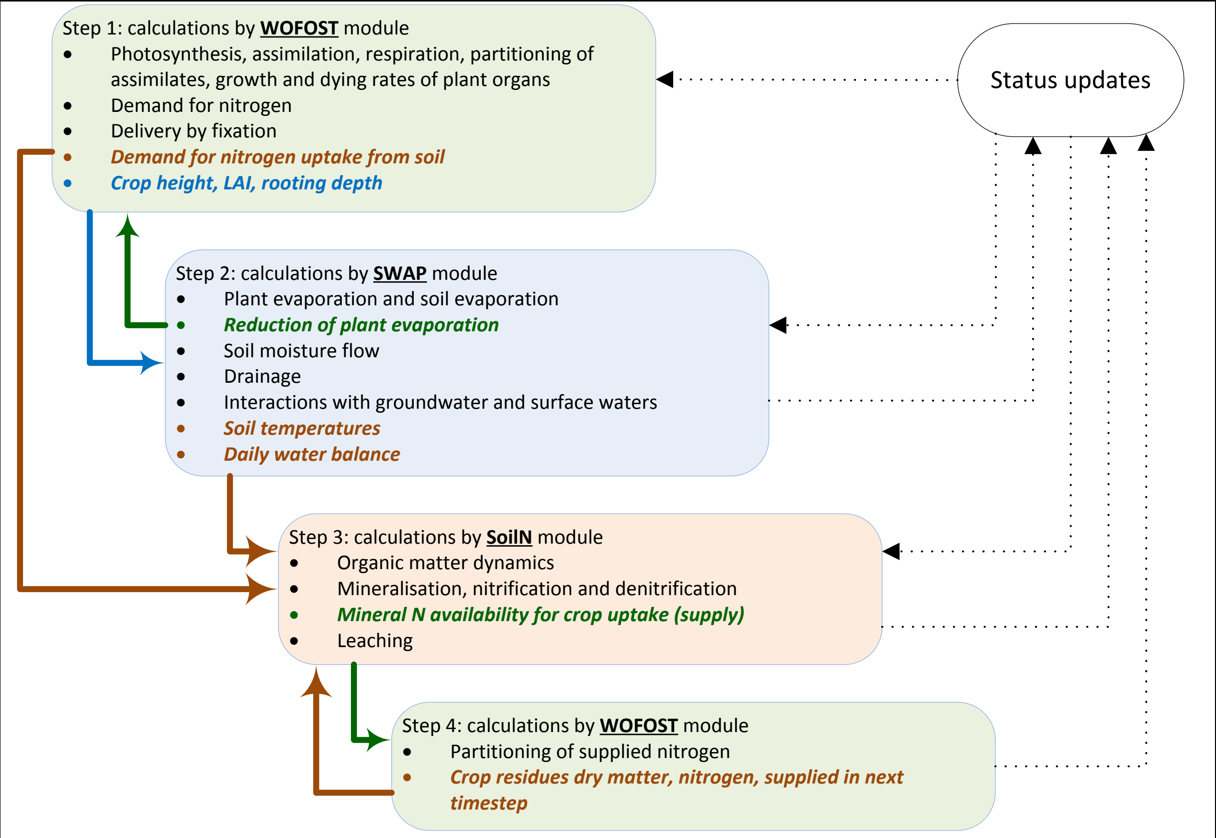


Figure 2: *Computational sequence and information exchange between modules implemented in the innovated model*

The SWAP / WOFOST model was already equipped to dynamically simulate the impact of soil moisture on crop production. The development of a soil nitrogen module, incorporated in the SWAP / WOFOST model, the interdependencies between crop growth, moisture and nitrogen processes can be unravelled. The new model was calibrated and tested for field data of fertilizer application trials in Maarheze in the Southern sand district of the Netherlands and the Waiboerhoeve in the recently reclaimed Flevopolder in the centre of the Netherlands.

Within the SIGMA project Environmental impacts of land use changes on groundwater and soil nitrogen were analysed for several sites from the global Joint Experiment for Crop Assessment and Monitoring (JECAM) network (www.jecam.org). Selected JECAM sites in Argentina and China are used to test the implementation. Examples of results are given by Groenendijk et al., 2016).

A newly developed soil nitrogen module interacts by exchanging information with the soil water model SWAP (Van Dam et al., 2008; Kroes et al., 2009) and the crop growth model WOFOST (Van Diepen et al.,1989; Supit et al., 1994; Boogaard et al., 1998, Boogaard et al., 2013) on a daily basis.

The RothC-26.3 model (Coleman & Jenkinson, 1997) has been taken as the starting point for the development of an organic matter module within WOFOST. The RothC-26.3 is widely used, is relatively simple to apply and has the flexibility to address different types of soils and crops.
The N balance of the soil in a mutual relation with organic matter cycle. Nitrogen supplied to the soil by fertilizer applications and by mineralization of organic bounded nitrogen is stored in the soil. Mineralization rates of NH_4 and NO_3 control the nitrogen mineralization and immobilization in relation to the processes in the organic matter cycle (Figure 3).

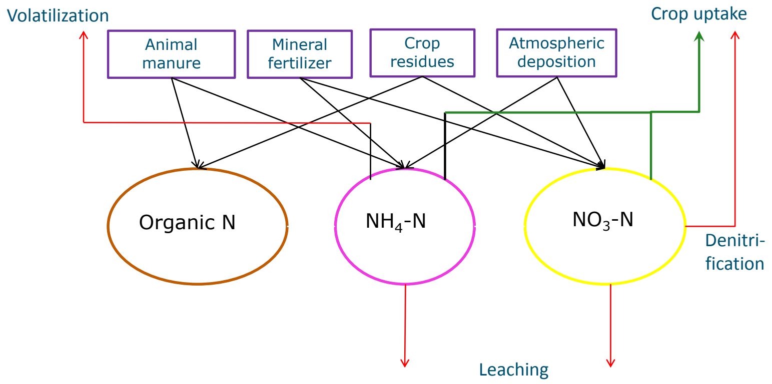


Figure 3: Schematic representation of the nitrogen pools, transformations and transport described in the SoilN module

Ammonium and nitrate balance are calculated calculated on a daily basis. The leaching of nitrate and ammonium is controlled by the stoch of mineral N present and the water fluxes leaching through the root zone .
The nitrogen distribution within a crop is, implemented in SWAP-WOFOST based on Shibu et al. (2010). The N-contents of crop residues are calculated by the WOFOST model and are passed to the SoilN module.

The description of nitrogen fixation was based on a simple approach, assuming that N_2 fixation from the air is potentially unlimited. The crop defines the demand for nitrogen and a user defined fraction indicates the amount of Nitrogen demand which met by N-fixation from air and soil. This allowed simulations for soybean in the Argentina JECAM site. For the Argentinian Pampas region Di Ciocco et al. (2011) reported from several studies that the N-fixation accounted for 20 to 55% of the plant-N. Collino et al. (2015) determined N-fixation in the northern half of Argentina. The percentage of N by N-fixation in the above-ground part of soybean was on average 60% (interquartile range 46-71%), which makes N-fixation an important part of the nitrogen cycle. An improved submodel for phenological in soybean in WOFOST was implemented based on phenological stages as described by Setiyono et al., 2007.

To improve simulations of winter wheat in several JECAM sites the phenological development is implemented, analogue to De Wit (2016), using three factors to influence the phenological development: temperature, photoperiod and vernalisation. The approach for vernalisation is based on the model concept from Wang and Engel (1998) as Van Bussel (2011) demonstrated the suitability of this approach for the phenological model in Wofost.
Crop growth and the corresponding N-demand are already limited by drought, which is simulated using the detailed hydrology from the Swap-model.

The increasing atmospheric CO_2 concentrations can be accounted for using the same method as Supit et al. (2012).

The innovated SWAP/WOFOST model, extended by the SoilN module and descriptions for soybean development, enables the evaluation of the impacts of land use and land management on environmental factors. A number of management actions can be imposed by specification of parameters in the model's input files:

- Apllication rates and timing of organic manure and other organic materials (e.q. compost, sewage sludge, ..);
- Application rates and timing of inorganic fertilizer;
- Management of above ground crop residues (remove or stay on the field);
- Crop rotations;
- Irrigation;
- Drainage.

Impacts of climate change on the crop production potential and some key indictors for soil quality (organic matter content, water holding capacity, …) can be analyzed by the innovated model since it accounts for different feedbacks between atmosphere, plants, soil characteristics, soil water and nitrogen limited crop growth.

3.3. Training activities

The project included a clear training component which is highlighted in this section.

3.3.1. Training courses

Introduction
SIGMA's main challenge is to develop innovative methods and indicators to monitor and assess progress towards "sustainable agriculture", focussed on the assessment of longer term impact of agricultural dynamics on the environment and vice versa, in support of GEOGLAM.

In this contex, on 18 and 19 September 2014 a workshop was organised in Wageningen. During this workshop the focus was on Environmental Impact Assessments. Expected output was a common understanding of project activities matching the main competences of each of the site partners'. An important starting point of this part of the workshop and training were the draft work plans and protocols.

18 September 2014
An introduction was given with an overview of WP5.1, its relation with other WorkPackages and a brief discussion about deliverables and planning. The remaining part of the afternoon was used to introduce modelling of soil water flow using the physically based concept of the model SWAP (www.swap.alterra.nl). Theory and practical exercises exchanged each other.

19 September 2014
This day started with short presentations from the participants about dominant environmental issues in the region/country of each participant.
Presentations were given about solute leaching, organic matter and soil nitrogen. Exercises were carried out by participants using meteorological data from the different JECAM sites. This was followed by a presentation about meta-modelling to support regional impact studies.
The day ended with a plenary discussion about deliverables, protocols and communication appointments. The activities within different JECAM were clarified. NL and BE will also participate within WP5.1 using local JECAM sites

Actions:

- Participants (INTA, IKI RAN, RADI, SRI, VITO, NL) adjusted their protocol with special attention on study plan (problem, objectives).

- DLO (Joop Kroes) merged protocols into an updated version of the Workplan for WP5.1.

3.3.2. Operationalising protocols using local JECAM data sets

A short guide was written to support the modelling activities within SIGMA project Workpackage 5.1. This setup is based on several training activities given by Wageningen University and Research Centre.

The central model in the training was SWAP (Kroes et al., 2009; Van Dam et al., 2008). The model simulates transport of water, solutes and heat in the vadose zone in interaction with vegetation development (WOFOST). The model employs the Richards equation including root water extraction to simulate soil moisture movement in variably saturated soils. Concepts are added to account for macroporous flow and water repellency. In case of solute transport, the model considers the processes convection, dispersion, adsorption and decomposition. For more detailed nutrient and pesticide studies, SWAP generates soil water fluxes for detailed chemical transport models such as PEARL for pesticides and ANIMO for nutrients. The model simulates soil heat flow taking into account actual heat capacities and thermal conductivities. SWAP is linked dynamically to the generic crop growth module WOFOST to simulate leaf photosynthesis and crop growth. The soil moisture, heat and solute modules exchange status information each time step to account for all kind of interactions. Crop growth is affected by the actual soil moisture and salinity status on a daily basis. An extensive test protocol ensures the numerical code quality of the hydrological modules.

In the vertical direction the model domain (figure 4) reaches from a plane just above the canopy to a plane in the shallow groundwater. In this zone the transport processes are mainly vertical. Therefore the model is a one-dimensional, vertical directed model. The flow below the groundwater level may include lateral drainage fluxes, provided that these fluxes can be prescribed with analytical drainage formulas. The model is very flexible with regard to input data at the top and bottom of the soil column. At the top in general basic weather data will suffice. For Nordic conditions a simple snow storage module has been implemented. In case of more focussed studies (e.g. runoff or diurnal transpiration fluxes) evapotranspiration and rainfall data should be specified in time intervals less than a day. At the bottom various forms of hydraulic head and flux based conditions are used.

In the horizontal direction, the main focus is the field scale. At this scale most transport processes can be described in a deterministic way, as a field generally can be represented by one microclimate, one vegetation type, one soil type, and one drainage condition. Also many cultivation practices occur at field scale, which means that many management options apply to this scale.

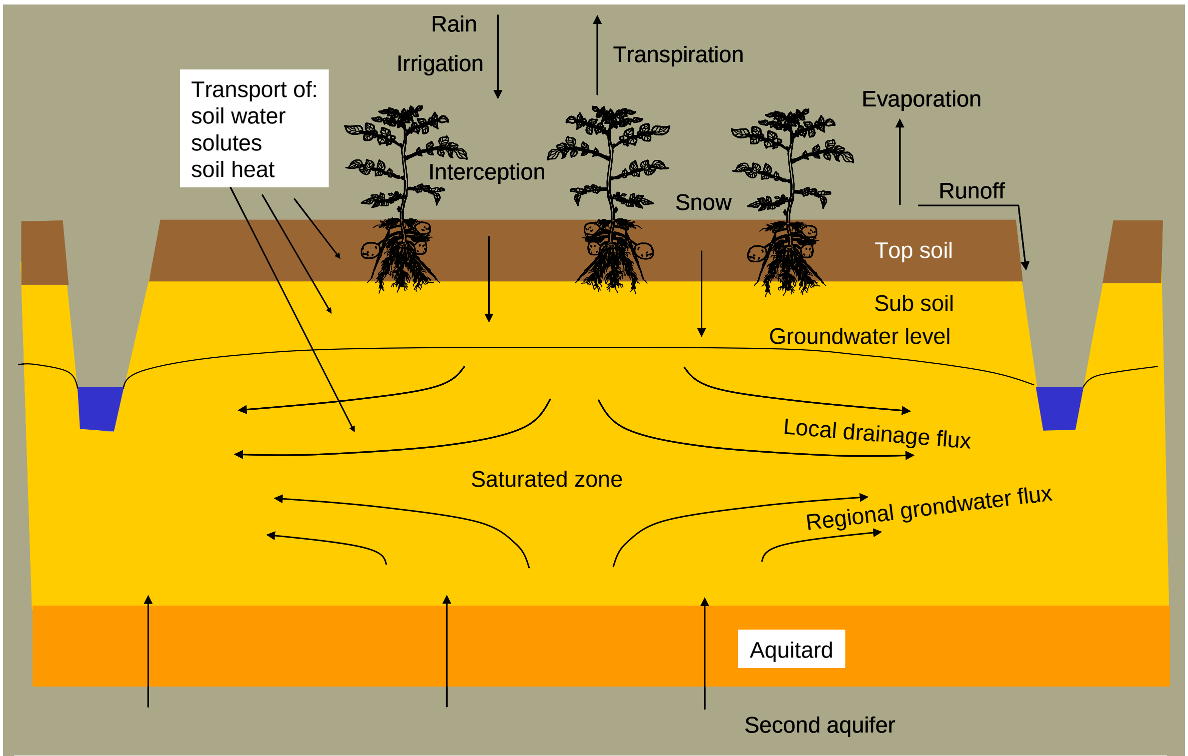


Figure 4: SWAP model domain and transport processes

Scaling up from field to regional scale for broader policy studies is possible with geographical information systems.

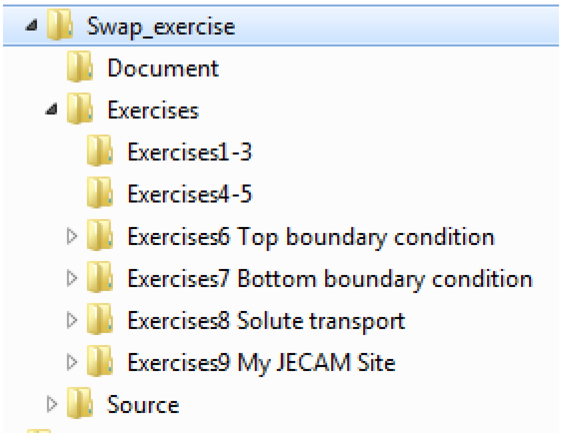
The smallest time steps in SWAP are in the order of seconds for fast transport processes such as intensive rain showers with runoff or flow in cracked clay soils. These time steps are automatically increased in periods with less fluctuating flow conditions.

SWAP is developed and maintained by Alterra and Wageningen University. The model is spread as public domain software, including the source code. The website www.swap.alterra.nl contains detailed information of the model, example input files and the model itself. More detailed information about modelled processes is also given by Moene and Van Dam (2014).

During the training a start is made with a simple exercise: a bare soil with a constant groundwater level. Gradually, complexity is added to the soil transport processes addressing the following topics:

- Field capacity
- Rain event
- Constant evapotranspiration
- Year with static crop
- Year with dynamic WOFOST crop
- Top boundary condition
- Bottom boundary condition
- Solute transport
- My JECAM Site

The figure 5 below shows the folder structure of the exercises. The main folder DOCUMENT contains the SWAP user manual, the handout and the presentations. The main folder SOURCE contains the SWAP computer program.



- Swap_exercise
  - Document
  - Exercises
    - Exercises1-3
    - Exercises4-5
    - Exercises6 Top boundary condition
    - Exercises7 Bottom boundary condition
    - Exercises8 Solute transport
    - Exercises9 My JECAM Site
  - Source

Figure 5: Folder structure of SWAP exercises

The ASCII output files of SWAP can be read by any editor or can be imported in most graphical software.

For the exercises appropriate input files are added on subfolders INITIAL. These files can be copied to the specific work folder by double clicking INITIAL.BAT. In that way these files can always be used as backup for the simulations in the work folder. The exercises will start with a reference run, for which the input and output can be verified.

In exercise 1 meteorological conditions from a JECAM site are used. Two crop files were available: maize and soy bean. Next results need to be presented in a table (table 3).

Table 3: Example table for simulation results for the exercise with MAIZE in 6 JECAM sites

Case	**Transpiration** T_{act} (mm/yr)			**Yield** Y_{act} (kg/ha DM)		
	min	ave	max	min	ave	max
1. meteoSwap_Arg						
2. meteoSwap_Burk						
3. meteoSwap_Chi						
4. meteoSwap_Neth						
5. meteoSwap_Rus						
6. meteoSwap_Ukr						

A similar exercise was carried out for soybean.

An exercise 2 was done using a different soil type. The soil physical parameters are:

ISOILLAY1	ORES	OSAT	ALFA	NPAR	KSAT	LEXP	ALFAW	H_ENPR
1	0.01	0.43	0.0227	1.548	9.65	-0.983	0.0454	0.0
2	0.02	0.38	0.0214	2.075	15.56	0.039	0.0428	0.0

Participants were asked to select another set of soil physical parameters from Wösten et al. (1999), namely a coarse sandy top soil:

1	0.025	0.403	0.0383	1.3774	60.00	1.250	0.0383	0.0

3.3.3. Some results for JECAM sites

Results for exercises 1 and 2 for different JECAM sites were as given in tables 4 and 5.

Table 4: Exercise 1: Simulation results for MAIZE

Case	**Transpiration** T_{act} (mm/yr)			**Yield** Y_{act} (kg/ha DM)		
	min	ave	max	min	ave	max
1. meteoSwap_Arg	85	193	273	233	3101	4820
2. meteoSwap_Burk	159	209	260	2422	3037	4820
3. meteoSwap_Chi	290	359	426	3079	4039	4822
4. meteoSwap_Neth	213	277	348	8522	9893	11106
5. meteoSwap_Rus	345	440	504	5100	7112	8768
6. meteoSwap_Ukr	282	357	431	5540	7837	10672

Table 5: Exercise 2: Simulation results for different soil type

Case		**Transpiration T_{act} (mm/yr)**			**Yield Y_{act} (kg/ha DM)**		
		min	ave	max	min	ave	max
1.	meteoSwap_Arg	84	190	271	227	2972	4756
2.	meteoSwap_Burk	157	205	242	2244	2979	4820
3.	meteoSwap_Chi	280	330	381	2610	3732	4756
4.	meteoSwap_Neth	213	276	347	8516	9831	11073
5.	meteoSwap_Rus	341	419	474	4156	6531	8756
6.	meteoSwap_Ukr	282	355	419	5514	7745	10633

The resulting values of the different exercises were meant to illustrate possible differences. The absolute values should not be considered because the required data have not been tested and verified by participants. Results were for discussion and to get insight into processes

The training provided the participants with the required background information on the simulation of water and nutrients in the soil. It provided them also with hands-on experiences in operating simulation models which is helpful when continuing this work in their home countries.

The Table of Content of the manual developed and applied during the training sessions is added as Annex F to this document.

3.4. Local JECAM site specific EiA

3.4.1. Introduction

Once the innovated tools were implemented, tested and training was carried out the applications at JECAM sites started. At first all JECAM were to be analysed with an Environmental Impact Assessment (EiA), but it soon became clear that this was not feasible given the limited time that remained for in debt analyses. It was therefore decided to give focus to JECAM sites where innovations could be tested and implemented and lead to new insights in environmental issues. The Argentina JECAM site was such a case. An intensive workshop was held in September 2016 of which the findings are given in paragraph 3.4.2.
Another EiA was applied for the Russian JECAM site SRIA and results are given in paragraph 3.4.3.

3.4.2. EiA for San Antonio JECAM site in Argentina

The Local Environmental Impact Assessment (EiA) in Argentina was based on items discussed during the development of the protocols and the training sessions held in previous workshops.
It was decided to give the EiA-workshop the following objectives:

- Data-collection and analyses (meteo-SQL-database, soil-data)
- Modelling for soy bean, first dry matter, then protein, including N-fixation and N-distribution in soil and crop.
- Modelling for 6 locations in Argentina
- Modelling for maize and wheat
- Modelling crop rotations for 6 locations in Argentina

3.4.2.1. Data-collection and analysis

Meteorological data for modelling were collected from INTA and update with missing data from sources collected by Alterra for the period 1994-2013 for 6 selected sites (STAC-database).

Soil data were collected local and it was decided to use the dominant series of cartographic unit for the 6 selected sites from the national soil database. Model parameters for Zavalla and San Antonio Areco were entered into files. A note was prepared for input of soil schematisation, soil organic matter and soil nitrogen using the San Antonio Areco case as example Annex G.

A field visit was made to the Zavalla – Rosario (UNR) where discussion with local experts resulted in a list of options for quality reduction of soy bean:

i) Soil compaction; some simulations will be interesting. A data set is available and will will be received from Jose Rotundo
ii) Changes in Rooting pattern (related to i)
iii) Changes in soil water balance (increasing surface runoff), related to (i)
iv) Soil degradation : soil organic matter, soil nitrogen, soil phosphorus, Micro-nutrients (Zn, ..): soil P may be deficit in some soils; micro-nutrients seem no problem
v) Pest and diseases: no problem, enough control
vi) Changes in climate : precipitation, temperature : should be analysed
vii) Changes in microbiological activity and its impact on rhizobium and N-fixation
viii) Introduction of new genotypes which produce high yields but have a relative low N-content
ix) Early sowing date results in high yield and low protein
x) Saline groundwater reaching root zone by capillary rise and occasional rising of groundwater levels

An additional analysis was carried out for groundwater levels and quality as a possible cause of stress in soy bean growth

The area of Rosario and Buenos Aires are part of basin “Rio De La Plata” with the Paraná River as its largest tributary (figure 6). The basin serves as the recharge zone for the Guarani Aquifer, one of the world's largest aquifer systems. Much silt is discharged into the Río de la Plata each year, where the muddy waters are stirred up by winds and tides; the shipping route from the Atlantic to Buenos Aires is kept open by continual dredging.

Two rivers with the same name are relevant for this area : Salado river (also called Salado del Sur) which flows below Buenos Aires into the Ocean and the Salado river which flows into the Parana river near Santa Fé (figure 6).

The 6 selected sites are located in the provinces of Buenos Aires, Cordoba and Santa Fe (figure 7).

Information from different federal institutes has been integrated in one national geographical information system: Sistema Federal de Aguas Subterráneas, SIFAS (http://pag-ar00.minplan.gov.ar/Mapa_SIFAS/ ; IGRAC, 2013). SIFAS is now fully operational as Argentina's national groundwater monitoring network and federal institutes upload data to the national system. It seems likely that in many areas “the bottom of the semiconfined aquifer layer is in direct contact with saturated sediments of marine origin that are saline. Therefore, if in the withdrawal area, extraction exceeds the horizontal inflow and the downward vertical recharge, the flow will be offset by the inflow of water from the lower levels of higher salinity” (Perez et al., 2015). The name of the 2 major rivers in the area “Salado” (English : salty) seem to confirm this salinity risk.

Analyses with the SwapWofost model confirm at least the possibility of leaching of solutes like nitrate.

The water contribution from a water table located approximately 1.5 to 2 m deep can represent up to 30% of the water requirements of soybeans in environments representative of the flooding sandy pampas, thus stabilizing the inter-annual variability of grain yield (Videla Mensegue et al., 2015).

In the Pampeana region, more than 6 million hectares are subject to the influence of a water table that oscillates at depths reached by the roots of the plants (Martini and Baigorri, 2002).

Sainato et al. (2003) reported salinity values for the region around Pergamino: “The Pampeano aquifer shows an increase in water salinity to the west; the dry residue is 800 mg l^{-1} at Arrecifes and 1000 mg l^{-1} at Pergamino. The water type is bicarbonate sodium. The salinity of this section increases at the flooding plains and toward the beds (discharge zones)”.

Some other relevant studies about the groundwater in the pampas of Argentina are Aragon et al. (2010), Kupper et al. (2015, Mercau et al. (2016), Nosetto et al. (2013), Vazquez-Amabile et al. (2013). Viglizzo et al. (2009)

It goes beyond the scope of this SIGMA project to analyse groundwater in more detail, but the risk should be mentioned and it is recommended to analyses this in greater detail, preferably using local and regional observations about levels and quality of groundwater.

Figure 6: The basin Rio de la Plata (en.wikipedia.org/wiki/Rio_de_la_Plata_Basin)

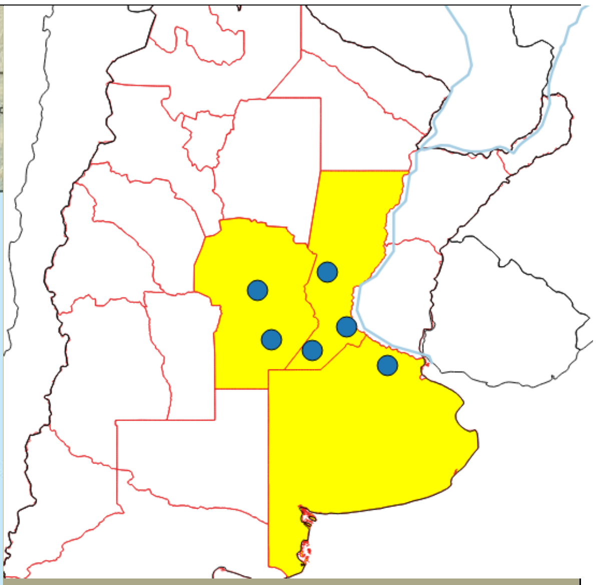


Figure 7: The 6 selected sites (blue) and 3 provinces (yellow): Buenos Aires, Cordoba and Santa Fe.

3.4.2.2. Modelling soybean dry matter, N-content and protein, incl N-fixation

Analyses of input parameters for Zavalla and San Antonio using local knowledge resulted in adjusted soil hydrologic modelling:

- bottom boundary was changed from free drainage (swbotb=7) to a bottom flux from hydraulic head of deep aquifer (swbotb=3). Depth of the hydraulic head was assumed to be at 5 m; the value for depth was based on local info (UNR).
- lateral drainage was introduced with only discharge (no infiltration) to a system at a distance of 500 m, with a surface water level at 3 meter and a high resistance of 500 days.
- maximum rooting depth (RDS) was increased from 1 to 2 meter.

The Zavalla35e field was used to calibrate soybean using field observations in 2013. Next a long term simulation (1990-2013) was carried out using meteo data from an updated database and from a local meteostation. Resulting yields (figure 8) showed a good agreement between both datasets. The yields show a mean bias error of 5 k/ha DM (<1%) between simulations with the 2 different meteo data sets.

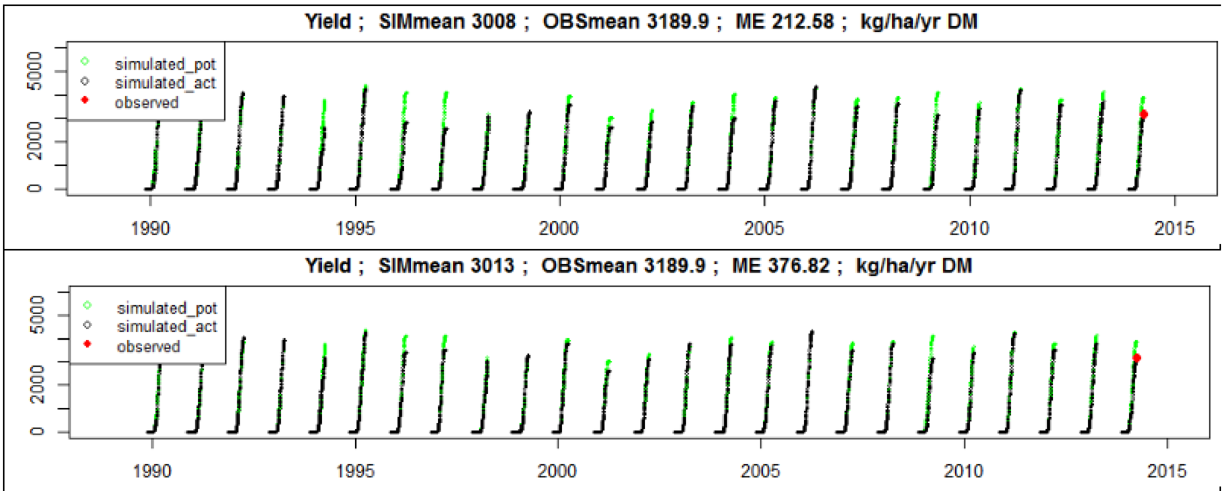


Figure 8: Simulated soybean yield (kg/ha/year DM) using meteo data from the updated database (top) and data from a local meteo station (bottom) for field 35e at the Zavalla experimental station

Results for N-uptake and N-content of the soybean crop in Zavalla are given in figure 9.

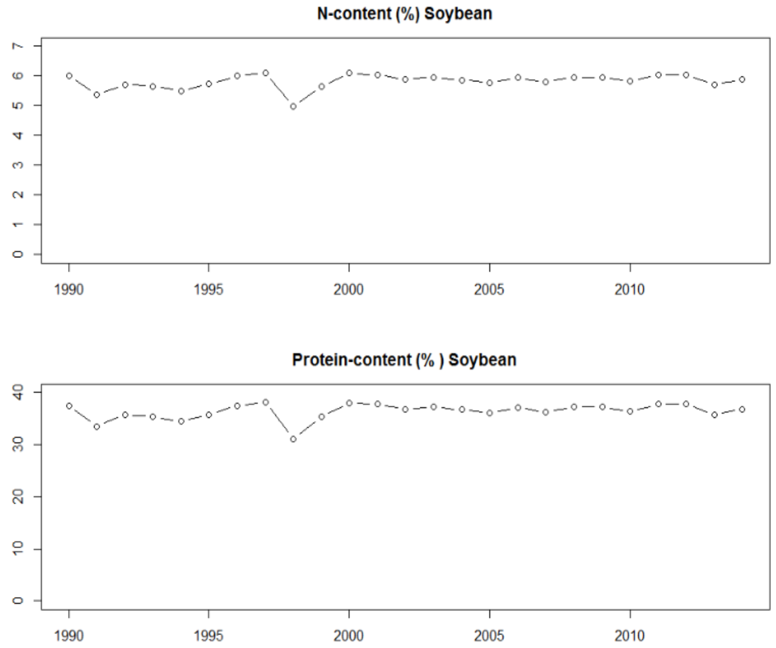


Figure 9: Simulated soy bean N-content (kg/ha/year N) (top figure) and Protein content (%) (bottom figure) using meteo data the updated database for field 35e at the Zavalla experimental station

3.4.2.3. Modelling soybean at 6 different locations

Next a simulation was carried out for 25 continuous years of soybean at 6 different locations (the selected sites, see figure 7). One single soy bean variety and one soil type with the same boundary conditions was simulated under local weather conditions.

Results were compared with regional statistics. Improvements are possible using i) different varieties per site, ii) local soil schematization; iii) irrigation was not applied, but could play a role.

Resulting yields of the 6 location are given in figure 10.

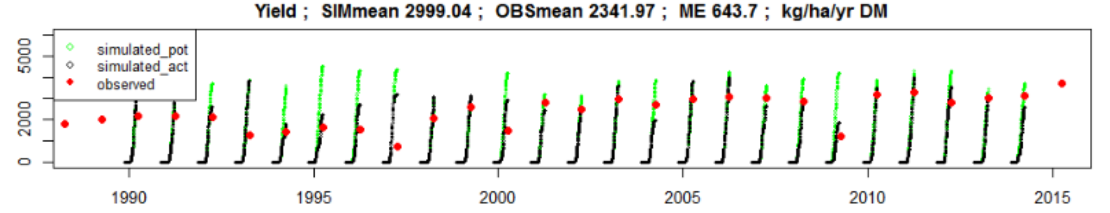
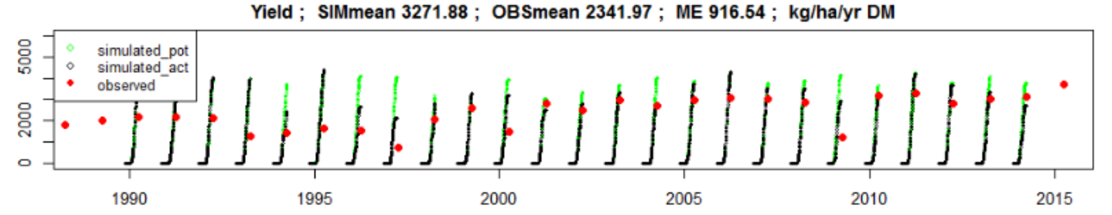
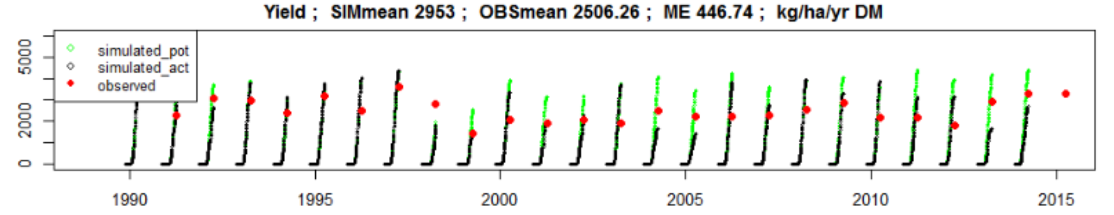
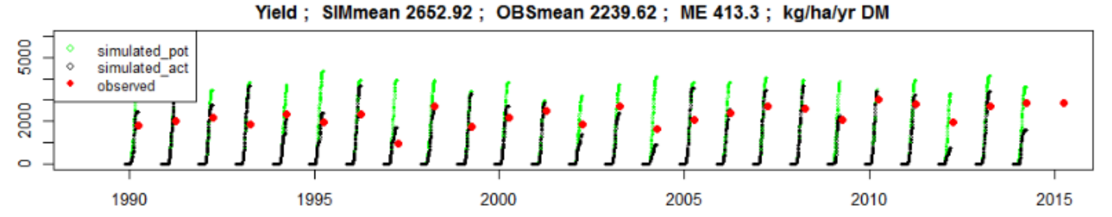
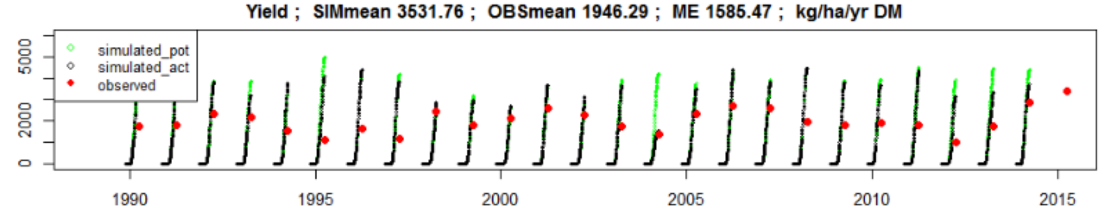
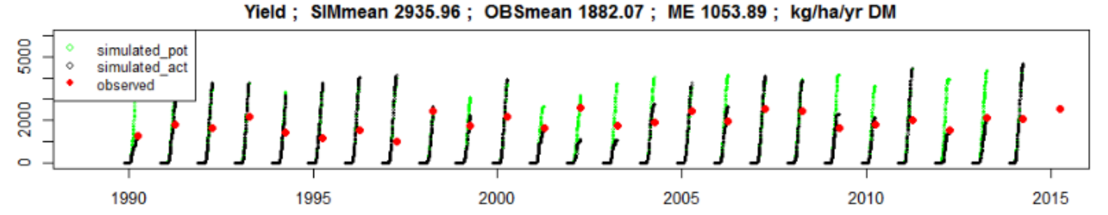
	1.San Antonio de Areco
	*2. Zavalla*
	*3. Vernado Tuerto*
	*4. Rafaela*
	*5. Manfredi*
	*6. La Carlotta*

Figure 10: Simulated and regional statistical yields for the 6 selected sites: 1.San Antonio de Areco, 2. Zavalla, 3. Vernado Tuerto, 4. Rafaela, 5. Manfredi, 6. La Carlotta

3.4.2.4. Modeling maize and wheat

The simulation for wheat and maize were calibrated; changes of input parameters are given below.

```
* 1. adjusted on 4-oct-2016 by Kroes and Supit:
* compared with original mag205.cab and has now following differences:
*   RDC    =  200.00
*   TSUMEA =  1250.00 ! Temperature sum from emergence to anthesis, [0..10000 C, R]
*    TSUMAM =  1100.00 ! Temperature sum from anthesis to maturity  [0..10000 C, R]
* other adjustments:
*  CH
* FraHarLosOrm_lv = 0.5   ! fraction harvest losses of organic matter from leaves        [0.0..1.0 kg.kg-1 DM, R]
* FraHarLosOrm_st = 0.5   ! fraction harvest losses of organic matter from stems         [0.0..1.0 kg.kg-1 DM, R]
** Nitrogen data from input file SWHEAT.DATo.DAT for use with LINTUL wheat, May 2013
**  which was based on WOFOST crop data set for WHEAT, SWheat-Flevo.crp, and spring barley data
* in file *.snp the size of the rootable zone was increased from 0.5 to 1.0 m
```

Calibrated changes of input crop file GmaizeD.crp

```
* 1. adjusted on 4-oct-2016 by Kroes and Supit:
* SIGMA-project, Argentina, Pampas, province Buenos Aires
* compared with original WWH107.CAB and has now following differences:
*  RDC    =  150.00
*  TSUMEMEOPT  =  60.0
*  FLTB and FSTB at DVS = 0.7 and FSTB at DVS = 1.5
* other adjustments:
*  CH
* FraHarLosOrm_lv = 0.5   ! fraction harvest losses of organic matter from leaves        [0.0..1.0 kg.kg-1 DM, R]
* FraHarLosOrm_st = 0.5   ! fraction harvest losses of organic matter from stems         [0.0..1.0 kg.kg-1 DM, R]
```

Calibrated changes of input crop file WheatD.crp

Results of simulated yields of wheat and maize, compared with regional statistics, are given in figure 11.

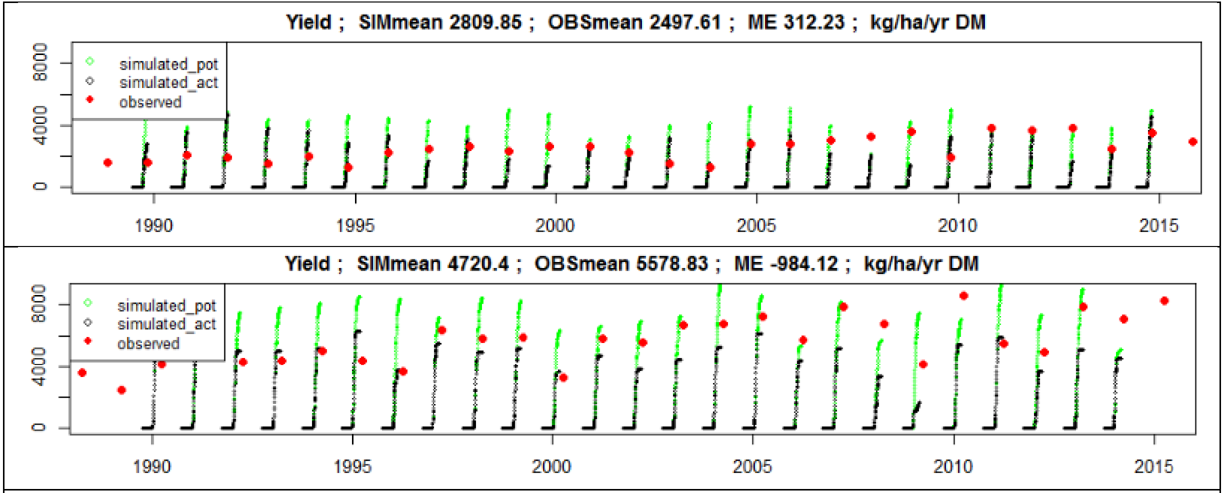


Figure 11: Simulated yields for wheat (top) and maize (bottom) at the JECAM site San Antonio

3.4.2.5. Modelling crop rotations and soybean in San Antonio Areco

For 3 crops used in a rotation (soybean, wheat and maize) a preliminary test was executed to obtain realistic yields and phenology. Subsequently a 25 year period was simulated using a 5 year crop rotation block consisting of a recommended rotations sequence:

```
INITCRP  CROPSTART      CROPEND       CROPNAME  CROPFIL     CROPTYPE
    2     01-oct-1989   15-apr-1990   'Maize'    'GmaizeD'      2
    2     01-nov-1990   25-apr-1991   'SoyD1'       'SoyD'      2
    2     01-jul-1991   30-nov-1991  'Swheat'    'SwheatD'      2
    2     01-dec-1991   01-aug-1992   'SoyD2'       'SoyD'      2
    2     01-oct-1992   15-apr-1993   'Maize'    'GmaizeD'      2
    2     01-oct-1993   15-apr-1994   'SoyD1'       'SoyD'      2
```

To achieve optimum values for the organic matter composition and distribution over the different organic matter pools, the simulation experiment was run for a period of 100 years for the cases soybean and crop rotation.

Results in figure 12 for continuous soybean and a recommended crop rotation

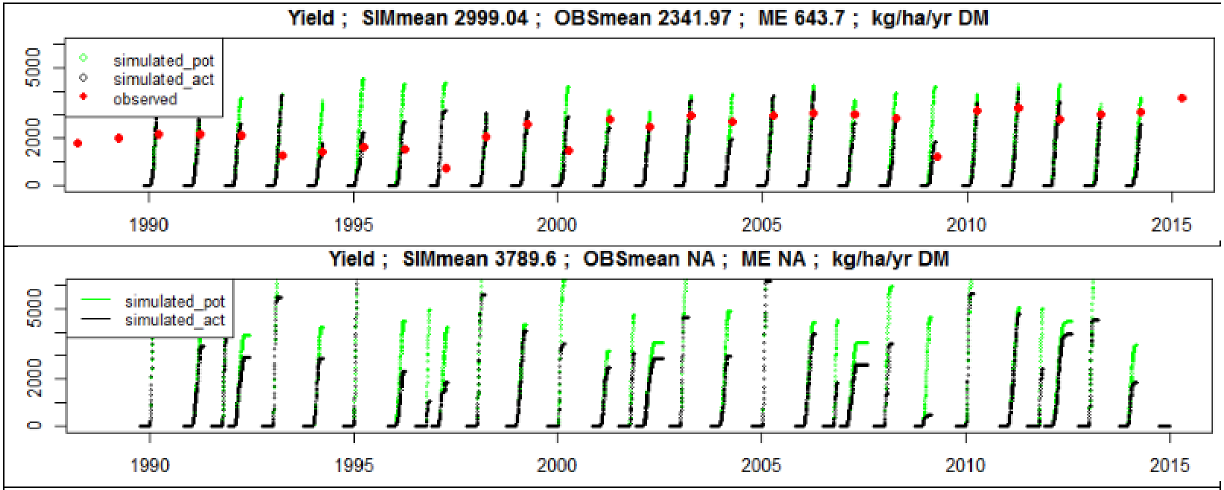


Figure 12: Simulated yields for soybean (top) and a recommended crop rotation (bottom) at the JECAM site San Antonio

For the soybean and crop rotation experiment additional results for leaching of water and nitrogen is given in respectively figures 13 and 14.

Results for total and fresh (FOM) organic matter in soil need additional analyses.

Leaching of water from the bottom of the rootable zone at 1 m-soil surface decreased 44 mm or 13%. The leaching of nitrogen increased with 24 kg/ha N or 48%.

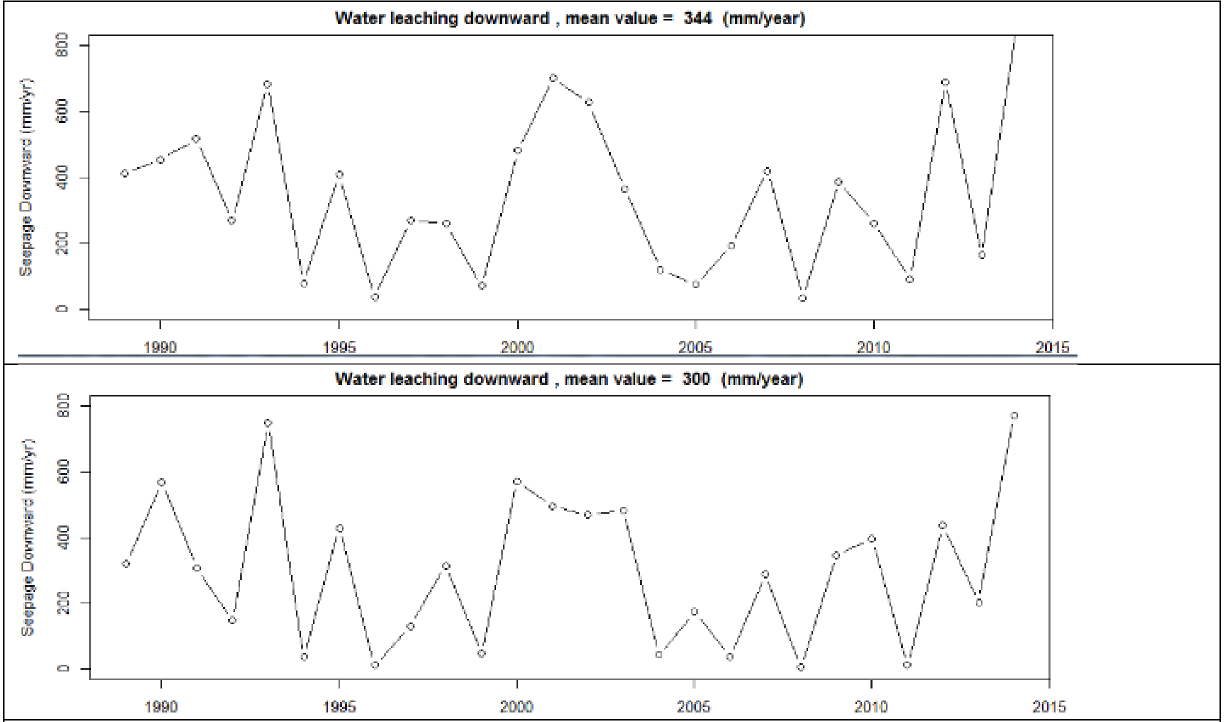


Figure 13: Simulated downward leaching of water (mm/year) for the continuous soybean cultivation (top) and the recommended crop rotation (bottom) at the JECAM site San Antonio

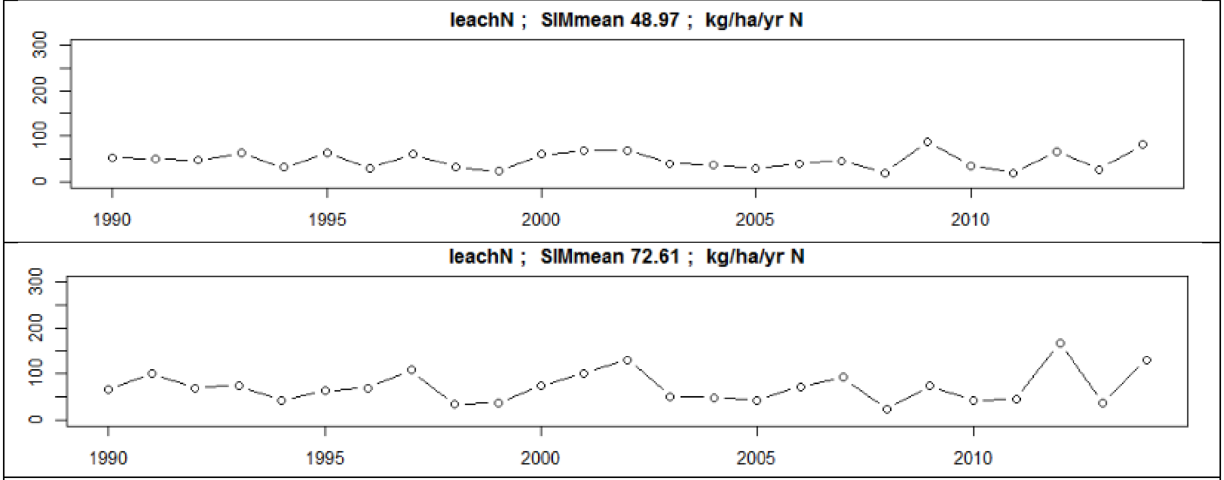


Figure 14: Simulated downward leaching of nitrogen (kg/ha/year N) for the continuous soybean cultivation (left) and the recommended crop rotation (right) at the JECAM site San Antonio

3.4.2.6. Summary

Findings were :

- Dropping protein contents in the observed yields are mainly caused by the interpretation of yield statistics. For example: yields increased, however the concentration of protein did not increase proportionally. As a result there is a decrease in protein content but not in the protein quantity;
- Dynamics of land management with respect to planting time and fertilizer time are very important issues for environmental impacts such as leaching losses of water and nitrogen. This may result in changes in soil hydrology, such as rising groundwater tables and pollution of groundwater by nitrogen and probably also other solutes;
- Rising groundwater in regions with vulnerable aquifers that contains salts may be another threat that, in combination with the rising groundwater tables, may hamper future agricultural production;
- The limited analyses of the Jecam site San Antonio Areco data-set with no-tillage for soybean and other crops didn't give an indication for soil degradation. However more analyses are required;
- Comparison of a 25-year recommended crop rotation and a 25-year monoculture crop showed that nitrate-leaching in the crop ration is higher than in the monoculture. This is directly linked to the fertilizer applications. Improved management, e.g. smaller doses and more precise timing, can reduce environmental impacts;
- Additional analyses are recommended to find a proper balance between positive and negative impacts of land use changes;
- Dynamics of crop rotation and its environmental effect can be monitored using a combination of remote sensing and modelling.

3.4.3. EiA for SRIA JECAM site in Russia

To address environmental issues concerning crop rotation intensification, rayons (sub-region units) of Stavropol region (Fig 15) were carefully assessed looking for evidences of agricultural activity affecting crop yields. This was performed through the regression analysis based on remote sensing data. There were following objectives to facilitate the analysis:

- Remote sensing data collection (MODIS, Landsat)
- Remote sensing data pre-processing, time series reconstruction, indicators calculation
- Implementing adaptive methods for winter crops and arable lands mapping to produce regional maps for 10 years in a row: 2004-2014
- EO-based and yield-related indicators extraction for related crops on yearly basis
- Multi-annual data statistical analysis
- Arable land maps series analysis to see evidence of land use change

3.4.3.1. **Data collection**

Ground information was collected in recent years on crops spatial distribution, hybrids specifications, their phenology, biophysical and harvested yields. Some fields were carefully studied and undergo specific surveys aimed at weekly LAI measurements and green biomass retrieval.

Remote sensing data were accumulated during last decade and stored in IKI satellite data archive, supported by CCU (Center for Collective Use) (Loupian et al., 2015). It includes, first of all, MODIS (Terra, Aqua) both source product (MOD09 surface reflectance) and IKI-derived numerous products, like temporal composites, smoothed vegetation indices and so on. Finer resolution systems, like Proba-V, Landsat, Sentinel-2, Russian Resours-P, Canopus-V and Meteor-M2 are also used for purposes of higher spatial accuracy.

Meteo measurements are provided by NOAA NCEP reanalysis data including grid-based values of numerous daily and hourly parameters (air and soil temperature, winds, precipitation, moisture, humidity, radiation, pressure and snow depth).

Multi-annual official statistical data on crop areas and yields on some crops (including winter crops) was accumulated at rayons level of Stavropol krai throughout the last decade.

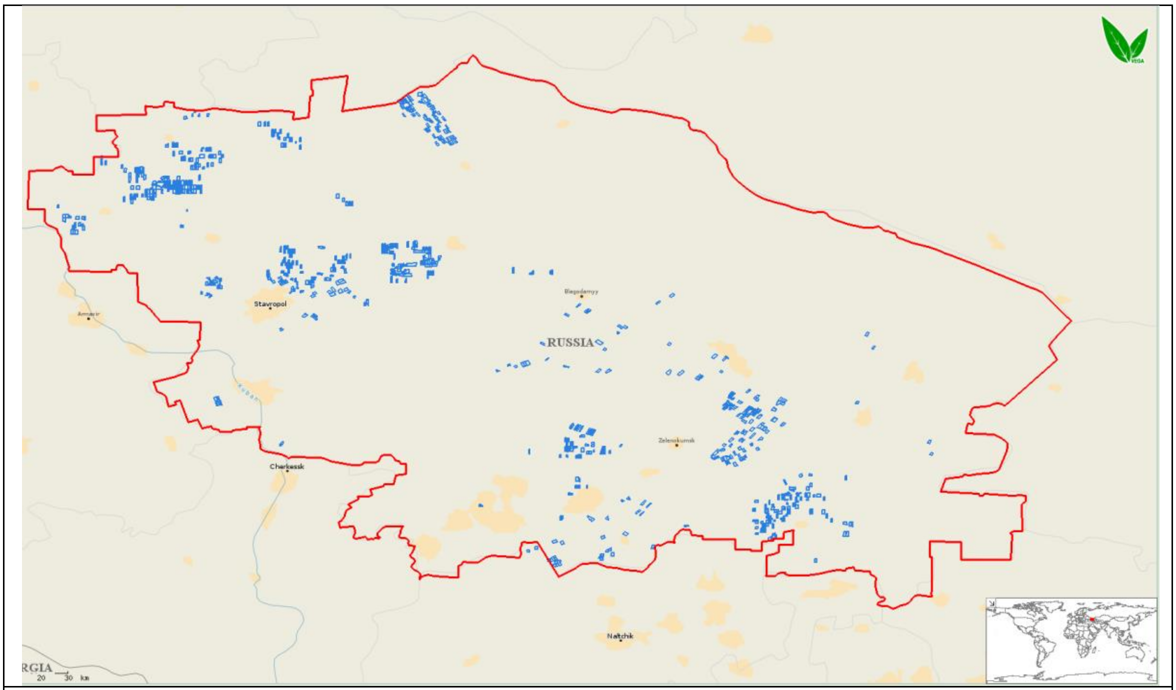


Figure 15: SRIA Jecam site boundaries and fields (shown in blue) where ground information was registered as shown in VEGA-Geoglam web interface

3.4.3.2. Methods and instruments

EO-based crop and arable lands mapping is performed in IKI on a regular basis (Bartalev, Plotnikov, Loupian, 2016; Plotnikov, Bartalev, Loupian, 2008). For this purpose USGS MODIS MOD09 daily surface reflectance data is processed in order to deal with snow, clouds and their shadows (Bartalev et al, 2011) followed by temporal image compositing. Multi-annual time series of weekly composite images are used for arable land recognition features calculation, while seasonal 4-days time series are involved into winter crop mapping routine (Plotnikov et al., 2008). Annual arable lands map yearly update yields a set of successive maps, where land use objects can be tracked through the time. Maps inter-comparison provides indication to parcels where significant land use change occurs. Crop and arable land maps provides spatial information facilitating yearly area estimation at rayon level.

Developed as web-based and user friendly prompt mediator between large satellite data archive and spatio-temporal tools, VEGA was used to extract EO-based indicators, such as NDVI seasonal maximum value corresponding to winter crop fields, which is proved to be strongly linked with crop yield (Becker-Reshef et al., 2010, Eroshenko et al, 2016).

LAI measurements were taken with fish-eye camera and processed in CanEye software.

3.4.3.3. Model building and sensitive areas environmental impact assessment

Arable lands of Stavropol krai have experience substantial increase in area during last decade according to both official and remote sensing data (Fig 16). Agricultural fields are being return to a crop rotation process from abandoned state. As Stavropol krai is mostly steppe region, re-cultivating of fallow lands is rather rapid and less costly process then almost anywhere in Russia. Cropland area increment takes place mostly in eastern part of Stavropol krai (Fig 17), where significant portions of arable land were abandoned due to less friendly conditions for agriculture. Cropland areas in central and western part of krai remain almost unchanged throughout last decade.

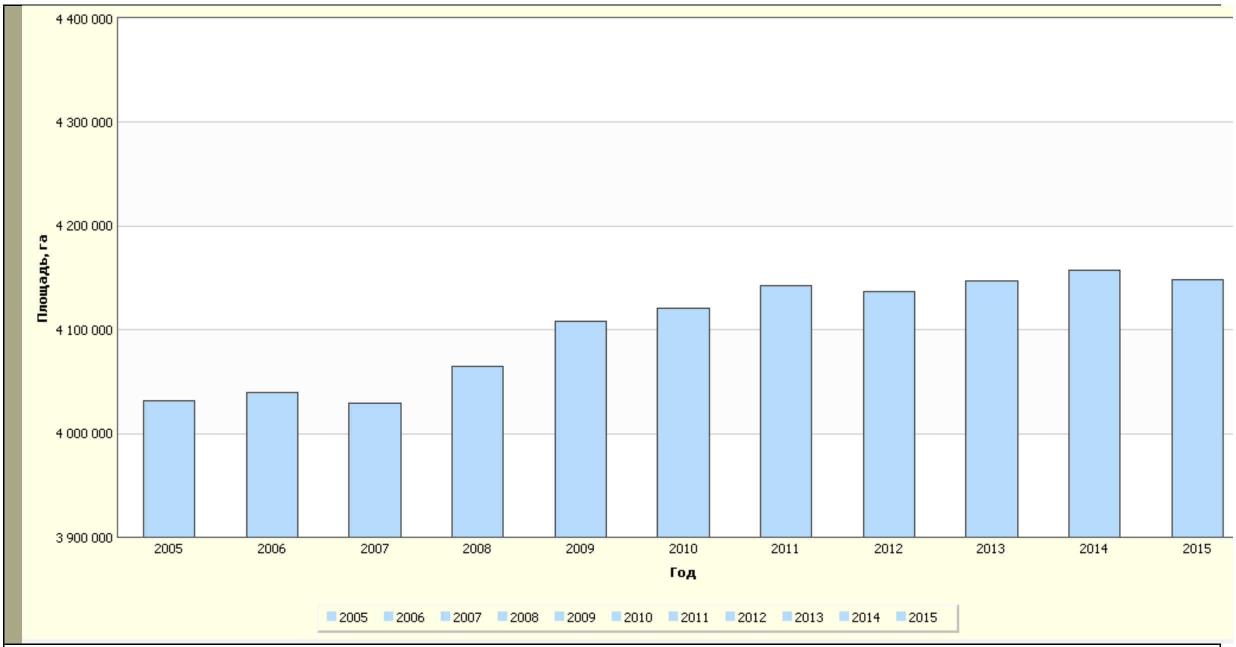


Figure 16: Arable lands area gradual increase since 2005 (minimum reached in 2007) to 2015 (maximum reached in 2014) in Stavropol krai

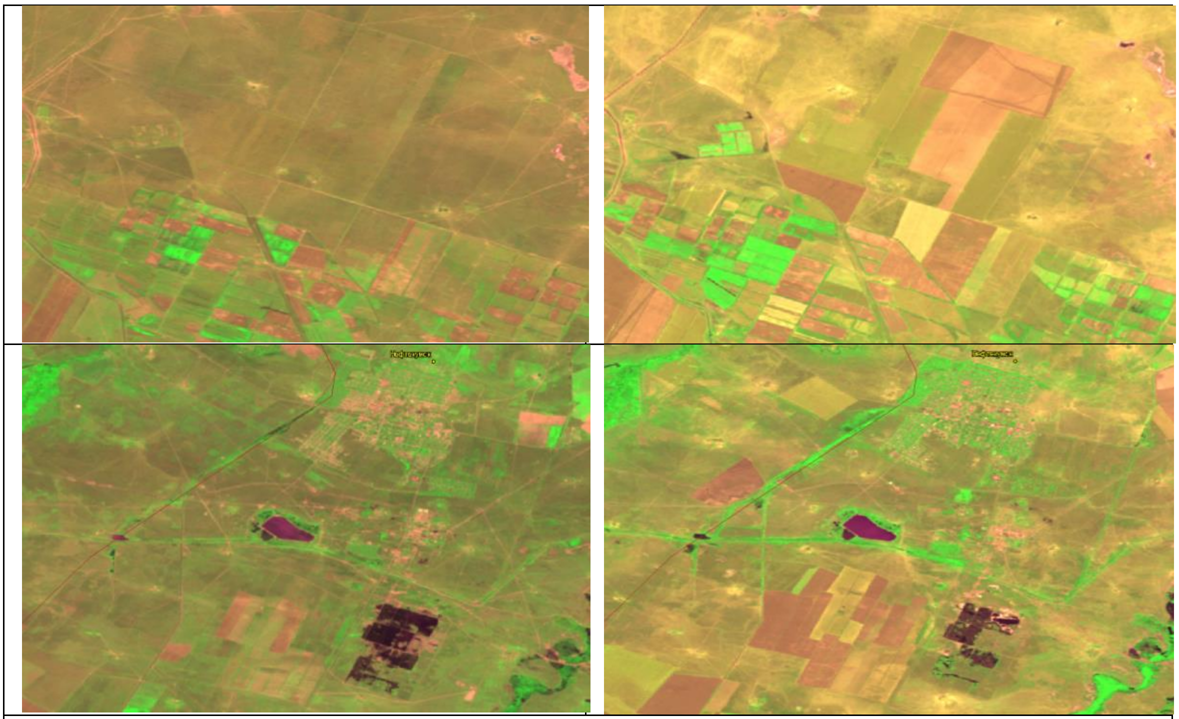


Figure 17: Land use change areas (top and bottom) over east of Stavropol region as seen from Landsat series satellites – May 2003 (left) and May 2014 (right)

Regional winter crops yearly area is also increasing, as both winter wheat and winter rapeseed are regarded as rather profitable. While crops area grows in eastern part, which more or less could be explained by land use change in there, similar tendency is observed almost in every rayon of the krai (Fig 18).

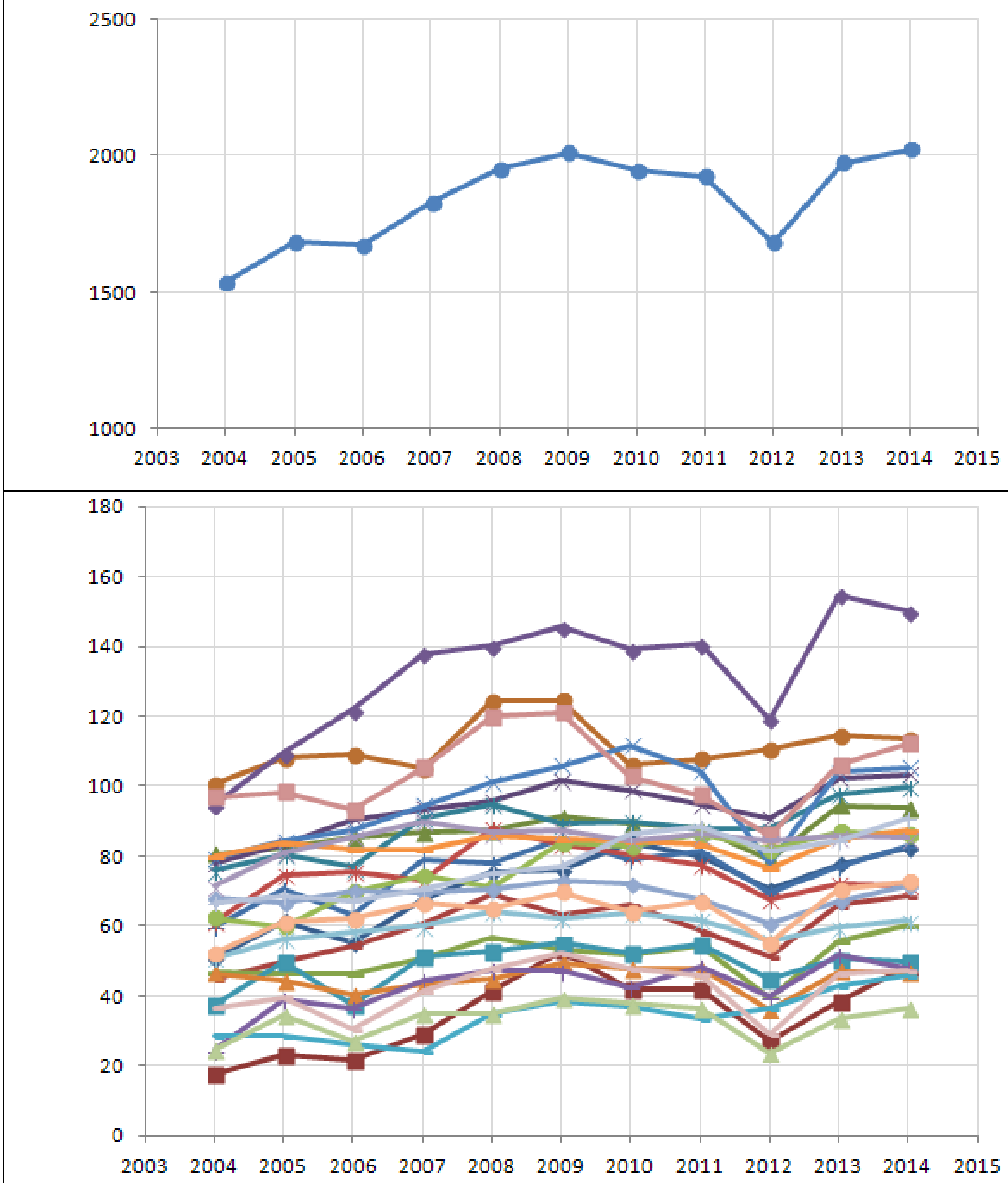


Figure 18: Winter crop yearly area variations at every rayon level (bottom) and at krai level (top) between 2004 and 2014, vertical axis is acreage in thousands ha, horizontal axis is years

If crop acreage increases with no available place for expansion, this leads to a change of crop rotation scheme in such a way so crop is eventually sown several years in a row. This forces farmers to use more fertilisers; otherwise yield is decreasing due to soil degradation. Yield may also decrease because of pests and weeds accumulating in a soil of such intensively exploited fields.
As remote sensing data provides timely and unbiased information, there is a demand to use them for monitoring of such environmental issues. This requires a reliable model for yield prediction accounting for dependence between crop acreage changes and subsequent productivity variations. Following steps were performed to build a model:

- winter crop map creation with MODIS spatial resolution (250 m)
- NDVI seasonal maximum value extraction from time series for every winter crop pixel
- NDVI and acreage data aggregation at rayon level
- Find statistically significant regression between multi-annual NDVI seasonal maximum values linked with yield and winter crop acreage estimation

Model was built for every rayon looking for inverse dependence between crop acreage and NDVI seasonal maximum value linked with yield (Fig 19). Many of them showed yield increase with winter crop area growth, meaning that farmers are investing into intensively used fields through fertilisers and herbicides. Nevertheless, there were also rayons with rather good model showing that yields are falling when acreage is rising- for instance, Novoselitsky rayon in mid-eastern part of the krai.

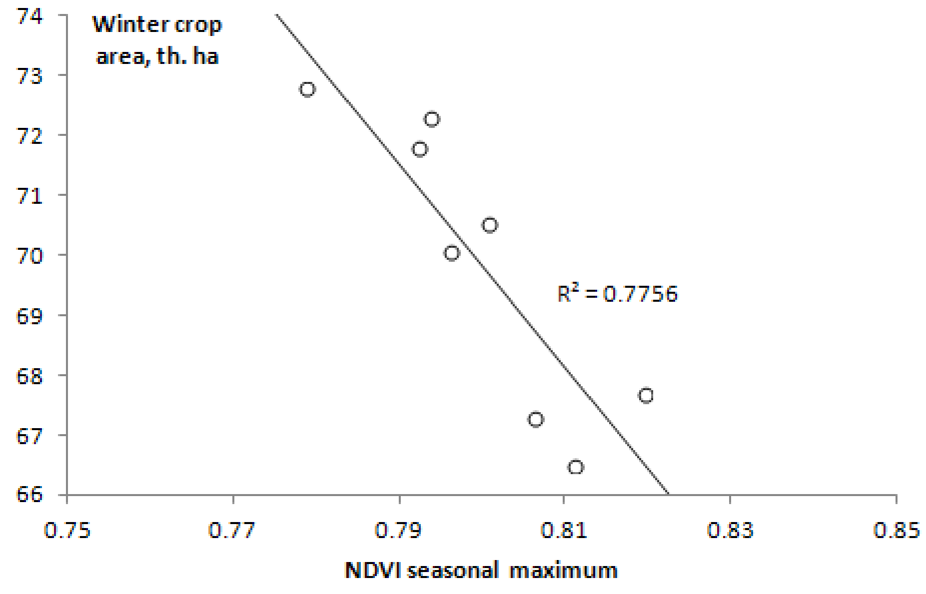


Figure 19: Regression model for Novoselitsky rayon of Stavropol krai

3.4.3.4. Summary

Major findings were:

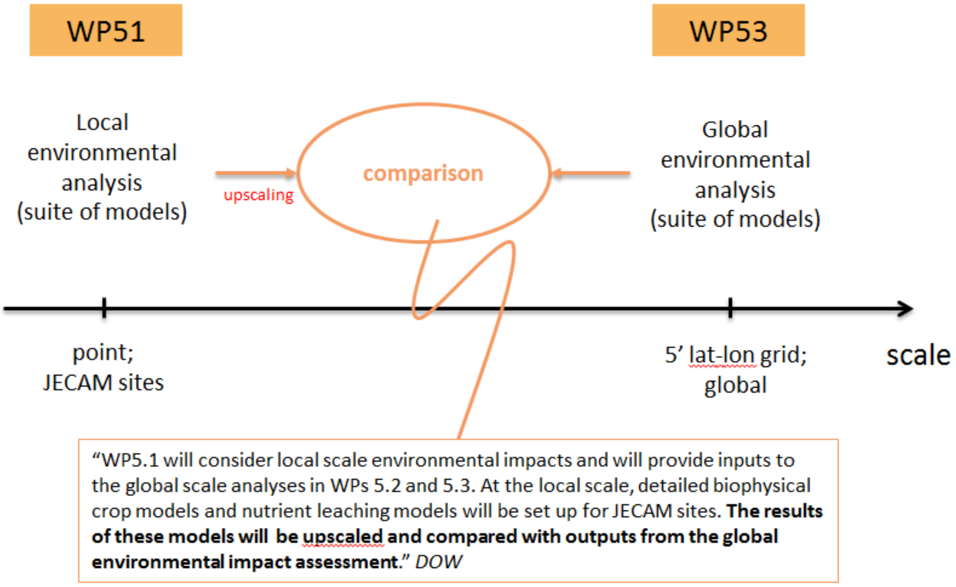
- Moderate resolution remote sensing data are proven to be helpful in environmental problems assessment in Stavropol region;
- Arable lands and winter crop area both experience substantial increase throughout last decade at rayons and krai levels, inducing both positive and negative changes in farmer's agricultural practices;
- Major land use changes occur in the eastern part of Stavropol SRIA JECAM site, while crop rotation intensification is seen in central parts;
- Regression models linking EO-based indicators related to yield and crop acreage is shown to be significant enough to explain the most of the yield decrease by ineffective management such as crops area increase with no significant support through fertilisers and herbicides.

3.5. Upscaling EiA from local to regional

3.5.1. Introduction

The intention is to upscale the simulation results obtained for the local JECAM scale to the global scale using a meta-model approach. The methodology was discussed and agreed upon during a meeting on 15 September 2016 in Wageningen. The key elements of the methodology are presented (Fig 20) and can summarized as:

- using meta-model to upscale WP51 work to WP53 spatial scale;
- The case of nitrate leaching associated to wheat and maize cultivation;
- IIASA receives meta-model coefficients, prepared the input variables, and compare EPIC-simulated N leaching to estimates from the meta-model, at EU-scale to illustrate the methodology,



“WP5.1 will consider local scale environmental impacts and will provide inputs to the global scale analyses in WPs 5.2 and 5.3. At the local scale, detailed biophysical crop models and nutrient leaching models will be set up for JECAM sites. **The results of these models will be upscaled and compared with outputs from the global environmental impact assessment**.” *DOW*

Figure 20: Key elements of the methodology for upscaling

3.5.2. Procedure for Metamodel / Transfer functions

The upscaling methodology outlined before is put in practice for N-leaching as explained in more detail below.

A series of mechanistic modelling experiments have been carried out. The purpose of these modelling experiments was to assess quantitatively the leaching vulnerability of key pedo-climatic (sub) zones (using mean conditions/characterization) for a number of farm management practices. The leaching vulnerability was characterized by the calculated total discharge of N via downward leaching to 1 meter below soil surface and via runoff and (sub)surface lateral leaching. As regards climate, long-term mean climate data have been used, but also data of relatively dry years and wet years, so as to analyze the inter-annual variability. The results of the model simulation experiments yield matrices of the 'nitrate leaching vulnerability'.

The main characteristics of the sites are given in table 6.

Figure 21: Location of groundwater scenario sites for which nitrate leaching simulations were performed.

Table 6: Main characteristics of 9 groundwater scenario sites

Location	Mean Annual Temp. (°C)	Mean Annual Prcipitation (mm a^{-1})	Top soil (USDA)	Organic Matter (%)
Châteaudun	11.3	648 + Irrigation	silty clay loam	2.4
Hamburg	9.1	786	sandy loam	2.6
Jokioinen	4.1	638	loamy sand	7.0
Kremsmünster	8.6	900	loam/silt loam	3.6
Okehampton	10.3	1038	loam	3.8
Piacenza	13.3	857 + Irrigation	loam	1.7
Porto	14.8	1150	loam	6.6
Sevilla	18.0	493 + Irrigation	silt loam	1.6
Thiva	16.2	500 + Irrigation	loam	1.3

The sites at DeBilt (Netherlands) and Warschau (Poland) were added to this data-set. Simulations have been made for 11 sites across EU-27 (Fig 21), using site-specific soil characteristics and 30 years weather data and for 4 cropping systems.

For each of the cropping systems and for each site, the total annual N leaching has been simulated, using the SWAP-ANIMO-model. This model requires the following input data:

- Soil – hydrology characteristics;
- Daily weather data,
- Cropping system,
- Input of N via fertilizer and/or manure,
- Attainable N uptake.

The parameters refer to the simple model to describe nitrogen uptake. The coefficients a, b and c have been used to estimate N uptake using the formula:

$$Nuptake = MC * [a + b * N\,input - c * (Ninput)^2]$$

Nuptake refers to the harvested forage and grain + straw, MC is a site specific correction factor for climate and management, a = constant, kg/ha, b = dimensionless constant , c = constant, ha/kg and *Ninput* is the effective N input in kg/ha. The effective N-input is calculated according to:

Ninput = Fertilizer N + *FNEV* * manure N

The fertilizer N effectiveness value (FNEV) depends on the timing of the fertilizer application.

For eleven sites in EU-27 simulations have been made of N leaching as function of cropping system and N fertilization practices (Table 7). The abbreviation MC stands for a 'management-climate' correction factor of the potential crop yield and N uptake (see text).

Table 7: Eleven sites in EU-27 for which simulations have been made of N leaching as function of cropping system and N fertilization practices

	Site name		MC
1	CHATEAUDUN	France, close to Paris	0.7
2	DEBILT	Netherlands	0.9
3	HAMBURG	Northern Germany	0.9
4	JOKIOINEN	South Finland	0.6
5	KREMSMUENSTER	North part of Austria	0.8
6	OKEHAMPTON	South England	0.9
7	PIACENZA	Italy, Po area	0.8
8	PORTO	North Potugal	0.7
9	SEVILLA	South Spain	0.5
10	THIVA	South Greece	0.4
11	WARSCHAU	Central Poland	0.6

The four dominant cropping systems in the EU-27 for which simulations have been made of nitrate leaching, as function of site-specific soil and weather characteristics, and N fertilization practices are given in table 8.

Table 8: Four dominant cropping systems for which nitrate leaching has been simulated

	Cropping system	Green cover Period	a kg/ha	b dimensionless	c ha/kg
1	Grassland	All year	150	1	0.009
2	Wheat	October-July	75	0.8	0.009
3	Maize	May –October	75	0.8	0.009
4	Maize + cover	May-April	90	0.9	0.009

The 'calibration' of the coefficients a, b, c, and MC has been done on the basis of mean crop yield statistics and data from MITERRA-Europe (Velthof et al., 2009; Oenema et al., 2009; Lesschen et al., 2011. Mean crop yields and mean uptake per crop per Member State are presented. There are large differences between Member States in crop areas, crop yields and N uptake. The mean N uptake by wheat ranges from less than 50 kg per ha per yr to more than 200 kg N per ha per yr. The mean N uptake by maize ranges from less than 100 to more than 200 kg N per ha per yr, and the N The mean N uptake by grassland ranges from less than 50 kg per ha per yr to more than 300 kg N per ha per yr. We assumed that the potential N uptake by the cover crop is 75 kg per ha per year, but the actual uptake depends on the MC coefficient and the effective N input. The resulting relations between N-uptake and N-input are given in figure 22.

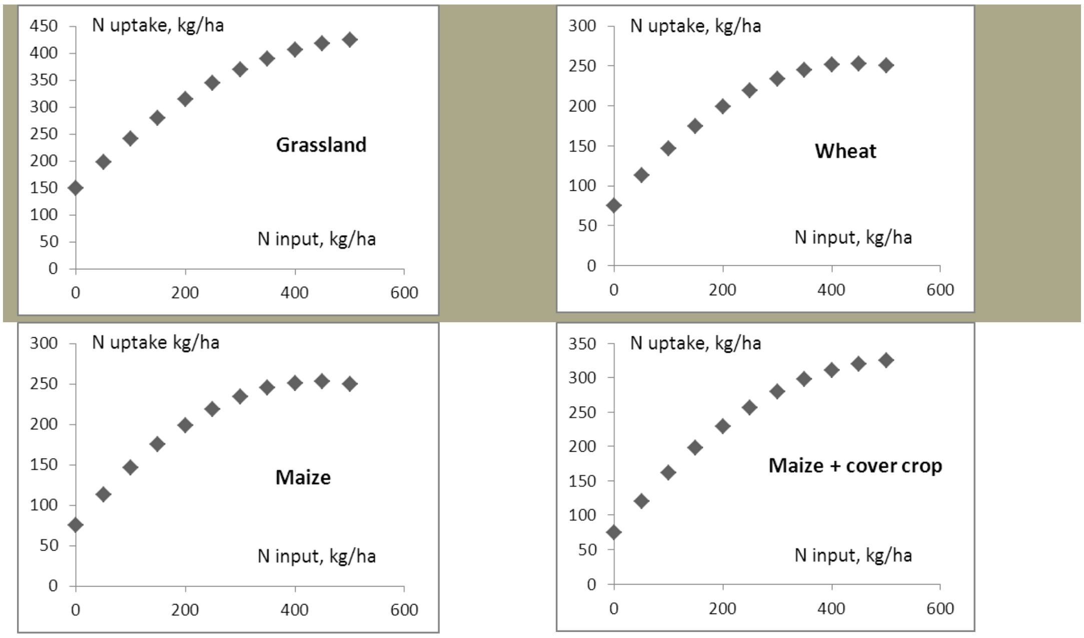


Figure 22: Potential N uptake curves used in the simulation, for grassland (upper left panel), wheat (upper righ panel), maize (lower left panel) and maize + cover crop (lower right panel).Potential N uptake refers to MC=1 (see text).

The combination of 4 application time strategies and 9 combinations of manure and mineral fertilizer dosages yielded 36 scenario's.

3.5.3. A case study as example

Results are given in figure 23 for the Chateudun site in France.

An analysis of the simulation resulted in a number of explaining factors responsible for the nitrate leaching at 1 meter depth:

- P : annual precipitation (mm a^{-1})
- ETact : annual actual evapotranspiration (mm a^{-1})

- Temp : mean air temperature (°C)
- FraSilt : silt weight fraction of mineral soil parts (-), averaged for 1 meter topsoil
- CntOm : Organic matter weight fraction of solid soil parts (-), averaged for 1 meter topsoil
- Nsurplus: annual mean nitrogen surplus (kg ha a^{-1}), calculated as fertilizer application + deposition – crop offtake.

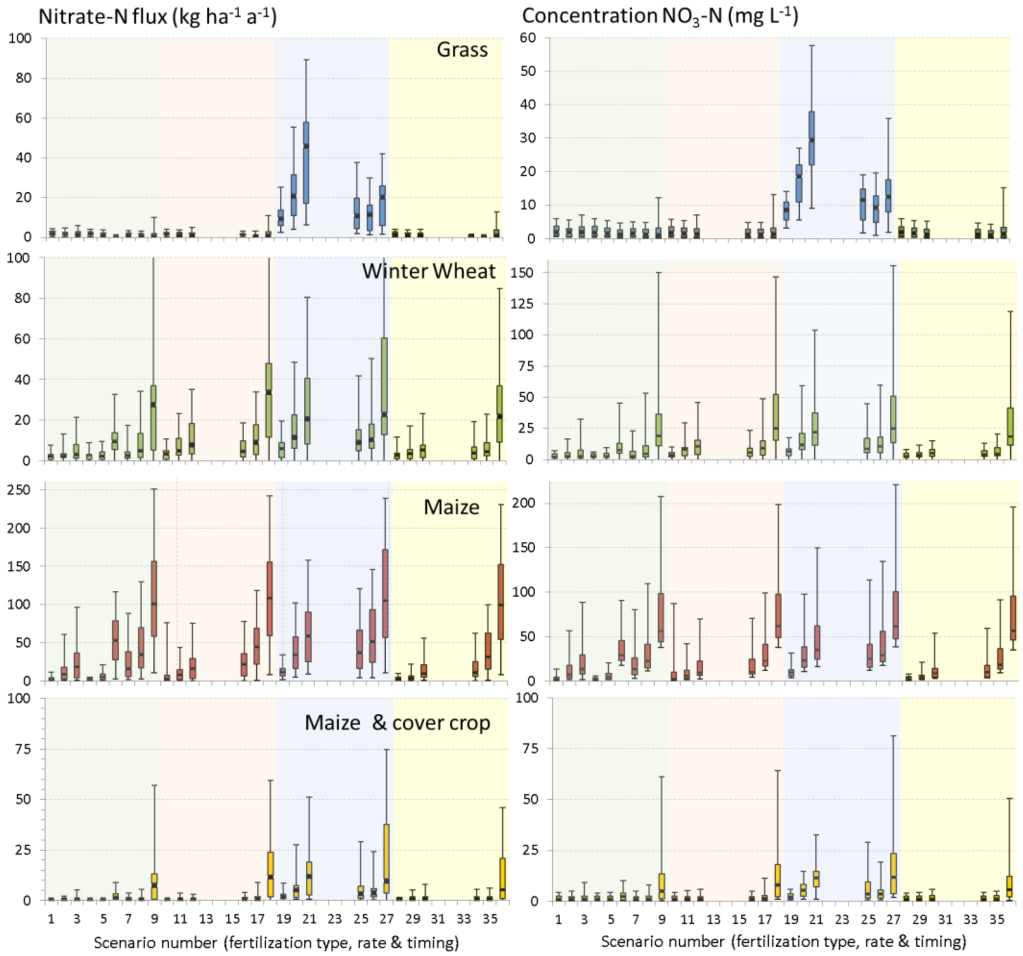


Figure 23: Total nitrate flux-N (kg ha^{-1} a^{-1}) at 1 m depth (left) and flow weighted nitrate-N concentration (mg L^{-1}) at 1 m depth (right) for grassland (upper panel), wheat (second panel), maize (third panel) and maize + cover crop (lower panel) as a function of fertilization practices, at the site Chateaudun in France. The box plots, summarize the results of 30 simulation years. Bars below and above the box indicate the 5 and 95 percentile annual values, the boxes the 25 and 75 percentiles, while the line in the box represents the median value

The model input with respect of the first five parameters are summarized below (Table 9) for the sites considered.

Table 9: Main characteristics of the scenario sites

Site	P	ETact	Temp	FraSilt	CntOm
Châteaudun	646	506	11.3	0.58	0.013
De Bilt	799	509	8.7	0.04	0.017
Hamburg	790	571	9.0	0.16	0.013
Jokioinen	644	467	4.1	0.21	0.029
Kremsmünster	871	590	8.6	0.47	0.015
Okehampton	1056	634	10.2	0.36	0.015
Piacenza	843	680	13.2	0.39	0.012
Porto	1140	697	14.8	0.37	0.017
Sevilla	472	448	17.9	0.52	0.012
Thiva	413	413	16.2	0.39	0.009

A regression was performed to obtain the parameters of the following equation to describe the ANIMO results as a function of the N-surplus and the afore mentioned parameters:

$$\text{N-leaching} = \text{N-surplus} \times (a_1 \times P + a_2 \times ETact + a_3 \times Temp + a_4 \times FraSilt + a_5 \times CntOm)$$

This equation was fitted (table 10) by minimizing the sum of squared differences using all the results of the combinations of crops, fertilization level, timing of application and sites.

Table 10: Statistics of the fitting of a transfer function based on the scenario results for nitrate leaching

	F(7,1019)	Prob > P	R-Squared	Adj-R2
	4247.855	0	0.966866	0.966638
	Estimate	Std. Error	t value	Pr(>|t|)
Precip	0.000189	0.000047	4.026282	0.000061
ETact	-0.00095	0.000128	-7.39652	0
Temper	0.046788	0.001939	24.13392	0
FraSand	1.208088	0.078508	15.38818	0
FraSilt	0.680212	0.138048	4.927361	0.000001
FraClay	-0.80009	0.065295	-12.2534	0
CntOm	-17.2964	2.733936	-6.32655	0

3.6. Summary

Existing models have been innovated to enable Environmental Impact Analyses within JECAM sties. The innovated models were tested with different datasets and applied at JECAM sites.

Participants have been familiarized with existing and innovated models. The training provided the participants with the required background information on the simulation of water and nutrients in the soil. It provided them also with hands-on experiences in operating simulation models which is helpful when continuing this work in their home countries.

Once the innovated tools were implemented, tested and training was carried out the applications at JECAM sites started. It was decided to give focus to JECAM sites where innovations could be tested and implemented and lead to new insights in environmental issues. The Argentina JECAM site was such a case. The Local Environmental Impact Assessment (EiA) in Argentina was based on items discussed during the development of the protocols and the training sessions held in previous workshops. Based on several modelling exercises the findings can be summarized as:

- Dynamics of planting and fertilizer time are important issues for environmental impacts like leaching losses to groundwater
- Rising groundwater in regions with vulnerable aquifers that contains salts may limit future agricultural production;
- Comparison of no-tillage for soybean and other crops gave no indication for soil degradation in soybean. More analyses are required
- Optimize management : crop rotations may increase risk of leaching nitrogen when compared to monoculture of soybean;
- Dynamics of crop rotation and its environmental effect can be monitored using a combination of remote sensing and modelling

A procedure for upscaling was developed, tested and successfully applied in the form of a metamodel focusing on leaching of nitrate.

About seven International presentations were held, highlighting the promising results of this work package. In the future outlook promising items are identified.

4. Outreach of project results

4.1. International presentations

Presentation at international joint meetings of the SIGMA project:

- Mol, November 2013 (SIGMA_kickoff)
- Beijing, October 2014 (SIGMA_Annual meeting 2014)
- Leuven, November 2015 (SIGMA_Annual meeting 2015)
- Buenos Aires, September 2016 (workshop)
- Kiev, October 2016 (SIGMA_Annual meeting 2016)

Contributions were given to the following Symposia:

- iCROPM2016, 15-17 March 2016, Berlin, Germany. Crop Modelling for Agriculture and Food Security under Global Change. Title of contribution: Disentangle mechanisms of nitrogen and water availability on soybean yields (Kroes et al, 2016a).

- EO-BAR symposium, 16-17 May 2016, Beijing, China. *International Symposium on Earth Observation for One Belt*. Title of contribution: Impact analyses of land use changes on soil nitrogen and crop water productivity in the delta of the Huanghe river (Kroes et al, 2016b).

4.2. Future outlook

Training activities using the innovated tools are planned for China RADI Shandong JECAM site (WP4). Training activities related to EIA-issues such as water productivity, water foot prints, soil degradation, groundwater level changes and groundwater pollution are very relevant for other JECAM sites such as San Antonio in Argentina. If time permits more detailed analyses are foreseen. This should result in publications about at least one EiA (China, WP5, WP6).

In January 2017 a workshop will be organized at IIASA about upscaling issues within WP5. During this workshop the established metamodel for nitrate leaching will be tested and options for other JECAM sites will be evaluated.

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6. Annexes

Annex A . General concept for protocol of JECAM site

Table 1: Protocol for the Flevopolder potential JECAM site in The Netherlands

Main Phase	Item	Description
Model study plan	Environmental problem and context	Nitrate leaching to groundwater and diffuse surface water pollution from agricultural land use
	Objectives	Prediction of impact of land use and land management on crop yield and nitrate leaching
	Data Availability	See table 2.2 and Groenendijk et al. (2005)
	Calibration and validation criteria	Select data sets for calibration and data sets for validation. Objective function: optimization of predictin performance of nitrate leaching and crop yields Performance indicators: - at field scale: RMSE, NashSuthcliff ModelEfficiency, Index of Agreement, Mean Absolute Error - at regional scale: RSME
	Terms of Reference for ex post evaluation of study	Only applicable for results obtained by modelling with updated data sets and discretization: - Accepted by stake holders (WP6, WP7) - Article accepted by peer reviewed journal
	Scenario definition	Historical and Future Climate series: 30 years using daily data. Climate in 2050 and in 2100. Time series definition will be based on KNMI Climate Change Scenarios in 2014.
Data and	Select algorithms and	Discretization: 250m grids; daily

Conceptualisation	methods	Tools: SWAP / WOFOST / ANIMO Aggregate grid data to field and sub-catchment data using area-weighted averaging. And aggregate daily and sub-annual data to annual.
	Define Data Requirements	See table 2.2 Time: multiple years, full years
	Process raw data	Preprocessing: see manuls of applied tools (references 8, 9 , 10) Remote Sensed data: land use, potential use of: rainfall, albedo, ET, yield.
	Gap filling methods	Use representative landuse types for types which lacked parameterization
Model Set-up	Scripts and algorithms	Wolf et al. (2003) and references 8, 9 , 10
	Test runs	Technical verification
Calibration and Validation	Sensitivity analysis	Potential use of: http://cran.r-project.org/web/packages/sensitivity/
	Optimisation method; select parameters to be optimised	Potential use of: http://www.pesthomepage.org/
	Validation	Dependent on study results
Simulation	Analyse and interpret results	Quantify nitrate leaching rates
	Predict	Predict impact of climate change on crop yield and nitrate leaching
	Assessment of Plausibiliy of simulation	Dependent on study results : by expert judgement, using uncertainty analysis
	Aggregation and transfer to regional scale models	Derive simple relations between key parameters and target variables: metamodelling on the basis of model results
Evaluation	Assessment of achievement of study objectives	Dependent on study results
	Auditing	External review
Dissemination	Report	Articles, Professional report

Table 2: Overview of available data for the Flevopolder potential JECAM site in The Netherlands, see also the most recent version of the spreadsheet "data needs from JECAM sites.xlsx"

Item	Source	Specification	Reference
Meteorological	KNMI	Rainfall: 6 rainfall stations, daily values Evapotranspiration: 1 station reference values for grassland	3
Land use	Alterra	Satellite images (LGN3+) combined with observation	6
Land Management	LEI, CBS	Fertilization Tillage and cultivation	4
Water Management	STONE	Irrigation Drainage Surfacewater management	4
Soil	Alterra	Soil type and characterization	4
Groundwater	RIZA	Upward and downward seepage fluxes	5
Calibration And Validation	Alterra	Calibration at field scale Validation at regional scale	1, 6,7

Table 3: Potential use of Earth Observation for environmental impact analyses

Theme	Specification	Observation type
Meteo	Albedo	
	Radiation	
	Rainfall	
	Actual evapotranspiration	
	Air temperature	
	Soil surface temperature	
	Snow cover	
	Cloud cover	
Land use	Crop type	
	Crop phenology	
	Land use changes	
	Dry Biomass	
	Wet Biomass	
Land Management	Field variability	
	Management calendar	
	Row direction	
	Management calendar	
Water Management	Presence of irrigation systems	
	Irrigation events	
	Presence of surface water systems	
	Presence of water in surface water systems	
	Surface runoff risk	
Soil	Soil moisture content upper soil part	
	Slope	
	Land surface roughness	
	Soil compaction	

Inputs	Fertilizer	
Other In-situ data	To be determined through discussions	

Annex B. Protocol for INTA-San Antonio JECAM site

General Description:
On one hand the area sown with soybeans in the Pampas has been increasing at an unprecedented rate which has altered the once typical agriculture/pasture rotation to one of continuos agriculture dominated by sobeans. On the other hand, genetic and technological improvements together with new management practices and tax policies are opening the door to inclusion of new crops (e.g. beans) or typical crops but managed differently (e.g. second season maize). We lack an adequate knowledge of the impacts these changes may have on the environment. Base information like crop type maps generated yearly are also scarce and need to be generated to perform such analysis. We defined two environmental problems to analyze: 1) land degradation associated to monoculture and 2) changes in the energy budget due to new crop management practices.

1) Land degradation associated to monoculture

This task consists on the generation of base information (crop type, crop rotation and yield maps) for the analysis of the environmental impact that soybean monoculture could generate. Recent ground truth measurements will be used for training and validation of yearly crop type maps that allow the generation of crop rotation maps. Yield estimations will be performed from Earth Observation (EO) sources and meteorological data. Satellite derived yield will be evaluated vs. crop simulation models yield over different crop rotation scenarios. Analysis relating the degree of soybean monoculture and estimated biomass and yield will be performed.

Table 1.A. Protocol for analysis of soil degradation associated to monoculture for the INTA-San Antonio JECAM site.

Main Phase	Item	Description
Model study plan	Environmental problem and context	Land degradation related to soybean expansion and monoculture.
	Objectives	Estimate changes in soybean production area and degrees of soybean monculturization. Characterization of soil degradation trough yield estimation comparisons.
	Data Availability	Crop type maps from 2010 to 2013. Ground data to be collected from 2014 to 2016

		to generate and validate new crop type maps. Yield information at specific fields. High Resolution (HR) Optical and RADAR images from 2010. Moderate Resolution (MR) optical images since 2000. Addtional data in Table 2.
	Calibration and validation criteria	Optimal combination of sensors, bands and dates for crop type classification will be selected based on Kappa Coefficient. Yield estimations will be validated for fields and years where gorund data is available. RMSE between satellite derived yield and SWAP-WOFOST model yield
	Terms of Reference for ex post evaluation of study	
	Scenario definition	Moderate Resolution time series (MODIS): From 2000 to 2016 HR time series: From 2010 to 2016 SIGMA/JECAM Area
Data and Conceptualisation	Select algorithms and methods	IDL procedure for BRDF correction of MODIS daily 250 m time series. Algorithms for crop biomass and yield estimations from EO data and meteorological information developed in R. SWAP-WOFOST model will also be run for different crop rotation scenarios.
	Define Data Requirements	Ground truth data of land use and yields.
	Process raw data	Calibration and georreferencing of HR images. BRDF correction of MODIS daily images. Image Classification. Generation of Crop Type and Rotations maps. Generation of vegetation index maps for biomass/yield estimations.
	Gap filling methods	Smooths splines when applicable.

		Apllied methods to EO data will generate maps of variables of interest.
Model Set-up	Scripts and algorithms	Yield estimation from simple models using remote sensing and meteorological information through R procedures.
	Test runs	Yield estimation validation with ground truth.
Calibration and Validation	Sensitivity analysis	Bootsraps with R. Aplicable to yield estimation methods.
	Optimisation method; select parameters to be optimised	
	Validation	Validation of Crop type classification and yield estimations with ground truth data.
Simulation	Analyse and interpret results	Analysis of SWAP-WOFOST simulations
	Predict	
	Assessment of Plausibiliy of simulation	
	Aggregation and transfer to regional scale models	
Evaluation	Assessment of achievement of study objectives	Check objectives and describe eventual deviations
	Auditing	External review
Dissemination	Report	Peer reviewed journal articles and extension notes

2) Changes in the energy budget

Crop identity together with crop management practices –in particular those that modify crop phenology- can affect the surface water and energy balance. Changes in the moment and duration **of the explosion of vegetated vs bare soil surfaces can alter the surface albedo, the longwave** radiation budget, and the partitioning of net radiation into sensible and latent heat fluxes with important regional climate consequences. Thus, knowledge of how new management practices may alter fluxes of water and energy can help us improve our abilities to anticipate changes in the Pampas climate.

Table 1.B. Protocol for analysis of changes in the energy budget for the INTA-San Antonio JECAM site.

Main Phase	Item	Description
Model study plan	Environmental problem and context	Inclusion of new crops (e.g. beans) or changes in management of typical crops (second season maize) could generate changes in albedo, superficial temperature and evapotranspiration.
	Objectives	Describe the changes in crops area, crop rotation and phenolgical changes during the last 15 years and assess its impacts upon surface energy balance (i.e. albedo, ET, T).
	Data Availability	See table 1.A. and 2.
	Calibration and validation criteria	
	Terms of Reference for ex post evaluation of study	
	Scenario definition	2000 to 2014.
Data and Conceptualisation	Select algorithms and methods	We will develop or adapt available algorithms and methods (Franch et al., 2014.
	Define Data Requirements	Meteorological data (daily ppt, solar irradiance, max and min temp), growing season ground control points for landuse clasification, growing season management per field.
	Process raw data	Preprocessing: meteorological data (solar irradiance, ppt, temp), landuse, management practices.
	Gap filling methods	Smooths splines when applicable
Model Set-up	Scripts and algorithms	IDL and R
	Test runs	
Calibration and Validation	Sensitivity analysis	Bootsraps with R
	Optimisation method; select parameters to be optimised	PEST
	Validation	

Simulation	Analyse and interpret results	
	Predict	
	Assessment of Plausibiliy of simulation	
	Aggregation and transfer to regional scale models	
Evaluation	Assessment of achievement of study objectives	Check objectives and describe eventual deviations
	Auditing	External review
Dissemination	Report	Peer reviewed journal articles and extension notes

Table 2 Available data for the INTA-San Antonio JECAM site

Item	Source	Specification	Reference
Meteorological	Weather stations	INTA weather stations networks	
Land use	JECAM Argentina	Crop type maps genreted in the framework of the JECAM activities in Argentina	
Land Management	Farmers	Descriptions of land management practice for specific fields	
Water Management			
Soil	Carta de la República Argentina - INTA	Maps and descriptions of soil types.	
Groundwater			
Calibration And Validation		Ground truth data for calibration and validation of crop type and yield maps.	

Annex C. Protocol for IKI-RAN-SRIA JECAM site

Table 1 Protocol for the IKI-RAN-SRIA JECAM site

Main Phase	Item	Description
Model study plan	Environmental problem and context	During last decades local farmers were modifying crop rotation technique to maximize their income. Winter crops (mainly wheat) fields provide high quality grain of high market demand. Thus winter wheat area in the region was subjected to a gradual increase. Due to peculiarities of local crop rotation technique (80% of arable area has 2-annual cycle of winter crop – clean fallow) this fact may cause soil degradation, lack of soil moisture, spread of pests and weeds and eventual crop yield decrease.
	Objectives	Quantification of the impacts of crop rotation intensification on crop yield. Look for evidence of land use change.
	Data Availability	- Produced by IKI MODIS-based crop type maps for several crop types - Crop calendar for specific fields (crop is winter wheat) - Ground data: LAI, soil chemical composition - In-situ measured yield information at specific fields - Regional soil map - Crop statistical data on yields and sown areas
	Calibration and validation criteria	Arable land and cropland area estimation through remote sensing data should be in line with official statistics; Regression model robustness is estimated with

		R-squared coefficient
	Terms of Reference for ex post evaluation of study	Research article
	Scenario definition	Moderate and high resolution EO data over SRIA JECAM site throughout last decade together with official statistics and in-situ data
Data and Conceptualisation	Select algorithms and methods	Statistical regression analysis , multi-temporal analysis, EO data pre- and post-processing, Locally-adaptive mapping methods
	Define Data Requirements	EO data of high and moderate resolution, ground truth data, official statistics
	Process raw data	Cloud and shadow screening, temporal compositing, consistent time series reconstruction
	Gap filling methods	Local moving window polynomial smoothing
Model Set-up	Scripts and algorithms	Yield prediction model using moderate resolution EO data for regions with crop rotation intensification
	Test runs	For each rayon and at rayon level
Calibration and Validation	Sensitivity analysis	
	Optimisation method; select parameters to be optimised	
	Validation	R-squared coefficient indicates whether yield decrease is explained by positive acreage change
Simulation	Analyse and interpret results	
	Predict	
	Assessment of Plausibility of simulation	
	Aggregation and transfer to regional scale models	
Evaluation	Assessment of achievement of study objectives	Further investigation of rayons which satisfy model to gain more data on actual crop

		rotation schemes and investments
	Auditing	External review
Dissemination	Report	Journal articles

Table 2 Available data for the IKI-RAN-SRIA JECAM site

Item	Source	Specification	Reference
Meteorological	Meteorological station	Temperature and precipitation data every 6 hours	
Land use	Earth observation data derived maps and ground truth data for selected fields	Arable lands, crop types, winter crop yield	IKI RAN
Land Management	No data		
Water Management	No data		
Soil	Ministry of Agriculture	Regional soil types map	
Groundwater	No data		
Calibration And Validation	Ground truth data for selected fields, official statistics on several categories at rayons level	Data on crop types and crop yield. Crop area is estimated both remotely and through statistical data	IKI RAN Rosstat

Table 3 Potential use of remotely sensed data for environmental impact analyses of the IKI-RAN-SRIA JECAM site

Theme	Specification	Observation type
Meteo	Temperature and precipitation data	Meteorological stations
Land use	Crop types	MODIS, Landsat
	Crop yield	MODIS
Land Management		
Water Management		
Soil		

Annex D Protocol for RADI Shandong JECAM site

Tabel 1 Protocol for the RADI Shandong JECAM site

Main Phase	Item	Description
Model study plan	Environmental problem and context	Improvement of Crop water productivity and Nitrate leaching change from agricultural land use
	Objectives	Prediction of impact of cropping management on water productivity and Nitrate leaching.
	Data Availability	see table 2
	Calibration and validation criteria	Select datasets from field, 70% used for calibration, 30% used for validation Objective function: optimization of prediction performance of evopatranspiration, yields, and nitrate leaching. Performance indicators: - at field scale: coefficient of determination, RMSE, Index of Agreement, Mean Absolute Error - at regional scale: coefficient of determination, RSME
	Terms of Reference for ex post evaluation of study	Only applicable for results obtained by modelling with updated data sets and discretization: - Accepted by stake holders (WP4, WP5) - Article accepted by peer reviewed journal
	Scenario definition	Historical and Future Climate series: 30 years, including daily data (Temperature, rainfall)
Data and Conceptualisation	Select algorithms and methods	Discretization : 250-1000m, daily Tools: references 3; ETWatch; Biomass*harvest index; SWAP, WOFOST Aggregate grid data to field and sub-catchment data using area-weighted averaging. And

		aggregate daily and sub-annual data to annual.
	Define Data Requirements	Spatial: meteo, soil, landuse, crop management, crop consumption, fertilizer application, remote sensing data Temporal: Multiyear
	Process raw data	Preprocessing: see manuls of applied tools (references 4,5); Remote Sensed data: Surface reflectance, NDVI, Surface temperature, albedo, ET, biomass, and yield.
	Gap filling methods	Data filling: Sanvitzky_Golay;spatial interpolation; Use representative landuse types for types which lacked parameterization
Model Set-up	Scripts and algorithms	Wu et al. (2008,2012); Vandam et al,(2006); and reference 4,5.
	Test runs	Technical verification
Calibration and Validation	Sensitivity analysis	TBD
	Optimisation method; select parameters to be optimised	Potential use of: http://www.pesthomepage.org/
	Validation	Dependent on study results
Simulation	Analyse and interpret results	Quantifying water productivity and nitrogen
	Predict	Predict impact of climate change on crop water productivity and nitrate leaching;
	Assessment of Plausibiliy of simulation	Dependent on study results
	Aggregation and transfer to regional scale models	Derive simple relations between key parameters and target variables: metamodelling on the basis of model results
Evaluation	Assessment of achievement of study objectives	Dependent on study results
	Auditing	External reviews
Dissemination	Report	Aricles and professional report

Table 2 Available data for the RADI Shandong JECAM site

Item	Source	Specification	Reference
Meteorological	CMA CERN/CAS	Rainfall: 2 rainfall stations, daily values Temperature: 2 stations, daily values Sunshine hours: 2 stations, daily values	1
Land use	RADI	see WP4 （2000，2005，2010 land use）	7
Land Management	RADI	see WP4 （tillage）	
Soil	RADI	see WP4 （Soil type and characterization）	6
Calibration And Validation	CMA CERN/CAS	Calibration at field scale Validation at regional scale	1,6

Table 3 Potential use of remotely sensed data for environmental impact analyses of the RADI Shandong JECAM site

Theme	Specification	Observation type
Meteo	Albedo	FY, MODIS
	Radiation	FY, Global radiation data from JRC
	Rainfall	TRMM
	Actual evapotranspiration	ETWatch
	Soil surface temperature	MODIS
	Cloud cover	FY2/MODIS
Land use	Crop type	HJ-1, GF-1, Landsat 8
	Crop phenology	Ground station MODIS
	Land use changes	Field survey, HJ-1, Landsat5, Landsat8
	Dry biomass	Ground station FY, MODIS, HJ-1
Land Management	Cropping intensity	MODIS, FY3A
	Cropped arable land proportion	MODIS, FY3A, HJ-1 and GF-1
	Tillage managements	HJ-1, Landsat8
	Crop type proportion	Field survey, crop classification based on high resolution images
	Crop rotation	Field survey, High resolution images, like Landsat8, GF-1
Water Management	Irrigation and rainfed area	Field survey MODIS
	Water consumption	ETWatch estimation (ET estimation system)
	Water efficiency	MODIS and ETWatch

Vegetation	Leaf nitrogen content	Field measurement Rapid-eye
Soil	Soil moisture	Ground observation; AMSR-E、FY-3 and GCOM/AMSR

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Annex E. Protocol for SRI NASU-NSAU Kyiv JECAM site

Table 1 Protocol for the SRI NASU-NSAU Kyiv JECAM site

Main Phase	Item	Description
Model study plan	Environmental problem and context	Soil degradation
	Objectives	Prediction of land use change on soil fertility and degradation Studying relationship between nitrogen and soil degradation
	Data Availability	See Table 2
	Calibration and validation criteria	Select data sets for calibration and data sets for validation (e.g. through cross-validation). Objective function: optimization of prediction performance of evopatranspiration and crop yields Performance indicators: - at field scale: coefficient of determination, RMSE, Mean Absolute Error (MAE) - at regional scale: coefficient of determination, RSME
	Terms of Reference for ex post evaluation of study	Article accepted by Peer reviewed article
	Scenario definition	Historical and Future Climate series: 30 years, including daily data (Temperature, rainfall)
Data and Conceptualisation	Select algorithms and methods	Discretization: 250m grids; daily Projection: equal area (e.g. Albers Equal Areas) Tools: SWAP / WOFOST / ANIMO Aggregate grid data to field and sub-catchment data using area-weighted averaging. And aggregate daily and sub-annual data to annual.
	Define Data Requirements	Spatial: meteo, soil, landuse, crop management,

		crop consumption, nitrogen, remote sensing data Temporal: multiyear
	Process raw data	Remote Sensed data: surface reflectance, NDVI, surface temperature, LAI, albedo, ET, biomass, and yield.
	Gap filling methods	TBD
Model Set-up	Scripts and algorithms	TBD
	Test runs	TBD
Calibration and Validation	Sensitivity analysis	TBD
	Optimisation method; select parameters to be optimised	TBD
	Validation	TBD
Simulation	Analyse and interpret results	TBD
	Predict	TBD
	Assessment of Plausibiliy of simulation	TBD
	Aggregation and transfer to regional scale models	TBD
Evaluation	Assessment of achievement of study objectives	TBD
	Auditing	TBD
Dissemination	Report	Articles Professional report

Table 2 Available data for the SRI NASU-NSAU Kyiv JECAM site

Item	Source	Specification	Reference
Meteorological	UHC	General: 9 stations for Kyivska oblast, 2005-present Rainfall: 9 stations, daily values Temperature: 9 stations, daily values	
Land use	SRI NASA	Satellite-derived at 30 m spatial resolution (Landsat, 2013) Satellite-derived at 500 m spatial resolution (MODIS, 2001-2013)	
Land Management	SRI	Nitrogen (TBD)	
Water Management	SRI	Surface waters map	
Soil	SRI	Soil type and characterization (at 1:2,500,000)	
Groundwater	-	Not available	
Calibration And Validation	UHC, UkrStat SRI	Crop yield statistics Biophysical parameters (LAI, FAPAR, FCOVER)	

Table 3 Potential use of remotely sensed data for environmental impact analyses of the SRI NASU-NSAU Kyiv JECAM site

Theme	Specification	Observation type
Meteo	Albedo	MODIS
	Actual evapotranspiration	MSG
	Soil surface temperature	MODIS
	Rainfall	MSG
Land use	Crop type	Landsat-7/8, Sentinel-2
	Land use changes	Landsat-5/7/s8
	Dry biomass	MODIS
Land Management		
Water Management		

Soil		

Annex F. Table of Content of Manual for training EiA sessions

SIGMA workshop/training
Environment Impact Assessment (WP5.1)

Joop Kroes
Piet Groenendijk
Iwan Supit
Jos van Dam

CONTENTS

Annex G. Input of soil parameters San Antonio Areco JECAM site

This Annex describes the schematisation and corresponding input of soil organic matter and soil nitrogen as required Soil Input data for SWAP-WOFOST.
Soil schematization and parameterisation are described, using an example from Argentina: soil serie Capitán Sarmiento (sm)

1. Define vertical discretization in *.swp-file

The numer of soil horizons (ISOILLAY) and the thickness and amount of model compartments (HCOMP and NCOMP) are defined in part 4 of the file *.swp. The values are based on the soil description for the field that is to be simulated.

```
* Part 4: Vertical discretization of soil profile
* Specify the following data (maximum MACP lines):
* ISOILLAY = number of soil layer, start with 1 at soil surface, [1..MAHO, I]
* ISUBLAY  = number of sub layer, start with 1 at soil surface, [1..MACP, I]
* HSUBLAY  = height of sub layer, [0.0..1000.0 cm, R]
* HCOMP    = height of compartments in this layer, [0.0..1000.0 cm, R]
* NCOMP    = number of compartments in this layer (= HSUBLAY/HCOMP), [1..MACP, I]
 ISOILLAY ISUBLAY  HSUBLAY    HCOMP    NCOMP
     1       1       18.0      1.0       18  ! A (A1+A2) 0-18 cm
     2       2       12.0      1.0       12  ! BA  from 18-30 cm
     3       3       15.0      1.0       15  ! Bt1 from 30-45 cm
     4       4       55.0      1.0       55  ! Bt2 from 45-100 cm
     5       5       50.0      1.0       50  ! BC  from 100-150 cm
     6       6      450.0     10.0       45  ! C   from 150-600 cm
* end of table
```

2. Define Soil hydraulic properties in *.swp-file

Several options exist to define soil hydraulic properties to the defined soillayers:

- As functions specifying for each soil layer: ORES,OSAT,ALFA, NPAR,KSAT,LEXP
- As Table: use this option in case you have observed values (switch SWSOPHY = 1)

For the functions you may use pedotransfer functions as given by Hypress (Wösten, et al.), UNSODA (Nemes et al.), ROSETTA (Schaap et al,) or StaringSeries (Wosten et al), see [3] .. [11].
Preferably try to find data sources within South America. Hodnett and Tomasella (2002) developed ptf's for water-retention curves of tropical soils and Wosten et al (2013) applied them in a study in S-Africa, but it requires a simplification for ptf's about hydraulic conductivity.

We started with a dataset from NL, but then decided to select the ptf's described by Wosten et al. (2001) and try to find data to verify the output. We used eq. 16 from Keller & Håkansson (2010) to estimate bulk density from soil particle size distribution and soil organic matter content.

```
Part 5: Soil hydraulic functions
* as table or as function
 SWSOPHY = 0   ! Switch for use of tables or functions[tables=1, functions=0]
* If SWSOPHY = 1 then supply input data for tables (see manual)

* If SWSOPHY = 0  Specify for each soil layer (maximum MAHO):
* ISOILLAY1 = number of soil layer, as defined in part 4 [1..MAHO, I]
* ORES   = Residual water content, [0..0.4 cm3/cm3, R]
* OSAT   = Saturated water content, [0..0.95 cm3/cm3, R]
* ALFA   = Shape parameter alfa of main drying curve, [0.0001..1 /cm, R]
* NPAR   = Shape parameter n, [1..4 -, R]
* KSAT   = Saturated vertical hydraulic conductivity, [1.d-5..1000 cm/d, R]
* LEXP   = Exponent in hydraulic conductivity function, [-25..25 -, R]
* ALFAW  = Alfa parameter of main wetting curve in case of hysteresis, [0.0001..1 /cm, R]
* H_ENPR = Air entry pressure head [-40.0..0.0 cm, R]

* For this example data were taken from the StaringSeries using indications from the
* soil profile description, such as Eq.humedad (%) and particle size distribution:
* first attempt using Staring Series from NL (Wosten et al.,1994)
  ISOILLAY1,  ORES,  OSAT,  ALFA,  NPAR,  KSAT,   LEXP,   ALFAW  H_ENPR
       1  ,   0.0100,0.4500,0.0152,1.4120,17.8100,-0.2130,0.0304,0.0000   ! B3
       2  ,   0.0100,0.4500,0.0152,1.4120,17.8100,-0.2130,0.0304,0.0000   ! B3
       3  ,   0.0100,0.4200,0.0163,1.5590,54.8000, 0.1770,0.0326,0.0000   ! B4
       4  ,   0.0000,0.6000,0.0243,1.1110, 5.2600,-5.3950,0.0486,0.0000   ! B11
       5  ,   0.0000,0.4100,0.0291,1.1520, 5.4800,-6.8640,0.0582,0.0000   ! O6
       6  ,   0.0000,0.4100,0.0291,1.1520, 5.4800,-6.8640,0.0582,0.0000   ! O6
* --- end of table
```

*Figure 1 Input section of *.swp-file*

Results with ptf's were poor and it was decided to switch back to the first attempt using the Staring Series.

3. Define Soil Organic Matter and Soil Organic nitrogen In *.snp-file

The sub-model for carbon and nitrogen in the soil uses a one-layer approach. The thickness of this layer should be defined as the input parameter dz_WSN. The value represents the thickness of the rootable zone and serves to interact between soil hydrology (defined by SWAP-modules) and roots for crop uptake and growth (defined by WOFOST-modules).

The value in the example is the rootable zone for soy beans in the soil series Capitan Sarmiento (Sm) :

```
* effective depth of soil layer
dz_WSN = 0.6
```

The organic matter content should be given for different soil organic matter pools [1].

The sum of these pools should be equal to the observed value. The observed value for the rootable zone is input and can be derived from observations taking the weighted average of the values for the different soil layers/horizons.

Be aware of the units: values for soil organic matter in the file *.snp are expressed in kg soil organic matter (SOM) per m3 soil.

In the example of the soil series Capitan Sarmiento (Sm) the weighted mean SOM value will be 2.42 % (= kg SOM / kg soil), assuming a dry bulk density of 1300 kg/m3 soil volume), then the input value for SOM becomes 31.46 kg SOM per m3 soil.

Initially, the total of the organic matter present in soil should be attributed to the ten pools. The total SOM value should be distributed over the SOM-pools as indicated by [1]: 92 % in pool HUM_t and the rest in the remaining SOM-pools.

Table A.1 Intial distribution of Soil Organic Matter: 10 values of the SOM-pools

		%	kg SOM/m3 soil
FOM1_t	DPM	0.20%	0.0629
FOM2_t	DPM	0.90%	0.2831
FOM3_t	DPM	0.10%	0.0315
FOM4_t	DPM	0.10%	0.0315
FOM5_t	RPM	1.30%	0.4090
FOM6_t	RPM	1.50%	0.4719
FOM7_t	RPM	1.30%	0.4090
FOM8_t	RPM	1.30%	0.4090
BIO_t	BIO	1.30%	0.4090
HUM_t	HUM	92.00%	28.9432
		100.00%	31.4600

Then, a pre-run is advised by which the model simulates the distribution of organic matter, as expressed by the pools' contents. The final distribution is given in the PROJECT_nut.end file.

The pre-run can be repeated a number of times. If the fractional distribution of the pools seems to be stable, the repetition of pre-runs can be stopped. This final fractional distribution can be used to assign the initial values.

Soil organic nitrogen requires no additional input. Table 4 of [1] gives the 10 N-values of the SOM-pools.

4. Additional info:

Paragraph 3.1 of the User Manual [1]

Chapter 8 of the User Manual for Nitrogen modeling with SwapWofost [2]

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