GROWING WATER LANDSCAPE: AN ACTOR-ORIENTED RESEARCH ON VITTEL WATERSHED

Arnaud GOBILLOT [1] *– Marc BENOIT* [1]

[1]SAD ASTER, INRA, 662, avenue Louis Buffet 88500 Mirecourt- France, Email: Arnaud.Gobillot@mirecourt.inra.fr; Marc Benoît : Email: Marc.Benoit@mirecourt.inra.fr

Introduction

AGREV 3 (Agriculture Environment Vittel), as research-action project (RAP) (Hatchuel *et al*., 2000), consists to preserve a mineral watershed under 6200 ha of agricultural land. To be labelled as natural mineral water, the water cannot contain more than 10 mg of nitrate L^{-1} and must not contain pesticides residues. In order to reach these goals, Agrivair (a Nestlé Waters entity) challenged INRA (French National Agronomic Institute), to imagine, to help to implement and to evaluate a re-designing of the agricultural practices and landscape to allow a valuable farming in the watershed and to keep capacity to produce mineral water on the long term.

The AGREV3 objective was threefold to (i)understand the relationship between farming practices and the nitrate rate in ground water, (ii)identify and test the practices necessary to reduce or maintain the rate of nitrates at the desired level rate, (iii)re-build and optimize the nitrogen cycle at different scales (field, farm and watershed). Since the first stages of our project (AGREV 1 & 2) in 1989, we propose an RAP framework to provide a useful and stimulating tool for farmer and Agrivair to preserve water resource and farming systems.

Materials and Methods

1. Tackling With The Research Protocol

The evolution of farming practices within the watershed responded mainly to the international food market and CAP regulations which are constantly moving. So, our research-action program has to be so continuously adapted to the current wishes of the farmers with a stable goal, improving the water resource quality. The demand to improve and adapt their different practices brings back many agronomical questions to solve at the landscape level of the watershed. The dialogue between the farming community and Vittel mineral enterprise, through the establishment of AGREV program, invited farmers to participate to build the research action program and to identify acceptable conditions for new production systems that would be compatible with Vittel's objectives and the long term evolution of their farming systems through their multiple objectives including food security, adequate cash income and social security. Thus an actor oriented perspective lead us to expect a range of responses to the promotion of a new agricultural landscape and agricultural technology.

2. Involving In The Data Acquisition And Mining Processes

a. Understanding the farming systems dynamics: why farmers do what they do at different scale of time and space?

The landscape designed by farmers reveals at various scales logical processes and driving forces related to the soil, climate, logistic management, and economical pressure whose understanding is a major challenge for landscape agronomists (Benoît *et al*., 2012). So, we try to deliver operative knowledge to the main landscape managers: the farmers and their organizations (Deffontaines *et al*., 1995; Cavazza, 1996; Benoît *et al*., 2007).

b. Identifying, testing, and validating the management practices to reduce the nitrate leaching through on farm innovation required a precise knowing of the spatial organization of farming practices and impacts. Thanks to our territorial diagnosis, we design within 24 farmers' field's experimentations with 170 ceramics cups and a net of 20 springs related to 20 characterized watersheds. This allows us to evaluate the water quality induced by their practices. We build this net of on farm innovation fields to be representative of the diversity of the farming practices, landscape patterns and soil characteristics of the watershed.

Those exchanges will allow us to promote technical systems which create the best nitrogen efficiency. This works aim to establish several different scenarios at the watershed scale to validate, with the farmers and watershed managers, the appropriate sectors. We are currently trying to lead to a win-win situation both for farmers and watershed managers.

3. Thinking About The Type Of Results Dissemination

The RAP leads to (i) a better understanding of their practice and also on the reason conditioning their farming practices, (ii) improve the spreading of best management practices. The knowledge supplied by the formal research becomes raw material for farmer experimentation. Thus, from an actor oriented perspective, farming practices re-design is a complex, multistranded, and multidirectional process, involving many actors other than scientist in the formal research system. Moreover, the emergence of particular strategies depends on coalitions which combine their resources to push for a particular pathway of technical change. These "coalitions building" involve many diverse actors and dissemination ways.

Results and Discussion

The evolution of nitrogen leaching has been measured since 1988 with ceramic cups collecting system. All of these trials give us more than 4000 measurements points on 10 different crops. A classification of the crops and amounts of farmyard manure applied according to their nitrate leaching level was done. All the measurements on plots, crop rotations, and precise data of agricultural practices build a territory agronomically well informed through a global farmland observatory. The eighteen years of on-farm's innovation trials allows to understand the trends of water quality and to contribute to changes in the use of the lands from the watershed. This methodological process is based on the idea of crop succession and observatory fertilizing practices, used as an indicator of the organization of the farming space and time (Xiao *et al*., 2014). One of our previous researches AGREV 1 & 2 led to the following prescriptions which are currently respected by the 30 farmers on the watershed to maintain a rate of 10 mg L^{-1} of N-NO_3^-:(i) Giving up maize production for animal feed (ii) Maintain producing pasture (iii) Reducing stacking rate to a maximum of one livestock unit per hectare (iv) Composting animal farmyard to achieve an optimal application in quantity and time within the fields, and mainly on the grassland (v) Giving up agrochemicals (no pesticides), (vi) Promoting technical solutions to optimized nitrogen use within the territory.

Conclusions

All of these rules have to be improved with our current new results and the farmer advice. Our presentation aims to show the methodology to be applied in order to share our approaches with other European researches in this way. To encourage the best agronomic management practices, we work on establishing several different scenarios at the watershed scales to validate, with the farmers and watershed managers, the best global solutions to lead to a win-win situation both for farmers and watershed managers. By our work we aim to build a participatory research that leads to:(i) understand the entire system and farmer perspective, through a common research question, (ii)develop appropriate agricultural technology through a common research protocol, (iii) actively involve the farmers in the entire farmer participatory research process, focusing on data acquisition and mining processes (Conducting the research in farmers' fields), facilitating and providing new idea and/or unknown technology to the farmers, promoting innovative methodologies and flexibility, (iv) think about the type of results dissemination,(v)build a continuous re-design of questions on the future of this water landscape.

Acknowledgements

We would like to thanks all the farmers and Agrivair for their constant help and questioning.

References

Benoît M. – Rizzo D. – Marraccini E. – Moonen A.C. – Galli M. – Lardon S. – Rapey H., – Thenail C. – Bonari E.: 2012. Landscape agronomy: a new field for addressing agricultural landscape dynamics. *Landscape Ecology,* **27**(10):1385–1394.

Benoît M. – Mignolet C. – Herrmann S. – Rizzo D. – Moonen C. – Barberi P. – Galli M. – Bonari E. – Silvestri N. – Thenail C. – Lardon S. – Rapey H. – Marraccini E. – Le Ber F. – Meynard J.: 2007. Landscape designed by farming systems: a challenge for landscape agronomists in Europe. In *Farming systems design 2007*, International symposium on methodologies on integrated analysis on farm production systems, Catania, Italy, book 1-Farm-regional scale design and improvement, pp. 137–138. Eds M. Donatelli, J. Hatfield and A. Rizzoli.

Deffontaines J.P. – Thenail C. – Baudry J.: 1995. Agricultural systems and landscape patterns: how can we build a relationship? *Landscape & Urban Planning,* **31**:3–10.

Fowler D. *et al*.: 2013. The global nitrogen cycle in the twenty-first century. *Philos. Trans. of the Royal SocietyLondon, Series B* **368**:20130164.

Hatchuel A.L.: 2000. Recherche, intervention et production de connaissances. *Conferences et Ateliers,* pp. 27–40.

Ledoux E. – Gomez E. – Monget J.M. – Viavattene C. – Viennot P. – Ducharne A. – Benoit M. – Mignolet C. – Schott C. – Mary B.: 2007. Agriculture and groundwater nitrate contamination in the Seine basin. The STICS–MODCOU modelling chain. *Science of the Total Environment,* **375**:33–47.

Xiao Y. – Mignolet C. – Mari J.-F. – Benoît M.: 2014. Modeling the spatial distribution of crop sequences at a large regional scale using land-cover survey data: a case from France. *Computers in Electronic Agriculture,* **102**:51–63.

INTENSIFYING FORAGE-LIVESTOCK SYSTEMS: TRADE-OFFS BETWEEN FOOD SECURITY AND INCOME

Skye GABB [1, 2] – Lindsay BELL [1] – Edi BASUNO [3] – Di PRESETWIDGE [1] – Julian PRIOR [2]

[1] Agriculture, CSIRO, Toowoomba, QLD, Australia, Email: skye.gabb@csiro.au
[2] School of Environment and Rural Science, University of New England, Armidale
[3] Indonesian Centre for Agricultural Socio-economic and Policy Studies, Bogor

Introduction

Sustainable intensification of crop-livestock systems requires production of more food and animal products without using more land, water or other inputs. Integrating forage legumes into farming systems can contribute to such intensification. However, the impact of forage legumes varies with social, economic and agro-ecological factors. This research explored the trade-offs and impacts of forage legumes, identifying optimal management strategies and target farm typologies.

Materials and Methods

This case study of maize-cattle farms in West Timor, Indonesia, assessed forage legumes impacts for six farms with different soils and climates. Each characterised household grew and then assessed Butterfly pea (*Clitoria ternatea*) using a resource flow diagram. This informed the scenario matrix analysed using the bio-economic model, the Integrated Analysis Tool (IAT) (Lisson *et al*., 2010). The ten year simulations assessed two forage options; (a) replacing increasing proportions of maize-cowpea intercrops with a maize-butterfly pea relay, or (b) a butterfly pea permanent stand; and two levels of cattle ownership, (a) current levels or (b) double breeder numbers.

Results and Discussion

Legume management, cattle ownership and arable cropping area influenced the impact of forage legumes on whole farm income. Permanent stands were more profitable than relays; returning on average 1,512,000 IDR/year per 0.1 ha planted compared with 1,403,000 IDR/year. However, the economic advantage of a permanent stand over a relay was only evident when at least 40% of the maize-cowpea crop was replaced, below this the difference in additional income was less than 10% (Figure 1). If 40% of a maize-cowpea crop was replaced by a permanent stand, food self-sufficient households experienced grain deficits (Table 1). While income was still above baseline levels after grain deficits were met, the cash balance of permanent stands and relays were similar. In fact, a permanent stand was only superior when breeder numbers were doubled and large areas were planted. Consequently, for the majority of situations a relay provided equivalent benefits without compromising maize grain self-sufficiency.

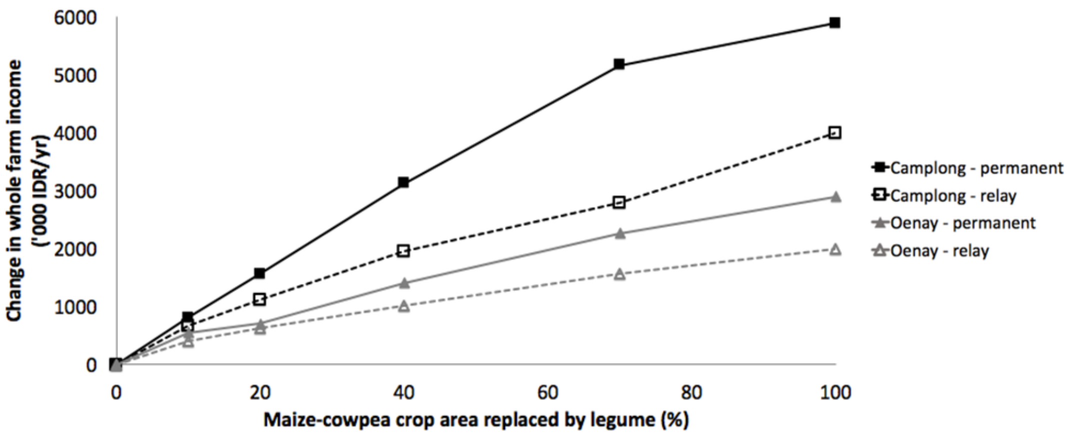

Figure 1. Change from baseline whole farm income for current levels of cattle ownership for two farms (Camplong and Oenay) when legumes were planted as a permanent stand (—) or relay (- - -).

Table 1. Food self-sufficiency and change from baseline whole-farm income where 40% of maize-cowpea crops were replaced with a maize-butterfly pea relay (Relay) or a butterfly pea permanent stand (Permanent) for six village farms

	Cattle herd (Cows)	**Maize (ha)**	**Maize self-sufficiency (kg/year)**	**Maize self-sufficiency (kg/year)**		**Change from baseline whole-farm income after meeting food security ('000 IDR/year)**			
						Baseline cows		**Double cows**	
Village farm	**Baseline**			**Relay**	**Perm anent**	**Relay**	**Perm anent**	**Relay**	**Perm anent**
Food Self-Sufficient									
Camplong	12 (4)	0.93	305	305	-69	1,960	1,938	6,093	8,204
Uel	1 (1)	0.40	96	96	-86	547	468	3,327	2,800
Manuali	4 (2)	0.05	15	15	-9	416	454	2,264	2,294
Oenai	1 (1)	0.36	42	42	-131	1,018	757	2,397	1,819
Non Food Self-Sufficient									
Ekateta	6 (2)	0.35	-190	-190	-330	1,373	1,155	2,145	1,466
Kesetnana	2 (1)	0.51	-198	-198	-443	502	-604	1,777	576

Despite this, farmers prefer permanent stands because of lower labour requirements and concerns that relays would reduce grain production. Consequently, they may prefer a small permanent stand that doesn't compromise food self-sufficiency. However, the financial returns of this option would depend on herd size, with income increasing more for ≥ 6 cattle (1,500,000 IDR/year) than for ≤4 cattle (900,000 IDR/year).

Conclusions

Forage-livestock intensification mainly benefits food-secure households with high resource endowments, while the trade-offs for poorer food-insecure households are too large. Forage-livestock intensification that minimises trade-offs and labour inputs is more likely to achieve the potentially large economic benefits.

Reference

Lisson S. – MacLeod N. – McDonald C. – Corfield J. – Pengelly B. – Wirajaswadi L. – Rahman R. – Bahar S. – Padjung R. – Nasruddin R.: 2010. A participatory farming systems approach to improving bali cattle production in the smallholder crop-livestock systems in Eastern Indonesia. *Agricultural Systems*, **103**(7):486–497.

AGRONOMICS: ENABLING FIELD-SCALE CROP RESEARCH

Daniel KINDRED [1] – Roger SYLVESTER-BRADLEY [1] – Ben MARCHANT [2] – Sebastian RUDOLPH [2] – Sarah CLARKE [1] – Susie ROQUES [1] – Vincent GILLINGHAM [3]

[1] ADAS Boxworth, Cambridge, CB23 4NN, UK, Email: daniel.kindred@adas.co.uk
[2] British Geological Survey, Keyworth, Nottinghamshire, UK
[3] AgSpace, Swindon, UK

Introduction

The challenge facing agriculture of producing more whilst impacting less is real and immediate. For success it is crucial that researchers, farms and the supply chains engage effectively. Knowledge exchange must become a multi-way process including increased interaction between the researcher and the farmer. Thus far, any extrapolation between small (science) and large (industry) scales has entailed large untestable 'leaps of faith'; the two communities have worked at different scales, with different concepts for the analysis of crop performance and different standards of proof. We contend that what is needed is a shared interest in the challenges and constraints faced in the field.
ADAS recently established an 'Agronōmics' initiative to develop common concepts, metrics, targets and techniques that could enable joint analysis of crop performance – in terms of both productivity and sustainability – by farmers and researchers. Traditional crop research employs experimental designs that minimise effects of uncontrolled environmental variables so that responses (e.g. in yield) to controllable inputs (seed, tillage, fertilisers, pesticides) can be tested. However, the area of these small plot trials commonly restricts their relevance to one site and, while their small scale may optimise internal precision and accuracy of the test, it limits wider relevance of the results.
We propose that, over and above the scientific challenges at lab scale, there are big opportunities for science in investigating the multiple variables and emergent properties affecting translation between small and large scales; not least amongst these are the interactions between agronomic innovations – new germplasm, chemistry or machinery – and soil. Research is needed to understand such interactions but current dependence on small-plot trials generally proves inadequate for this because 'sites', even if there are many, confound many factors with soil, especially climate and farming system. However, technologies for on-farm automation ('precision farming') now provide opportunities for quantitative phenotyping at field and farm scales, and also (critically) they provide new understanding of spatially variable factors, particularly soil.
We have identified five key challenges necessary to support an 'Agronōmics' approach: (i) acceptance by farmers and scientists of common concepts for explanation of crop performance, such as 'resource capture'; (ii) motivated and co-ordinated networks of farms that embrace regional and landscape dimensions; (ii) more precise and accurate farm machinery; (iii) new spatially-referenced statistical techniques for modelling and testing on-farm data at intra-field scale; and (v) facilitating software.

Materials and Methods

A farm research network was developed called 'LearN' to study nitrogen (N) nutrition of wheat. Conventional and tramline trials were established on each farm testing standard, low (-60 kg ha^{-1}) and high (+60 kg ha^{-1}) rates of fertiliser N. Through ADAS's Agronōmics Project, tramline trials were supported by detailed treatment and harvesting protocols, bespoke software, and spatial statistics that enable location-specific establishment, treatment and harvesting of sub-tramline areas, transfer and storage of data in standard format, data cleaning (to remove outliers), identification of combine run, direction and position, correction for time lags and GPS drift, location of treatments and wheelings, and calculation of means and variances for combine runs, tramlines, and sub-tramline blocks. 'Spatial Discontinuity Analysis (SDA)' was devised (Rudolph *et al*., 2016) to test differences across a treatment boundary, and whether these varied longitudinally i.e. due to soil.

Results and Discussion

Yield maps of example tramline trials are shown in Figure 1. Spatial variation within fields was generally larger than the effects of imposed treatments. SDA showed effects at tramline scale to have detection limits between 0.05 and 0.8 t ha^{-1}, dependent on the quality of the yield data and the unmodelled spatial variation. The more precise trials also identified significant soil x treatment interactions. Adjacent conventional small-plot trials gave LSDs between 0.34 to 1.8 t ha^{-1}.

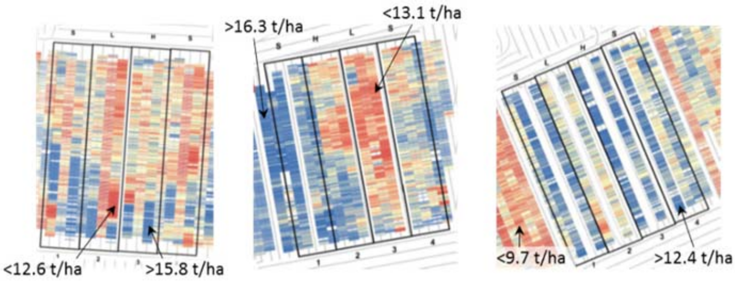

Figure 1. Three example yield maps from commercial harvesters showing effects of low (L), standard (S) and high (H) N treatments applied by farm spreader. Yields increase from red to blue.

Conclusions

Whilst the quality of data from yield monitors and statistical approaches could both be improved, and further validation is required, comparable precision can be achieved in tramline-scale comparisons as in small-plot trials. We conclude that wider adoption of an Agronōmics approach offers powerful opportunities for both farms and researchers to work jointly on questions that matter to both, at a scale that is relevant to commercial cropping, and that enables new understanding of soil (and other spatial) interactions.

Acknowledgements

The Agronōmics Project is led by ADAS UK Ltd. with the Courtyard Partnership, BASF, Trials Equipment Ltd., VSN International and the British Geological Survey, and is co-funded by Innovate UK. Data were taken from the AHDB funded LearN project involving ADAS, NIAB TAG, Agrii and CF Fertilisers.

Reference

Rudolph S. – Marchant P.B. – Gillingham V. – Kindred D. – Sylvester-Bradley R. 2016. Spatial Discontinuity Analysis a novel geostatistical algorithm for on-farm experimentation. *Proceedings of the 13th International Conference on Precision Agriculture.* Monticello, IL: International Society of Precision Agriculture.

NAMASTE: A DYNAMIC INTEGRATED MODEL FOR SIMULATING FARM PRACTICES UNDER GROUNDWATER SCARCITY IN SEMI-ARID REGION OF INDIA

Marion ROBERT [1] – Alban THOMAS [2] – Jacques-Eric BERGEZ [1]

[1] UMR 1248 AGIR, INRA, F-31326 Castanet-Tolosan, France, Email: marion.robert@toulouse.inra.fr
[2] Toulouse School of Economics, UMR 1081 LERNA, INRA

Introduction

Farming systems are complex structures with several dimensions interacting in a dynamic and continuous manner. This complexity peaks in semi-arid regions of India, where small farms encounter a highly competitive environment for markets and resources, especially unreliable access to water from rainfall and irrigation. To represent farmers' management strategies in this environment, we propose the model NAMASTE, which was conceived and based on data collected in the Berambadi watershed in southern India.

Conceptual Approach

The farm system is divided into three interactive sub-systems: i) the decision sub-system (manager or agent), which describes the farmer's decision process; ii) the operating sub-system (technical system), which translates the decision orders into action execution and dynamics of farm resources; and, iii) the biophysical sub-system, which describes interactions between physical and biological elements, in particular the relations between ground water, soil, and plant growth and development (Le Gal *et al*., 2010). The farm system interacts with an external system that simulates pressure and conditions in the farming environment such as rainfall (Weather), market prices (Market), electricity service (Electricity) and the village source of labor and equipment (Village). The model is implemented in the RECORD platform (Bergez *et al*., 2013).

Dynamic Functioning

Farmers make decisions at different stages of the decision-making process:

1. **Yearly Loop, Beginning Of The Year:** Farmers decide whether to invest in irrigation equipment and select the corresponding cropping system that will ensure the best income for their long-term climatic and price expectations.
2. **Seasonally Loop, Beginning Of The Season:** Farmers integrate new observed knowledge about climate and prices so that the cropping system initially selected in the strategic stage may no longer best optimize their income. They review their crop selection and match the best practices to obtain the best cropping system for the known farming conditions.
3. **Daily Loop, Every Day Over The Entire Season:** From the cropping system selected in the tactical stage, farmers decide and adjust their daily crop operations in each plot depending on climate conditions and resource constraints.

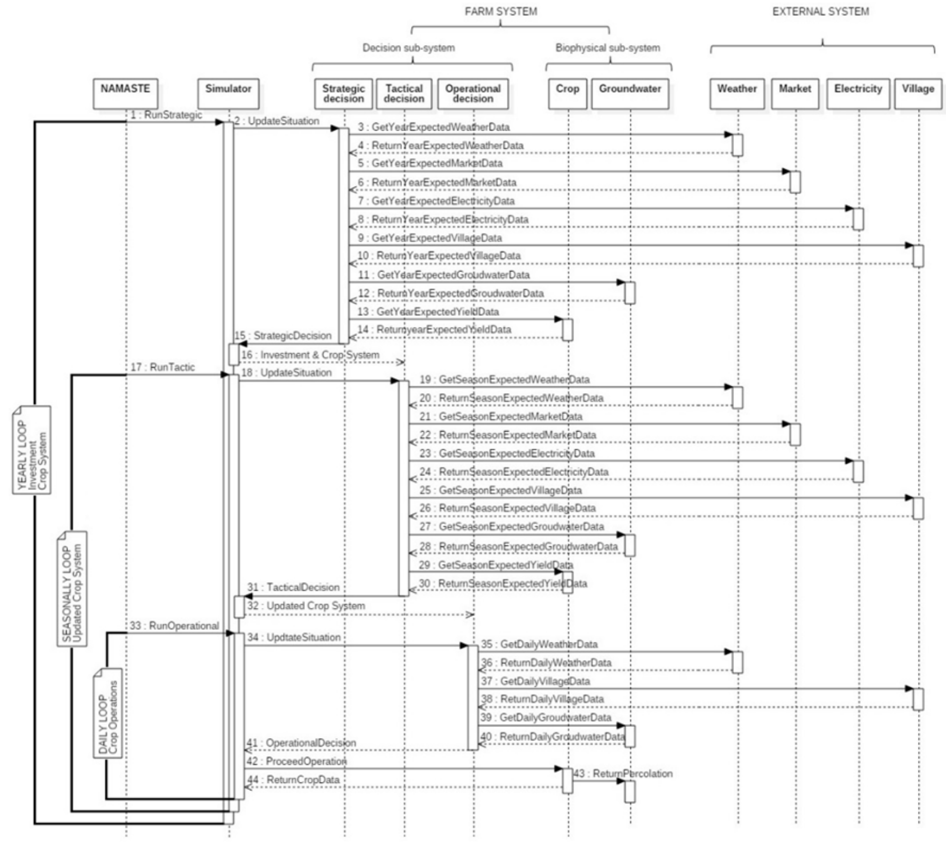

Figure 1. Sequence diagram of a NAMASTE simulation.

Uses of the Model

A baseline scenario was developed to simulate current farming practices. Scenarios with changes in climate, groundwater table, and government subsidies were developed to predict their impacts on cropping systems and the water table.

Acknowledgements

This study was funded by the CEFIPRA, the INRA flagship program ACCAF and the Doctoral School of the University of Toulouse (EDT).

References

Le Gal P. – Merot A. – Moulin C.: 2010. A modelling framework to support farmers in designing agricultural production systems. *Environmental Modelling & Software,* **25**(2):258–268.

Bergez J.E. – *et al.*: 2013. An open platform to build, evaluate and simulate integrated models of farming and agro-ecosystems. *Environmental Modelling & Software,* **39**:39–49.

EX ANTE EVALUATION OF CROPPING SYSTEMS FOR WEED-MEDIATED PESTS AND ENVIRONMENTAL BENEFITS WITH SIMULATION-BASED INDICATORS

N. COLBACH [1] – C. BOCKSTALLER [3] – F. COLAS [1] – S. GIBOT-LECLERC [2] – D. MOREAU [1] – O. POINTURIER [1] – W. QUEYREL [2] – J. VILLERD [3]

[1] INRA, UMR1347 Agroécologie, 21000 Dijon, France Email: Nathalie.Colbach@dijon.inra.fr
[2] AgroSup Dijon, UMR1347 Agroécologie, 21000 Dijon, France
[3] INRA, UMR1121 LAE, Nancy-Colmar, France

Introduction

Integrated crop protection tolerates residual weed floras if they are not harmful for crop production. These weeds can host harmful crop pests, among which parasitic plants such as broomrape (*Phelipanche ramosa*). They can also contribute to reduce soil erosion as well as nitrate and pesticide leaching. To evaluate these weed impacts of management practices *ex ante,* we developed indicators for the weed dynamics model FLORSYS (Colbach *et al*., 2014) and then used the model to predict weed-mediated broomrape risk and environmental benefits in cropping systems from five French regions.

Materials and Methods

FLORSYS is a virtual field on which cropping systems can be tested. It predicts indicators of weed impact on biodiversity and production (Mézière *et al*., 2014). Here, several new indicators were developed (Table 1). For instance, for the potential weed contribution to reduce soil erosion, the potential rain interception by weeds is calculated each dayby summing the relative light interception (as a proxy for rain interception) for each plant p of each weed species w: $Iweed_d = \sum_w \sum_p Light\ interception_{wpd}$. The daily interception $Icrop_d$ by crop plants is calculated on the same principle. For a given cropping season, the indicator value *Ierosion* is the sum of days from crop harvest *h* to harvest *h+1* with $Iweed_d > 0.1$ and $Icrop_d < 0.2$.
Then, 246 arable cropping systems from five French regions (Aquitaine Burgundy, Lorraine, Paris Basin, Poitou-Charentes) were simulated over 27 years and repeated 10 times with randomly chosen regional weather series.

Results and Discussion

Antagonisms and synergies between weed-impact indicated were analysed with Pearson correlation coefficients (Table 1). For instance, weed-mediated broomrape was positively correlated to weed-based food offer for bees and carabids, and, to a lesser degree, to vegetal biodiversity, field infestation and weed-mediated environmental benefits. Then, regression trees were used to quantify the effect of cultural practices on weed-impact indicators (Fig. 1).

Conclusions

There tended to be an antagonism between weed-mediated environmental benefits and biodiversity on one hand, weed-mediated pests and harmfulness on the other hand. Additional analyses and simulations will be necessary to design innovative cropping systems that reconcile high weed benefits with low harmfulness.

Table 1. Examples of antagonism (in bold) and synergy between weed benefits and harmfulness. Pearson correlation coefficients between weed-impact indicator values of 246 cropping systems averaged over 27 simulated years

New Weed-Impact Indicators	Vegetal **Biodiversity**: Species Richness	Weed-Based **Food Offer** For			Weed **Harmfulness**: Field Infestation	Weed-Mediated **Pest**: Broomrape	Weed-Mediated **Environmental Benefits**	
		Birds	Carabids	Bees			Erosion Protection	Reduced Pesticide Leaching
Broomrape Risk	**0.55**	-0.02	**0.64**	**0.82**	0.45	1.00	**0.49**	**0.45**
Erosion Protection	0.50	**-0.15**	0.37	0.64	**0.20**	**0.49**	1.00	0.45
Reduced Pesticide Leaching	0.56	0.07	0.48	0.62	**0.61**	**0.45**	0.45	1.00

[$] All coefficients were significant at *P*=0.001

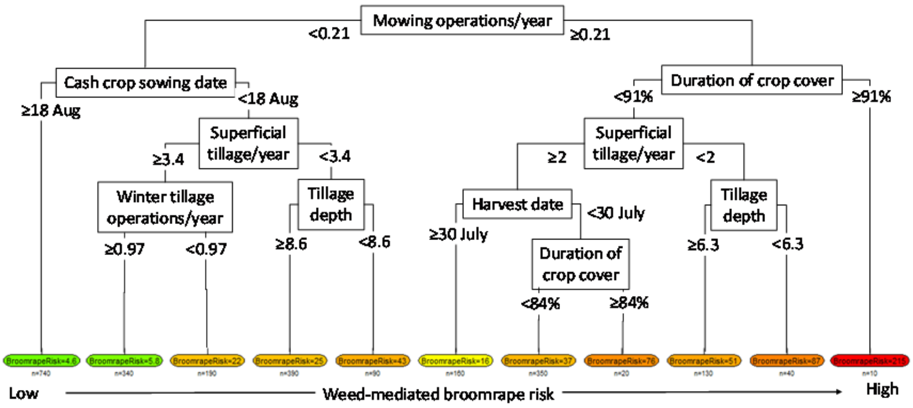

Figure 1. Identification of combinations of cultural practices that affect weed-mediated broomrape risk. Regression tree of indicator values of 246 cropping systems averaged over 27 simulated years.

Acknowledgements

This project is supported by INRA, the French project CoSAC (ANR-14-CE18-0007) and the research programme "Assessing and reducing environmental risks from plant protection products" funded by the French Ministries in charge of Ecology and Agriculture.

References

Colbach N. – Biju-Duval L. – Gardarin A. – Granger S. – Guyot S.H.M. – Mézière D. – Munier-Jolain N.M. – Petit S.: 2014. The role of models for multicriteria evaluation and multiobjective design of cropping systems for managing weeds. *Weed Research,* **54**:541–555.

Mézière D. – Petit S. – Granger S. – Biju-Duval L. – Colbach N.: 2015. Developing a set of simulation-based indicators to assess harmfulness and contribution to biodiversity of weed communities in cropping systems. *Ecological Indicators,* **48**:157–170.

TRADE-OFFS ANALYSIS BETWEEN DURUM WHEAT YIELD AND NITROGEN EFFICIENCY IN THE FIELDS OF FARMERS IN TUNISIA

Y. BEN ZEKRI[1, 4] – K. BARKAOUI[3] – I. MEKKI[2] – H. MARROU[1] – H. BELHOUCHETTE[4] – J. WERY[1]

[1] SupAgro [3] Cirad [4] IAMM, UMR System, 2 Place Viala, Bâtiment 27, 34060 Montpellier, France, Email: youser_0301@hotmail.fr
[2] INRGREF, Laboratoire Génie Rural, 2080 Ariana, Tunisia

Introduction

Satisfying the growing demand for agricultural products while improving N input efficiency in Mediterranean cereal systems (Hochman *et al*., 2013) will require significant change in cropping systems structure and management. Our hypothesis, developed from the concepts of eco-efficiency (Keating *et al*., 2010) is that it is possible to obtain a better compromise between production and resource efficiency by adopting transformational technologies, such as changing genotype or by temporal and/or spatial diversification of crops. In this study, the hypothesis is tested on rotation as a temporal complexification of a cereal system structure. We addressed the following question: does crop rotation allow for a better trade-off between nitrogen efficiency and yield of Durum wheat in farmers' conditions and how far can it compensate for the reduction of area allocated to wheat?

Materials and Methods

We introduced in the efficiency analysis two intermediate variables between nitrogen supply and grain yield in order to establish a four-quadrant diagram (Fig 1). Nitrogen uptake was used, on the right of this diagram, to separate the efficiencies of resource capture and resource conversion (De Wit, 1992). On the left, N-efficiency was introduced as intermediate variable, in order to visualize trade-offs between efficiencies and production or input. In each quadrant we established boundary curves which represent the maximum achievable performances (yield, N uptake, N efficiency) when the input (here N fertilizer) is the only limiting factor. This framework has been tested on 432 "agronomic situations" (climatic year, previous crop and N rate) of Durum wheat in farmers' fields representative of the diversity of farmers practices in four regions of Tunisia.

Results and Discussion

Nitrogen capture by Durum wheat is benchmarked against boundary curves that represent achievable nitrogen uptake when nitrogen supply is the only limiting factor (Fig 1.A).These boundary curves were significantly different according to the preceding crop. The highest achievable N absorbed was found for irrigated wheat grown after vegetables (CM_Dwi), followed by rainfed wheat grown after legumes (LG_Dwr). In contrast, the lowest achievable N absorbed was found for rainfed wheat in a cereal-wheat rotation (CE_Dwr), revealing the poor N-capture potential of rotation sequences based on cereals only. Our method of estimation of N absorbed (Fig 1.B) does not allow discussion of the effect of the preceding crop on the efficiency of N conversion into grain but experimental data showed that this factor does not break the proportionality of yield to N absorbed. The equations of boundary curves of quadrants A and B allowed us to establish the trade-off curves between N efficiency and an objective of grain production (Fig 1.C) or of N fertilizer use (Fig 1.D). They show that in cereal-based systems of Tunisia high N efficiency can be obtained but only with low level of fertilization and grain yield. Changing the preceding crop into legume does not change this tendency but creates a new efficiency frontier which allows both an increase in Yield and N efficiency (Fig 1.C), especially if the level of N fertilizer used on this area has to be limited for environmental purposes (Fig 1.D). In irrigated systems, where wheat is grown after vegetable, these shifts in the efficiency frontiers are sufficiently high to compensate for the reduction of Durum wheat area in a 3-year rotation, especially at low level of N fertilization.

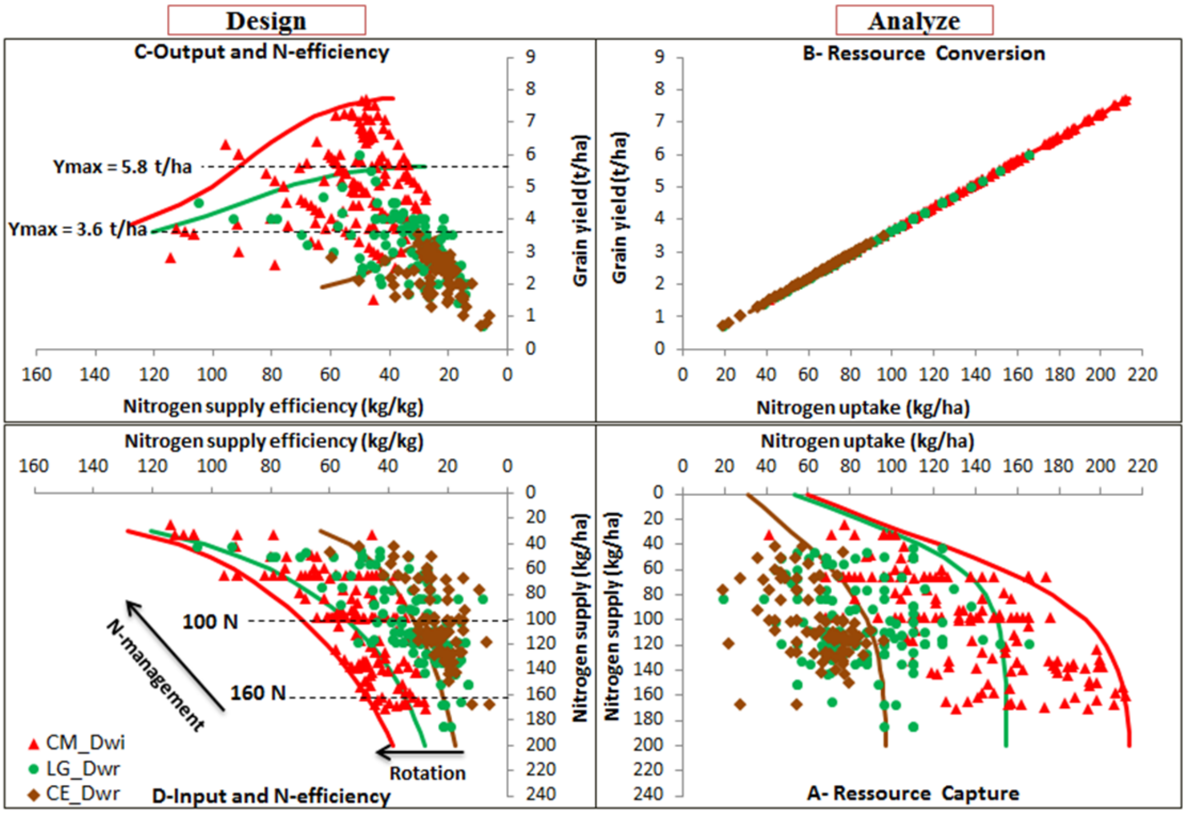

Figure 1: Four-quadrant diagram to analyze nitrogen efficiency according to rotation type:CM_Dwi: irrigated wheat after crop vegetable, CE_Dwr: rainfed wheat after cereals, LG_Dwr: rainfed wheat after legumes.

Conclusions

This four quadrant framework allows to combine process-based (right part) and design oriented (left part) analysis of food production vs. resource use in cropping systems, making use of easy to access data in farmers fields. It showed the breakthrough which can be obtained in high production-low N input cereal-based systems through crop diversification and irrigation. Nevertheless, the level and frequency of N absorption efficiency gaps for each preceding crop suggest that there are other crop management factors to be taken into account in farmers' fields.

References

De Wit C.T.: 1992. Resource Use Efficiency in Agriculture. *Agricultural Systems*, **40**:125–151.

Hochman Z. *et al*.: 2013. Prospects for ecological intensification of Australian agriculture. *European Journal of Agronomy*, **44**:109–123.

Keating B.A. *et al*.: 2010. Eco-efficient Agriculture: Concepts, Challenges, and Opportunities. *Crop Science*, **50**:S-109–S-119.

DEVELOPMENT OF AN ICT-BASED IRRIGATION ADVISORY PLATFORM IN WEST AFRICA

Gorka LANDERAS [1] – Emanuel BEKOE [2] – Mbaye DIOP [3] – Joseph AMPOFO [2] – Madiama CISSÉ [3] – Ernesto ORTIZ [1] – Nora IBÁÑEZ [4]

[1] Department of Plant Protection and Production, NEIKER, Basque Institute of Research and Agricultural Development, Centro de Arkaute Apd. 46 E-01080 Vitoria-Gasteiz, Spain. Email: glanderas@neiker.net
[2] Surface Water Division, CSIR-Water Research Institute, Accra-Ghana
[3] Laboratoire National de Recherches sur les Productions Végétales, ISRA, Institut Sénégalais de Recherches Agricoles, Dakar Senegal.
[4] RTD Area, Inkoa Sistemas, S.L.

Introduction

Informal irrigation schemes are those developed by individual farmers or communities, which represent the vast majority of irrigation in most West African countries like Ghana and Senegal (IWMI 2007). They are characterized by limited knowledge and skills in irrigation farming, and lack of sufficient support services from extension services and other advisory systems so as to realize its full potential. Therefore farmers are experimenting to find out appropriate agronomic practices, on-farm water management or irrigation techniques, and crop protection practices on their own. Thus irrigation scheduling, which concerns the farmers' decision on "how much" water to apply and "when" to irrigate so as to maximize crop profit, is not properly conducted, since it is a very complex decision making process requiring specific knowledge on crop water requirements and irrigation methods and equipments. The development of an ICT-based irrigation advisory service would be a major breakthrough for West African agriculture, since it will advice farmers on their crop irrigation needs and irrigation scheduling, as well as on the most suitable irrigation technologies. IRRIWEST Project is a collaborative three-year project approved on the 2012 call for proposals of the African Union Research Grants Program. IRRIWEST Project is aimed at enhance irrigation practices in order to optimize water resources management and increase agricultural productivity in West Africa, contributing to increased food security and poverty reduction strategies through the testing and transfer of ICT and innovative irrigation advisory services. The project is focused in Ghana and Senegal, and has embraced the following main research activities: (i) Develop and adjust a soil water balance model for determining irrigation requirements of crops such as rice and vegetables; (ii) Design, development and implementation of a sensor network for monitoring environmental parameters; (iii) Design, development, implementation and testing of an ICT-based irrigation advisory service. (iv) Build on target stakeholders' capacities in irrigation and ICT technologies and foster replicability to other African regions through wide spread dissemination of the project outcomes

Materials and Methods

Six pilot fields were selected: 4 in Ghana and 2 in Senegal. A sensor network capable of monitoring key environmental parameters at the pilot fields of Ghana and Senegal was implemented, in order to use the obtained environmental data for determining crops' water needs. An ICT-based irrigation advisory web-platform was implemented according to the information of the pilot fields of Ghana and Senegal and based on FAO56 soil water balance models. The software application has been developed employing the following components: Internet Information Service (IIS) as the web server; Microsoft SQL Server as the relational database server for the management of the information stored in the database; Visual basic as the programming language; API (Application Programming Interface) of Google maps as the visualization tool; SOAP (Simple Object Application Protocol) for the development of the interface to access data measured by the sensor network deployed at the 6 pilot plots. The implementation embraced the integration of the sensor networks and the ICT-platform, and testing of communication and data transmission between the sensor networks deployed at the pilot fields and the ICT platform. During 2015 and 2016 campaigns the software was evaluated, and field data was collected at the pilot fields in order to adjust some parameters of the FAO56 soil water balance models.

Results and Discussion

The IRRIWEST Irrigation Advisory Service (IAS) is a multi-language web-based platform, available in English and French. The IRRIWEST IAS is based on the FAO56 soil water balance models. More specifically, the IAS includes the two approaches of FAO56 model for the estimation of water balance: FAO 56 Single crop approach (Kc) and FAO56 Dual crop approach (Kc=Kcb+Ke). The general structure of the application is organized into five main modules: Irrigation Advisory Service module; Meteorology consultation module; Reports module; Users' management module; Masters' management module. The IRRIWEST Platform embraces five different user profiles whose permissions are as follows: Super administrator; Administrators; Advanced users – associations / cooperatives; Advanced users – S&T agents; Normal users. The system provides registered users with a notification service on irrigation recommendations via SMS and/or email. Although the standard SMS and email notification service sends irrigation recommendations for 1 day, 3 days and 7 days irrigation frequency, the user can configure the frequency of notifications according to its crops' irrigation frequency. In addition the notification service sends notifications to the users when their crops are out of season, so as to inform them about the end of the service for that irrigation campaign. It is worth noting that the SMS and email notification service is configured to send the notifications in French to Senegalese users and in English to Ghanaian users. The IRRIWEST Web Platform provides registered users with an email notification service for weather warnings. The user is able to set up the desired weather warnings in the IRRIWEST Web Platform and the preferred frequency for the email notifications (once a day or once a week).

Conclusions

According to the results, the Irrigation Advisory Platform developed in IRRIWEST project could be the basis for a future Irrigation Advisory Service in West Africa.

Acknowledgements

This project is supported by the African Union Research Grants Program (AURG/2/121/2012).

DESIGNING AND EVALUATING ARABLE CROPPING SYSTEMS WITH CASH AND COVER CROP LEGUMES IN SOLE CROP AND INTERCROP TO IMPROVE NITROGEN USE

L. BEDOUSSAC[1,2] – H. TRIBOUILLOIS[2] – D. PLAZA-BONILLA[2] – E.-P. JOURNET[2,3] – E.JUSTES[2]

[1] ENFA, F-31320 Castanet-Tolosan, France, Email: laurent.bedoussac@toulouse.inra.fr
[2] INRA, UMR1248 AGIR, F-31320 Castanet-Tolosan, France
[3] CNRS, UMR2594 LIPM, F-31320 Castanet-Tolosan, France

Introduction

Increasing concern about climate change and environmental impacts requires transformation of cropping systems. Introducing more legumes (grain or cover crop forage) grown alone or in intercropping (IC) is an interesting option to benefit from N_2 fixation and also for break crop effects. Rotational position of legumes needs to be carefully analyzed to maximize their benefit. From field experiments and crop modelling the objective of our work was to design and evaluate prototypes of arable systems analyzing: 1) impact of grain legume at the rotation level, 2) potential of IC with legumes for improving yield and cereal protein content and 3) effect of cover crops with forage legume to achieve nitrate capture and green manuring services. Materials and Methods Two 6-year field experiments were initiated in 2003–04 at INRA Toulouse (SW France). Six rotations of three-years differentiated by the frequency of legumes in the rotation and the presence or not of cover crop were compared. Crop management was based on decision rules to adjust technical acts, in particular N application, to the soil and crop status. Simulations at the rotation time scale were carried out using the STICS soil-crop model for water and N dynamical budgets (Plaza-Bonilla *et al*., 2015). Complementary experiments with IC were carried since 2005–06 with a large range of IC combinations (durum wheat, bread wheat or barley intercropped with pea or faba bean) with various cultivars, sowing densities and N treatments. Grain yield and cereal grain protein content were used to evaluate the efficiency of the IC over the sole crops (SC). The percentage of N derived from N_2 fixation of legumes was estimated with 15N dilution method with also nitrogen content in plant and soil (Bedoussac *et al*., 2015). In addition others experiments were conducted to analyze ten cover crop species (five legumes and five non-legumes) selected according to their rapid growth rate and contrasted shoot/root architectures. Species were evaluated in three French experimental sites with contrasted climate conditions and soil characteristics both in SC and in IC and compared to a bare soil as control. Biomass, N acquisition, C:N ratio and soil mineral N were measured and ecosystem services of N management were assessed using both experimental and modelling data (Tribouillois *et al*., 2015).

Results and Discussion

Winter and spring legumes preceding crops show positive effects on durum wheat, notably due to higher soil mineral-N availability at wheat sowing. However, higher soil mineral-N levels after legume crops at harvest and in November increased the potential risk of nitrate leaching which was efficiently reduced by the introduction of cover crops. Cover crop mixtures and non-legume SC reduced similarly nitrate leached during the whole drainage period compared to the bare soil. Legume SC only slightly reduced N leaching in comparison to bare soil. Cover crops were particularly efficient during wet winters because the more the drainage volume, the more the reduction of nitrate leaching and nitrate concentration in leached water. N release from cover crop residues could be sufficient to compensate in a great part the pre-emptive competition for soil mineral-N when destroyed before winter. Prediction of mineralized N from cover crop residues was significantly higher for mixtures than for non-legume crops. IC experiments showed that the total IC grain yield was almost always higher than the mean SC (3.3 *vs* 2.7 Mg ha^{-1}) and similar result was found with accumulated N (121 vs 101 Kg N ha^{-1}). IC was more efficient than SC for low N availabilities due to dynamic complementarity for light and N acquisition. Cereal grain protein concentration was significantly improved in IC compared to the respective SC (11.1% *vs* 9.8%) and the lower the SC value the higher the increase in the IC due to: i) a lower cereal grain yield in IC and ii) a quite similar (*c*. 90%) amount of available soil N for the cereal in both systems because of a higher legume N_2 fixation rate in IC than in SC (75% *vs* 62%). Conclusions Legume sole crops, intercropping a legume and a non-legume are of particular interest both for grain production and cover crops ecosystem services to design innovative cropping systems. This is due to the complementarity between legumes and nonlegumes in improving use of N resources especially in low N systems. Bispecific cover crop with a legume can simultaneously provide good compromises between nitrate capture and green manuring ecosystem services by recycling the soil mineral-N in good synchrony with the succeeding cash crop. Intercropping for grain production provided compromises between grain yield, cereal grain protein content and species proportion. A number of factors still needs to be optimized in order to propose optimized future cropping systems including intercrops like: i) species and cultivars, ii) correct rotational position to not increase pests and diseases and also iii) sowing practice (e.g. alternate row or mixture within each row, density of each component, width between rows,…). These choices depend on specific goals like for grain production the maximum total yield, the global protein production or the highest wheat grain protein content while for cover crops the choice of a mixture must be adapted according to site's soil and climate conditions, priorities of fallow-period management and services desired.

References

Plaza-Bonilla D. *et al*.: 2015. *Agriculture, Ecosystem and Environnement,* http://dx.doi.org/10.1016/j.agee.2015.06.014.
Bedoussac L. *et al*.: 2015. *Agronomy for Sustainable Development*, http://dx.doi.org/10.1007/s13593-014- 0277-7.
Tribouillois H. *et al*.: 2015. *Plant and Soil,* http://dx.doi.org/10.1007/s11104-015-2734-8.

INNOVATIVE APPROACHES TO OPTIMIZE GENETIC DIVERSITY FOR SUSTAINABLE FARMING SYSTEMS OF THE FUTURE: QUANTIFYING ECOLOGICAL PERFORMANCE

Robert SIMON[1] *– Hans Jürgen REENTS*[1]

[1] Chair for Organic Farming and Agronomy, Technical University of Munich, Email: robert.simon@tum.de

Introduction

Climate change is expected to have a significant impact on the variability of abiotic and biotic factors affecting yield stability in agro-ecosystems. Future farming systems will have to be highly self-regulatory in order to compensate for adverse site effects and lower fossil fuel, fertilizer and pesticide inputs (Østergård *et al*. 2009). Crop diversity is a key element of the change necessary in farming systems (Howden *et al.* 2007). In the INSUSFAR project (INovative approaches to optimize genetic diversity for SUStainable FARming systems of the future), diverse wheat (*Triticum aestivum* L.) populations of different origin and degrees of diversity will be tested regarding the influence of intra-crop genetic diversity on crop performance under variable and changing environments. Yield, biodiversity and quality parameters of different composite cross populations (Döring *et al.* 2015) will be determined in field experiments and on-farm trials. To this end, new criteria for the assessment of ecological sustainability will be developed. Based on these results, scenario modelling of their integration into on-farm operations will allow an assessment of the ecological sustainability of these wheat populations.

Materials and Methods

On-farm experiments will be conducted on at least 8 German farms with differing site conditions, input strategies and tillage systems, in addition to field trials on experimental farms across Germany. Within each of the experiments, a plot with large spatial heterogeneity will be cultivated with novel composite cross populations and, for comparison, a reference line variety or hybrids. Utilizing portable spectroscopy and GPS equipment, non-destructive measurements of yield development and soil sampling will conclude in a site-specific map of the varieties' responsiveness to site heterogeneity. Innovative indicators for handling inter- and intra-specific diversity will be developed. Ecological sustainability will be assessed with REPRO software, mapping the whole production process including all inputs and outputs.

Work Progress

At the time of writing, three preliminary experiments employing different experimental designs had been established on TUM experimental sites. All three designs aim to utilize spatial heterogeneity in order to measure reactivity to adverse site conditions of the tested populations in comparison with reference line varieties.

Figure 1. Schema of experimental design

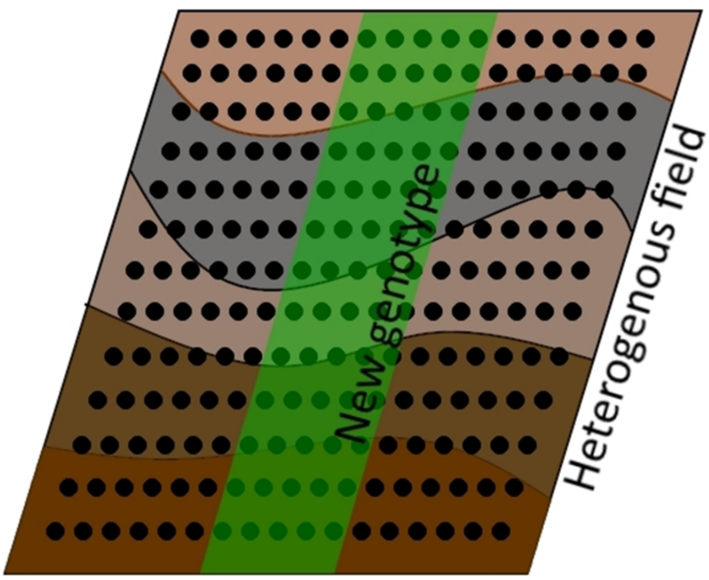

Figure 1. Schema of experimental design.

Varying in different geostatistical approaches, all three designs follow the same design principle (Fig. 1). After calibration of the measuring equipment and geo-spatial referencing, spectroscopy measurements will be visualized in a map. Results will indicate the relation between genetic heterogeneity and reactivity to adverse site conditions.

Based on the preliminary results, one experimental design will then be selected and applied to on-farm experiments starting in September 2016.

Acknowledgements

The authors gratefully acknowledge the German Federal Ministry of Education and Research (BMBF) for their support by financing the INSUSFAR project.

References

Döring T.F. – Annicchiarica P. – Clarke S. – Haigh Z. – Jones H.E. – Pearce H. – Snape J. – Zhan J. – Wolfe M.S.: (2015): Comparative analysis of performance and stability among composite cross populations, variety mixtures and pure lines of winter wheat in organic and conventional cropping systems. *Field Crops Research* **183**:235–245.

Howden S.M. – Soussana J.F. – Tubiello F.N. – Chhetri N. – Dunlop M. – Meinke H.: (2007): Adapting agriculture to climate change. *Porceedings of the National Academy of Sciences* **104**:19691–19696.

Østergård H. – Finck M.R. – Fontaine L. – Goldringer I. – Hoad S. – Kristensen K. – Lammerts Van Bueren E.T. – Mascher F. – Munk L. – Wolfe M.: (2009): Time for a shift in crop production: embracing complexity through diversity at all levels. *Journal of the Science of Food and Agriculture* **89**:1439–1445.

FUNGICIDE ALTERNATIVES FOR SCOTTISH SPRING BARLEY: FARMER PERSPECTIVES

Stacia STETKIEWICZ [1,2,3] *– Cairistiona TOPP* [1] *– Ann BRUCE* [2] *– Richard ENNOS* [3] *– Fiona BURNETT* [1]

[1] Crops and Soil Systems, Scotland's Rural College, Peter Wilson Building, King's Buildings, W. Mains Road, Edinburgh EH9 3JG, Email: Stacia.Stetkiewicz@sruc.ac.uk
[2] Innogen, School of Social and Political Sciences, University of Edinburgh
[3] Institute of Evolutionary Biology, School of Biological Sciences, University of Edinburgh

Introduction

Spring barley is Scotland's main arable crop, and therefore a useful starting point for considering the potential for Integrated Pest Management (IPM) in these arable systems. Survey work has therefore been undertaken to identify current practice relating to fungicide use and three key fungal diseases in Scottish spring barley (*Rhynchosporium commune*, *Ramularia collo-cygni*, and *Blumeria graminis* (mildew)), as well as to gauge farmer interest in specific IPM techniques.

Materials and Methods

Farmers were surveyed using a paper questionnaire, which focused on current management strategies on-farm, as well as assessing the farmer's willingness to take up specific IPM techniques. Participants were recruited at 4 cereal events across Scotland in Jan 2016. These events are run annually by SRUC and AHDB: Cereals and Oilseeds and this year focused on risk, resilience and reward in arable Scottish farming. Despite the potential for bias in the survey sample, these events were used due to the high concentration of farmers, thus ensuring a relatively large sample size at low cost. A total of 43 farmers responded to the survey, with an average response rate of 28%. The preliminary results relating to varietal disease resistance and variety choice are reported here.

Results and Discussion

Overall, there is general openness to reducing fungicide use amongst the farmers growing spring barley with nearly 81% of farmers (34 of 42 surveyed) agreeing or strongly agreeing, and no farmers disagreeing with the statement "If I could use less fungicide and have it be as cost-effective, I would."
More than two thirds of farmers (28 out of 42) ranked varietal disease resistance rating as important or very important in their decision to sow particular varieties of spring barley. However, the five most commonly sown varieties in the past five years, as listed by the respondents – Concerto, Optic, Belgravia, Waggon and Odyssey – were only ranked highly for mildew resistance, based on the SRUC Cereals Recommended lists as shown in Figure 1.

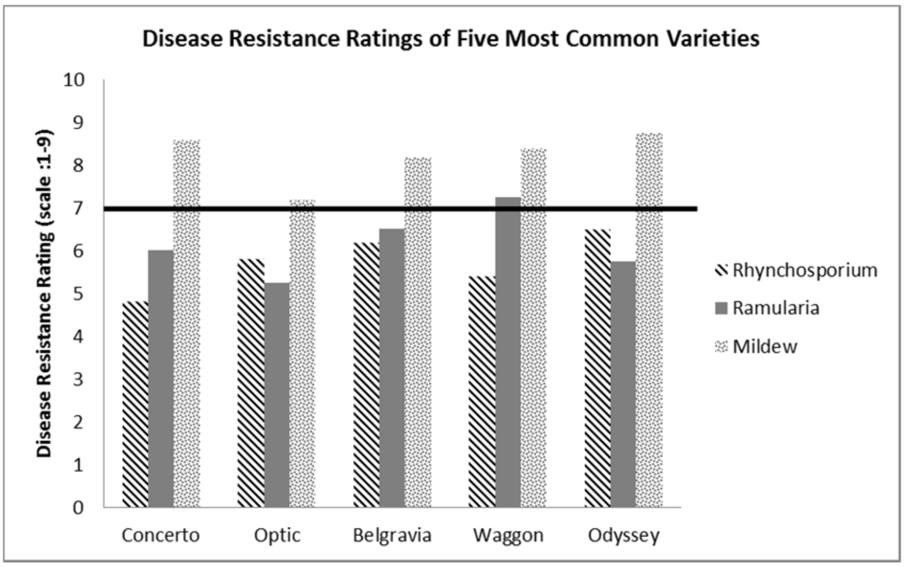

Figure 1. Average disease resistance ratings for the past five years (Data for Ramularia and Odyssey runs only from 2012–2015, as they were not assessed in the SRUC Cereal Recommended lists prior to this date). A rating of 7 or above, as indicated by the black line, is considered to have high resistance.

While Ramularia and Rhynchosporium resistance ratings are consistently lower than those for mildew, both are considered by farmers to have a greater effect on yield than mildew, and Rhynchosporium is thought to have been the most common of the three diseases in recent years, as highlighted in Table 1.

Table 1. Farmer perceptions of the importance of the three diseases in the past five years

	Most common on spring barley in the past five years	**% of response**	**Impacted spring barley yield most in the past five years**	**% of response**
Mildew	3	7.5%	2	5.13%
Ramularia	3	7.5%	11	28.21%
Rhynchosporium	34	85%	24	66.67%

The perception of the commonness and yield impact of mildew may be buffered by the relatively high disease resistance of the varieties sown by farmers – however, the lack of a shift towards disease resistant Rhynchosporium varieties given the perception of this disease is perhaps surprising. A potential explanation for this is the fact that market demand for a particular variety was listed as important or very important by nearly 93% of farmers surveyed (39 of 42), more than any other consideration listed.

Conclusions

Farmers surveyed were generally open to reducing their fungicide use. However, it is important to consider the wider farming context when considering potential for uptake of IPM strategies. More detailed analysis of the results from this questionnaire will review current farmer practices and preferences in depth to gain a more thorough understanding of drivers and pressures.

Acknowledgements

This work is funded by Scottish Government. Thank you to those at AHDB Cereals and Oilseeds and SRUC who helped to encourage participation in the survey at the January Cereals events.

Reference

SRUC: 2011–2015. *SRUC Cereals Recommended Lists*. Available online: <www.sruc.ac.uk/downloads>

PARTICIPATORY RESEARCH AND SYSTEMS THINKING TO FOSTER THE IMPLEMENTATION OF AGROECOLOGICAL PRACTICES

Fernando PELLEGRINI – Paolo BARBERI

Institute of Life Sciences, Scuola Superiore Sant'Anna, Piazza Martiri della Libertà 33, 56127, Pisa , Italy, Email: f.pellegrini@sssup.it; paolo.barberi@sssup.it

Introduction

Agro-ecological principles and practices like living mulch may help fostering the sustainability of agroecosystems. However, the major challenge is to implement these innovations among farmers, and this process entails technical and institutional change at different levels, an issue often overlooked by agricultural scientists (Röling, 2009). The transition towards agroecological food systems may in fact slow down if little attention is paid on social and political aspects (Tittonell, 2014). In order to highlight the factors hindering farmers' adoption of agro-ecological practices, systems approaches and participatory research tools are highly needed (Noe *et al*., 2015). Our aim was to study the barriers to the implementation of agro-ecological practices among farmers.

Materials and Methods

We performed two sets of 10 semi-structured interviews between spring 2015 and winter 2016. The first set of interviews aimed at researchers and technicians, whilst the second set included full-time arable crop farmers. We also attended local farmer meetings and events with the aim of having a broader picture of the current farming practices in the area of study.

Results and Discussion

Nine out of ten farmers interviewed do not use living mulches, but five out of ten regard it as a feasible alternative for increasing the organic matter content in the soil. They are mostly interested in trying it for wide-rows summer crops, rather than for winter crops. Half of the farmers interviewed complain about the lack of animal manure in the area, its cost of transport, and the opposition that most urban neighbors demonstrated. They nonetheless expressed their interest in finding alternatives for restoring the soil organic matter content.
Moreover, we found that conventional farmers in the area are applying a trade-off between weed management and soil fertility management: due to herbicide resistance weeds, they are forced to abandon no-tillage, and they regard this management shift as detrimental for the level of organic matter in their soil.
Lastly, mowing or ploughing the field after harvest to avoid weeds enriching the seedbank was regarded by researchers a good preventive agroecological practice. Yet they assumed it to be a rare and hard-to-implement practice among farmers. On the contrary, eight out of ten farmers interviewed are currently doing it, both for soil fertility and weed management.
The results indicate a need for researchers to look closer at current farming practices when carrying out research on agroecological innovations, especially during the initial explorative phase. By applying participatory and systems approaches at an early stage, it is possible to gain penetrating insights into farmers' opinion. This would be good when assessing the relevance of an innovation, the trade-offs involved, and the way farmers would implement it.

Conclusions

This experience provides a good indication that universities need to incorporate more systems and participatory approaches in their agenda, especially when adoption of novel, agro-ecological practices is sought. Activities that encourage the involvement of farmers in the research process from the start may foster innovation in agriculture.

Acknowledgements

We thank all the farmers, technicians, researchers who took part in this study, for the precious time they dedicated to us.

References

Noe E. – Alrøe H.F. – Thorsøe M.H. – Olesen J.E. – Sørensen P. – Melander B.– Fog E.: 2015. Knowledge asymmetries between research and practice: A social systems approach to implementation barriers in organic arable farming. *Sociologia Ruralis,* **55**(4):460–482.

Röling N.: 2009. Pathways for impact: scientists' different perspectives on agricultural innovation. *International Journal of Agricultural Sustainability,* **7**(2):83–94.

Tittonell P.:2014. Ecological intensification of agriculture—sustainable by nature. *Current Opinion in Environmental Sustainability*, **8**:53–61.

NO TILL INCREASES MYCORRHIZAL COLONIZATION IN WINTER WHEAT THUS REDUCING THE NEED FOR NITROGEN FERTILIZATION

Julien VERZEAUX [1] – David ROGER [1] – Jérôme LACOUX [1] – Elodie NIVELLE [1] – Hazzar HABBIB [1] – Bertrand HIREL [2] – Frédéric DUBOIS [1] – Thierry TETU [1]*

[1] Ecologie et Dynamique des Systèmes Anthropisés, FRE 3498 CNRS, Université de Picardie Jules Verne, 33 rue St Leu, 80039 Amiens Cedex, France, *Email : julienverzeaux@gmail.com
[2] Adaptation des Plantes à leur Environnement. Unité Mixte de Recherche 1318, Institut National de la Recherche Agronomique, Centre de Versailles-Grignon, R.D. 10, F-78026 Versailles Cedex, France

Introduction
Arbuscular mycorrhizal fungi (AMF) form obligate symbiosis (mycorrhizas) with most cultivated plants (Mardukhi *et al*., 2011) and provide them many benefits throughout their growth (Bücking & Kafle, 2015). The intra-radical colonization of roots by AMF can enhance the absorbing capacity of plants for nutrients (Rillig & Mummey, 2006), especially by extending the reach of the plant beyond the depletion zone surrounding a root. In agricultural systems, tillage and N fertilization may interfere with this plant-fungi relationship (Martinez & Johnson, 2010). However, little is known about their combined effects on AMF colonization and N uptake in the field, especially in winter wheat.

Materials and Methods
Four treatments each with four replicate plots were set up in 2010: conventional tillage with (CTNX) or without (CTN0) N fertilization; no-till with (NTNX) or without (NTN0) N fertilization. The crop rotation between 2010 and 2015 was peas - maize - wheat - flax - beet - wheat. In June 2015, at the anthesis stage of wheat, six plants with their root systems and six 15-cm deep soil cores were randomly sampled in each plot Aboveground wheat biomass, N content, and soil C:N ratio were determined. Root staining and assessments of mycorrhizal infection were performed according to Koske & Gemma (1989) and McGonigle *et al*. (1990) respectively.

Results and Discussion
Both CT and N fertilization strongly decreased wheat root colonization by AMF ($P<0.001$) (Figure 1A). Aboveground biomass and N uptake of wheat were the highest under CTNX and NTN0, and the lowest in CTN0 ($P<0.05$; Table 1). Once intra-radical colonization by AMF is established, arbuscules enhance the absorbing capacity of the root for water and nutrients (Rillig & Mummey, 2006) and this speeds up plant growth (Pellegrino *et al*., 2015). Moreover, the mycorrhizosphere, as a spatial extension of the rhizosphere associated with the hyphosphere (Veresoglou *et al*., 2012), obviously increases the soil volume from which N uptake may occur.
The soil C:N ratio was significantly higher in NT plots ($P<0.001$), suggesting a higher amount of C from crop residues in the upper soil layer. Hodge *et al*. (2001) provided evidence that AMF are able to acquire N directly from soil organic material.
Taken together, our results suggest that direct seeding appears to be more appropriate for wheat production within the framework of a low-input sustainable agriculture.

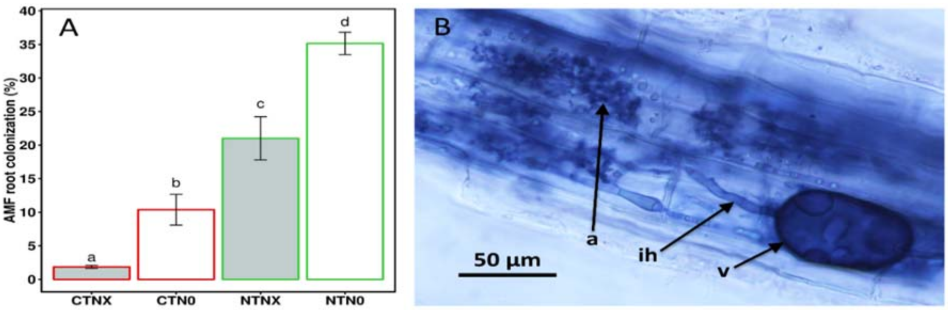

Figure 1. (A) Effect of tillage and nitrogen fertilization on the percentage of wheat root length colonized by AMF. Letters indicate differences among treatments according to Conover's post-hoc tests ($P < 0.05$) following a significant Kruskal-Wallis test ($P < 0.001$); (B) Wheat root colonized by arbuscular mycorrhizal fungi. a: arbuscule, v: vesicle, ih: intraradical hypha.

Table 1. Impact of nitrogen fertilization and tillage on wheat agronomic traits and soil C:N ratio

	H(*P*)	**CTNX**	**CTN0**	**NTNX**	**NTN0**
AG biomass (g plant^{-1})	10.61 (0.014)	7.02 ± 0.43**b**	4.88 ± 0.27**a**	6.07 ± 0.30**ab**	7.13 ± 0.65**b**
N uptake (mg plant^{-1})	9.25 (0.03)	72.37 ± 4.95**b**	46.98 ± 4.06**a**	66.83 ± 7.03**ab**	68.02 ± 5.37**ab**
Soil C:N ratio	17.64 (0.0005)	9.01 ± 0.08**a**	8.93 ± 0.10**a**	10.08 ± 0.14**b**	10.04 ± 0.21**b**

H: Values of the Kruskal-Wallis test with its probability in brackets. Letters give the result of Conover's post-hoc tests ($P < 0.05$). NS: non significant. AG biomass: aboveground biomass.

Acknowledgements

Research in this work was funded by Bonduelle and Syngenta companies (project *VEGESOL*).

References

Bücking H. – Kafle A.: 2015. Role of Arbuscular Mycorrhizal Fungi in the Nitrogen Uptake of Plants: Current Knowledge and Research Gaps. *Agronomy,* **5**:587–612.

Hodge A. – Campbell C.D. – Fitter A.H.: 2001. An arbuscular mycorrhizal fungus accelerates decomposition and acquires nitrogen directly from organic material. *Nature,* **413**:297–299.

Koske R.E. – Gemma J.N.: 1989. A modified procedure for staining roots to detect VA mycorrhizas. *Mycological Research,* **92**:486–488.

Mardukhi B. – Rejali F. – Daei G. – Ardakani M.R. – Malakouti M.J. – Miransari M.: 2011: Arbuscular mycorrhizas enhance nutrient uptake in different wheat genotypes at high salinity levels under field and greenhouse conditions. *Comptes Rendus Biologies,* **334**:564–571.

Martinez T.N. – Johnson N.C.: 2010. Agricultural management influences propagule densities and functioning of arbuscular mycorrhizas in low- and high-input agroecosystems in arid environments. *Applied Soil Ecology,* **46**:300–306.

McGonigle T.P. – Miller M.H. – Evans D.G. – Fairchild G.L. – Swan J.A.: 1990. A new method which gives an objective measure of colonization of roots by vesicular-arbuscular mycorrhizal fungi. *New Phytologist,* **115**:495–501.

Pellegrino E. – Öpik M. – Bonari E. – Ercoli L.: 2015. Responses of wheat to arbuscular mycorrhizal fungi: A meta-analysis of field studies from 1975 to 2013. *Soil Biology and Biochemistry,* **84**:210–217.

Rillig M.C. – Mummey D.L.: 2006. Mycorrhizas and soil structure. *New Phytologist,* **171**:41–53.

Veresoglou S.D. – Chen B. – Rillig M.C.: 2012. Arbuscular mycorrhiza and soil nitrogen cycling. *Soil Biology and Biochemistry,* **46**:53–62.

TO DRASTICALLY REDUCE PESTICIDES USES: TWO CASES OF RE-DESIGNED SYSTEMS WITH BIODYNAMIC AND PROTECTED DESIGNATION OF ORIGIN CONSTRAINTS

Marie THIOLLET-SCHOLTUS[1] *– Julie GRIGNION*[1] *– Joseph WEISSBART*[2]

[1] INRA - SAD - UR-0055-ASTER, 28, rue de Herrlisheim 68000 Colmar France. Email: marie.thiollet-scholtus@colmar.inra.fr
[2] Organisation Professionnelle de l'Agriculture Biologique en Alsace (OPABA) 2 allée de Herrlisheim 68000 Colmar France, Email: joseph.weissbart@opaba.org

Introduction

EU and France have decided for their agricultural policy in the next years to drastically reduce inputs and especially pesticides use in vineyards before 2018. Agricultural policy makers are responding by calling for more and more sustainable production systems. In this context, redesigning all sort of cropping systems has become a major challenge for agricultural professionals (Le Bellec *et al*., 2012). For the last years, agricultural researchers have been re-designed methods and tools to facilitate the design of innovative production systems (Cerf *et al*., 2012; Metral *et al*., 2012; Meynard, 2012). Working with winegrowers at the very beginning of the re-design process of the system is not very often done. Using directly very low input-pesticides systems, i.e. biodynamic ones, to re-design is also another challenge. The aim of this paper is to improve the participatory re-design method applied innovative production systems to the case of biodynamic combined to Protected Designation of Origin (PDO) grapes production in Alsace (France) (Thiollet-Scholtus *et al*., 2013).

Materials and Methods

Materials of the research program are a group of biodynamic winegrowers and two of them owners of family-owned farms in Alsace Protected Designation of Origin (PDO) area. Motivation of winegrowers to co-work with Research Development and Extension (RDE) agents is essential to reach the goal of the program: to drastically reduce pesticide inputs by strongly re-designing their production system (Doorman, 1990). The first part of the method deals with: (i) brainstorming and meetings with winegrowers to get technical limits and bottlenecks of pest management and unsolved failures of it. The second part of the method has 5 steps: (i) finding winegrowers to do participatory research; (ii) selecting two fields; (iii) choosing the testing innovations; (iv) designing the experimentation protocol for each innovation and finally (v) assessing years' results to improve the re-designed system.

Results and Discussion

The *main global result* is re-designing two systems and their corresponding experimentation protocol in two biodynamic farms. We showed that it is possible to *combine scientific constraints and operational implementation* in the farm during a long-term experimentation (results of the two first years of the six expected). The *second result* is the worldwide relevance of the two tested innovations for grape production systems, under strong constraints: biodynamic system and high quality of grapes according to PDO. The first tested innovation is "fungicide application with less than one kilogram of cupper /hectare/year mixed with different essentials oils". The second one is to simplify soil cover management under and between rows of vine in the field. The *first tested innovation (HE) is a success* for quality of grapes, yield and rot rate (downy mildew, white and grey rots) in two different climatic years conditions, 2014 and 2015. It is slower to assess the results of the *second tested innovation (SC), which* has been introduced to the system late in spring 2014. However, it is still possible to *show that the first goals of the SC are achieved:* **(**i) keeping the same desired yield and (ii) reducing soil tillage during summer. The two others goals of the SC are (i) providing a indirect fertilization of the vine with leguminous plants, and (ii) increasing floristic diversity and pollinator quantity and diversity. The assessment of them will be done with measurements and surveys next years.

Conclusions

At mid-point of the program, *participatory research* between RDE agents and owners of wineries is a *success*. Two strongly re-designed systems under strong constraints are assessed in biodynamic farm conditions. Re-designing systems does *not reduce yield or PDO grape quality or increase pest sensitivity.* Some more analyzed years data will validate the first results and also allow increasing the level of the innovating re-designed systems.

References

Cerf M. – Jeuffroy M.-H. – Prost L. – Meynard, J.-M.: 2012. Participatory design of agricultural decision support tools: taking account of the use situations. *Agronomic & Sustainable Development,* **32**:899–910.

Doorman F. 1990.: A social science contribution to applied agricultural research for the small farm sector: the diagnostic case study as a tool for problem identification. *Agricultural Systems,* **32**:273–290.

Le Bellec F. – Rajaud A. – Ozier-Lafontaine H. – Bockstaller C. – Malezieux E.: 2012. Evidence for farmers' active involvement in co-designing citrus cropping systems using an improved participatory method. *Agronomic & Sustainable Development,* **32**:703–714.

Metral R. – Lafond D. – Gary C. – Merot A. – Metay A. – Wery J.: 2012. How to design and experiment new cropping systems with low pesticide inputs for perennial crops: framwork development and application to vineyards. *In* "ESA2012", Vol. 1, Helsinki, Finland. Eds F.L. Stoddard and P. Mäkelä.

Meynard J.-M.: 2012. La reconception est en marche ! Conclusion au Colloque « Vers des systèmes de culture innovants et performants : De la théorie à la pratique pour concevoir, piloter, évaluer, conseiller et former. *Innovative Agronomy,* **20**:143–153.

Thiollet-Scholtus M. – Ley L. – Bockstaller C. – Delière L. – Forget D. – Metral R. – Lafond D.: 2013. Design and assessment of new low-input viticulture systems. *In* "GiESCO", Vol. 1, Porto, Portugal.

FARMER PARTICIPATORY RESEARCH AS A TOOL FOR IMPROVING THE PRODUCTIVITY OF AGRICULTURAL IRRIGATION SYSTEMS IN MAURITANIA

E. GARCÍA-PONCE [1] – L.MATEOS [1] – H. GÓMEZ-MACPHERSON [1]*

[1] Instituto de Agricultura Sostenible, CSIC, Córdoba, Spain, Email: egarcia@ias.csic.es

Introduction

After severe famines during the 1970s and 1980s in the Western Sahel, irrigation schemes were developed with the general objective of enhancing food security in the region. In Mauritania, most irrigated land was designed to fit with rice (*Oryza sativa L.*) cultivation and government assistance focused almost exclusively on that production system. Irrigation development has not, however, responded to expectations, and many schemes have been abandoned. Recently, crop diversification has been promoted by Mauritanian government to improve the sustainability of irrigated agricultural systems (IFM, 2011). The objective of this study was to evaluate the potential role of irrigated sorghum (*Sorghum bicolor* L. Moench) cropping and its limitations, in smallholder irrigation schemes in the Mauritanian side of the Senegal River Valley.

Materials and Methods

This study presents part of the results of a project focused on the improvement of irrigation for food sovereignty in Mauritania (2007–2012). It was carried out on five small, community-managed, irrigation schemes in mid Senegal River Valley (García-Ponce *et al*., 2013). We used methods of conventional on-farm research supported by community-based Participatory Learning and Action Research (Defoer *et al*., 2009). Actors involving were: (i) the cooperative board; (ii) collaborating farmers; and (iii) researcher/extension agents. Other farmers participated in RRA and in farmer-to-farmer and end-of-season discussions and evaluations. Grain yield, water productivity and gross margin of sorghum and rice were measured two years at plot level and compared.

Results and Discussion

Global average rice yields over years and schemes was 5.6 t ha^{-1}, ranging from 3.4 t ha^{-1} to 7.9 t ha^{-1}, in line with the global average of 5.7 t ha^{-1} obtained by Mauritanian farmers following integrated rice management recommendations developed by AfricaRice and partners (Haefele *et al*., 2000). A lower average yield of 2.5 t ha^{-1} was obtained for sorghum, ranging from 1.5 t ha^{-1} to 4.8 t ha^{-1}, well below the expected 5 t ha^{-1} according to the cultivar description provided by ISRA, Senegal. However, both crops had similar total above-ground biomass at maturity.

Distribution of sorghum yields (Figure 1) revealed that most collaborating farmers achieved low yields (positively skewed distribution) and only few had high yields showing that yields in sorghum plots corresponded to subsistence level. As farmers become skilled, the distribution should shift to the right, corresponding to commercial production level, comparable to that of rice.

Sorghum required less irrigation water than rice (435 vs.601 mm) but the smaller yield resulted in similar irrigation water productivity (0.87 vs. 0.96 kg m^{-3}) and fuel (pumping) productivity (1.71 vs. 1.93 kg MJ^{-1}). Despite greater yields, rice profitability, consistent with other studies in Mauritania (Poussin et al., 2006), was significantly lower than that of sorghum (788 vs. 1172 ha^{-1}). Irrigated sorghum grain is highly valuable because it is harvested when it is in short supply in the market. Sorghum straw is also valuable for its high sugar content and nutritional value for animal fodder. Complications in cost comparisons arise, however, because of different pricing decisions for water.

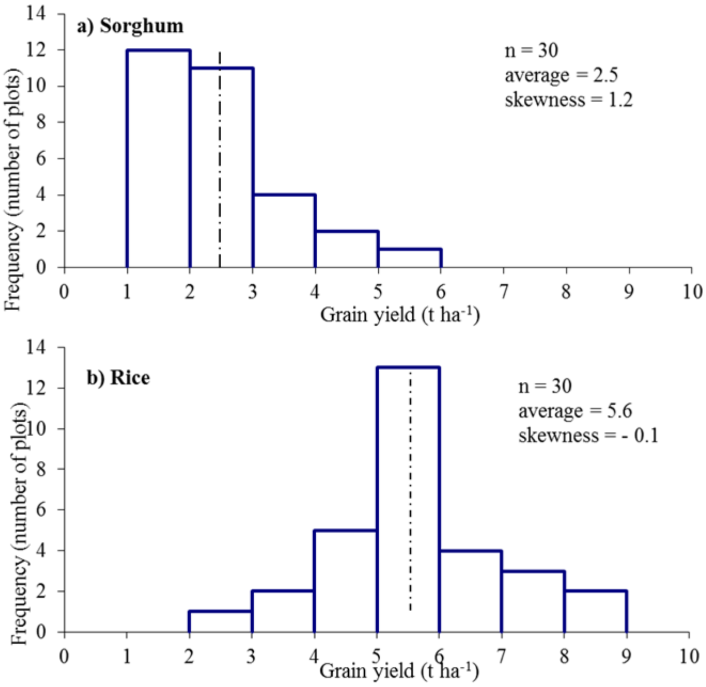

Figure 1. Distribution of sorghum and rice plots yields obtained during the study. Vertical lines refer to global mean yields.

Conclusions

Our results revealed several limitations to irrigated sorghum cropping, many related to characteristics of rice schemes and to farmers' habits. However, the low irrigation requirement, the high average profitability of sorghum crops and the large yield variation among farmers showed considerable scope for sorghum production, particularly if harvested when sorghum is in short supply. Schemes developed on relatively light soils and designed specifically to grow crops other than rice offer opportunities for profitable crop diversification.

Acknowledgements

The authors express their gratitude to the local staff and collaborating farmers. This study was supported by a project funded by the Spanish Agency for International Cooperation for Development and the Ministry of Rural Development in Mauritania.

References

Defoer T. – Wopereis M.C.S. – Idinoba P. – Kadisha K.L. – Diack S. – Gaye M.: 2009. *Curriculum for Participatory Learning and Action Research (PLAR) for Integrated Rice Management (IRM) in Inland Valleys of Sub-Saharan Africa: Facilitator's Manual*. Benin: Africa Rice Center, Cotonou.

García-Ponce E. – Gómez-Macpherson H. – Diallo O. – Djibril M. – Baba C. – Porcel O. – Mathieu B. – Comas J. – Mateos L. – Connor D.J.: 2013. Contribution of sorghum to productivity of small-holder irrigation schemes: On-farm research in the Senegal River Valley, Mauritania. *Agricultural Systems,* **115**:72–82.

IFM.: 2011. Islamic Republic of Mauritania: Poverty reduction strategy paper. *IMF Country report No. 11/252*. International Monetary Fund, Washington, D. Available on http://www.imf.org.

Haefele S.M. – Johnson D.E. – Diallo S. – Wopereis M.C.S. – Janin I.: 2000. Improved soil fertility and weed management is profitable for irrigated rice farmers in Sahelian West Africa. *Field Crops Research,* **66**:101–113.

Poussin J.C. – Diallo Y. – Legoupil J.C.: 2006. Improved collective decision-making in action for irrigated rice farmers in the Senegal River Valley. *Agricultural System,* **89**:299–323.

VALIDATION OF A NEW MULTI-PEST INTEGRATING INDICATOR OF PESTS AND DISEASES DAMAGE IN GRAPES

Nathalie SMITS [1] *– Lionel DELBAC* [2] *– Anne MEROT* [1] *– Jean ROUDET* [2] *– Marc FERMAUD* [2]

[1] INRA, UMR SYSTEM, 2 place Viala, 34060 Montpellier cedex 2, France, Email: smits@supagro.inra.fr
[2] INRA, UMR SAVE 1065, 71 av. E. Bourlaux, CS 20032, 33882 Villenave d'Ornon, France

Introduction

Vineyards, as high value crops, use large inputs of pesticides so that they are protected against yield loss caused by several pests and diseases. However, recent social and environmental constraints aim at reducing pesticide inputs to reduce chemical pollution, while maintaining a sustainable income to growers. To find acceptable trade-offs between grape protection and pesticide reduction, tools are needed to choose, implement and assess innovative protection strategies. Along with indicators for pesticide use, such as EEP (Wijnands, 1997) or FTI (Butault *et al*., 2010), we propose an Assessment Indicator of Damage in grape Clusters (AIDC, Fermaud *et al*., 2016), to quantify the overall result of pests and diseases incidence and pesticide sprays for a given year at the plot level. The objective of this work is to validate this multi-pest integrating indicator, primarily developed on Merlot noir cv., with other grape cultivars and to characterize the relations between AIDC and grape yield components.

Materials and Methods

The Assessment Indicator of Damage in Grape Clusters consists of two main components. The inflorescences may be damaged by downy mildew (severity: YDMF) and grey mold (YGMF) early in the season (before flowering). Further damage may be caused later to remaining clusters by downy mildew (YDMB), powdery mildew (YPM), grey mold (YGMB) and tortricid moths (YTM). The AIDC represents the proportion of remaining healthy clusters and is computed as

$$AIDC (\%) = 100-[100 - (YDMF + YGMF)] * [1 – (YDMB+YPM+YGMB+YTM)/100]$$

The data used were collected between 2006 and 2008 in two vineyards near Bordeaux (France), planted with Cabernet franc. The full details of the experimental conditions were presented in Savary *et al*. (2009). Major pests and diseases were monitored, *i.e.* powdery and downy mildews, *Botrytis* and incidence of berry moths. Different levels of protection against pests and diseases were applied, to obtain contrasted situations. The grapevine phenology and plant development were monitored, and yield components were measured at harvest. Based on these data, the AIDC values were computed on each vineyard × year combination.

Results and Discussion

Among the 108 subplot x year combination, we obtained a whole range of AIDC values, from 100% to 0%. The total yield per plant varied from 2.29 kg to 0 (average: 0.74 kg). In 45 cases out of 108 (42%), AIDC was lower than 10%, indicating a rather low incidence of pests and disease on the subplot. The average yield in cases with AIDC <10% was 1.17 kg, and average yield was lower (0.43 kg) in the 63 cases with AIDC >10%.
The total yield per plant (and all yield components measured) is negatively correlated with AIDC. The highest correlation was found between AIDC and cluster mass (Pearson correlation: -0.82; Figure 1.
Relationships observed on these data were similar to those previously found on Merlot cv. when this indicator was developed (Fermaud *et al*., 2016). This confirms the feasibility of extending its field of use.

Conclusions

Through this study, we validated the use of the integrating AIDC indicator under different viticultural (experimental site, cultivar) and seasonal conditions from those in which it had been developed (Fermaud *et al*., 2016). These data and analyses have allowed us to establish some relationships between the AIDC and different components of grapevine yield. Further work will be needed to extend the field of application of AIDC to other pests and diseases than those presently taken into account, in order to use it in different grapevine growing regions worldwide and/or with emerging pests and/or diseases. A next step will also consist in investigating the potential relationships between AIDC and qualitative variables of the grape must at harvest.

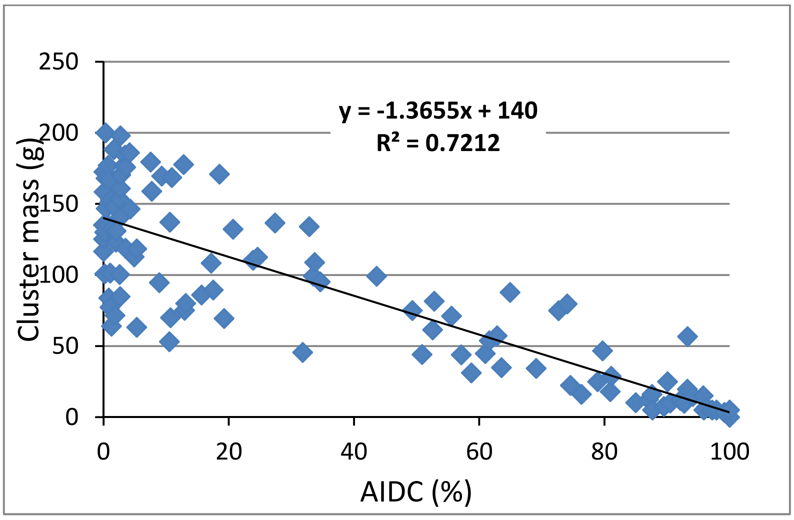

Figure 2: Relationship between AIDC and cluster mass in 108 subplot x year combination between 2006 and 2008, and linear regression.

Acknowledgements

The authors would like to thank Dr. Serge Savary, who initiated the 2006-2008 experiments in Bordeaux, for letting them use the data for this work.

References

Butault J.P. – Dedryver C.A. – Gary C. – Guichard L. – Jacquet F. – Meynard J.M. – Nicot P. – Pitrat M. – Reau R. – Sauphanor B. – Savini I. – Volay T.: 2010. ECOPHYTO R & D: what ways to reduce pesticide use. *Summary report*. 91 pp.

Fermaud M. – Smits N. – Merot A. – Roudet J. – Wery J. – Thiéry D. – Delbac L.: 2016. A new multipest damage indicator to assess protection strategies in grapevine cropping systems. *Australian Journal for Grape and Wine Research*, **22**(2):288–295.

Savary S., Delbac L., Rochas A., Taisant G., Willocquet L.: 2009. Analysis of nonlinear relationships in dual epidemics, and its application to the management of grapevine downy and powdery mildews. *Phytopathology*, **99**(8):930–942.

Wijnands F.G.: 1997. Integrated crop protection and environmental exposure to pesticides; Methods to reduce use and impact of pesticides in arable farming. *European Journal of Agronomy*, **7**:251–260.

IMPLEMENTATION OF SUSTAINABLE IRRIGATION STRATEGIES FOR ALMOND ORCHARDS THROUGH A PARTICIPATORY APPROACH

M. GARCIA-VILA [1] – P. GAMERO-OJEDA [1] – M.A. CARMONA [2] – J. BERLANGA [2] – E. FERERES [1]

[1] University of Cordoba, Cordoba (Spain), Email: g82gavim@uco.es
[2] Genil-Cabra Irrigation Scheme, Santaella (Spain)

Introduction

Spain is the world's third largest almond producer (around 5% of the world production; FAOSTAT, 2013), only surpassed by the United States and Australia. It has the largest acreage, though, but yields have been very low (391 kg ha^{-1} in-shell yield; MAGRAMA, 2015), as compared to US and Australian producers (5,185 and 3,783 kg ha^{-1} in shell yield, respectively; FAOSTAT, 2013). The main reason for the low productivity is that most orchards are grown extensively in rain fed areas (only 9% of the almond area is under irrigation; MAGRAMA, 2015), while in the USA and Australia almost all almond production is under irrigation. Despite the huge effort made in recent years by the production sector to move towards more intensive plantations with an increase in the irrigated area of 23% between 2014 and 2015 (MAGRAMA, 2015), and even though there has been progress in irrigation management research in almond (Goldhamer & Girona, 2012; Egea *et al*., 2013), adoption of modern irrigation techniques by farmers has been slow. Farmers are still far from implementing a sustainable irrigation management due to reliance on their previous traditional rain-fed crop-management know-how. Under the framework of the LIFE+ IRRIMAN project, through a participatory approach, sustainable irrigation strategies for almond orchards are being designed, implemented, validated and disseminated. Participatory approaches may be effective tools for successful design and diffusion of irrigation strategies, especially in traditional rain fed crops such as almonds in the Mediterranean countries.

Materials and Methods

The implementation of the LIFE+ IRRIMAN project is taking place in an irrigation district of Southern Spain (Genil-Cabra Irrigation Scheme, Andalusia). The participatory approach designed has four phases: i) design and implementation of sustainable irrigation strategies in a demonstration farm (DF); ii) dissemination of the best irrigation practice tested in the initial year throughout the irrigation scheme by the irrigation advisory service; iii) assessment of the degree of adoption and re-design of the dissemination strategies; and iv) based on the results obtained, elaboration of sustainable irrigation guidelines to transfer the knowledge generated in the district more widely at regional and national levels and to promote changes in irrigation practices. The achievement of the objectives for each stage is encouraged by involvement of farmers, irrigation communities, public administration and researchers.

Here, we will focus on the first phase of the project during which a DF was set-up in 2014 to implement sustainable irrigation strategies for almond orchards. The DF (a 2 ha plot of cv. 'Antoñeta') was divided into three irrigation sectors, establishing three different irrigation treatments: i) a regulated deficit irrigation strategy based on previous research and adapted to the local conditions (RDI); ii) a control treatment (C) receiving 30% more water than RDI; and iii) the farmer irrigation strategy (F), which was allowed to vary as farmer knowledge and confidence with regard to irrigation management increased.

During the growing season, midday stem water potential and soil water content was monitored with a pressure chamber and TDR sensors, respectively; at harvest time, vegetative growth (canopy volume and trunk perimeter), yield and yield components (fruit load, and kernel weight and size) were determined.

A meeting with all the stakeholders was held at the end of this first phase to analyze and discuss the results and to develop a strategic plan for the dissemination phase.

Results and Discussion

The participatory approach was successful in the first step of the implementation process of innovative irrigation practices for almond tree. The dialogue between farmers and scientists allowed adaptation of the new management strategies to local conditions and challenges.

In the DF, RDI yield increased significantly (77%; Figure 1a) with respect to farmer's yield in the previous year, leading to an increase in total gross margin of around 4,500 € ha^{-1} (in constant currency). Nevertheless, there were no significant differences between RDI and F treatments (Figure 1a), since the farmer changed his practice based on the results of the previous year and followed an irrigation program which was nearly the same as that of RDI (Figure 1b). Irrigation water productivity did not differ among treatments, being 0.25 kg m^{-3}. The speed and degree of uptake of the new irrigation strategy by the farmer highlights the success of the approach.

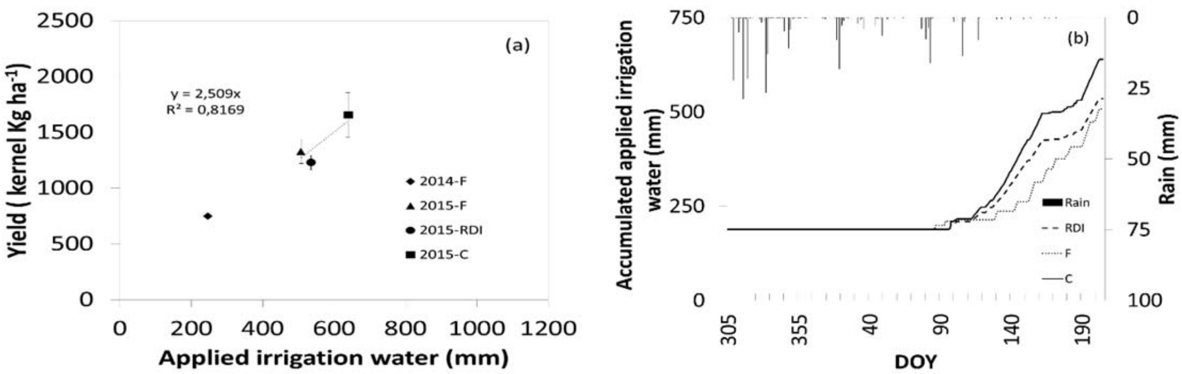

Figure 1. (a) Relationship between kernel yield and applied irrigation water;
(b) Accumulated applied irrigation water throughout the season 2015

Conclusions

The adoption of innovative irrigation strategies is affected by many factors, thus the use of a participatory approach for their design, implementation and dissemination may play a crucial role, especially in traditional rain fed crops, as can be seen from LIFE+ IRRIMAN project performance.

Acknowledgements

This work has been financed by the European Union across the LIFE + IRRIMAN project (LIFE13 ENV/ES/000539)

References

Egea G. – Nortes P.A. – Domingo R. – Baille A. – Pérez-Pastor A. – González-Real M.M.: 2013. Almond agronomic response to long-term deficit irrigation applied since orchard establishment. *Irrigation Science,* **31**(3):445–454.

FAOSTAT.: 2013. *FAO Statistics databases*. http://faostat.fao.org/.

Goldhamer D.A. – Girona J.: 2012. Almond. In *Crop yield response to water*. FAO Irrigation and Drainage Paper 66. Eds P. Steduto, T.C. Hsiao, E. Fereres and D. Raes. Rome: FAO.

MAGRAMA.: 2015. *ESYRCE*. Madrid: Encuesta sobre Superficies y Rendimientos, MAGRAMA.

FIRST STEPS IN PARTICIPATORY DESIGN OF A WEED MANAGEMENT DECISION SUPPORT SYSTEM

Floriane COLAS [1] – Sylvie GRANGER [2] – Jean VILLERD [3] – Nathalie COLBACH [1]

[1] INRA, UMR1347 Agroécologie, 21000 Dijon, France, Email: floriane.colas@dijon.inra.fr
[2] AgroSup Dijon, UMR1347 Agroécologie, BP 86510, 21000 Dijon Cedex, France
[3] INRA, UMR1121 LAE, Nancy, Université de Lorraine, 54505 Vandœuvre-lès-Nancy, France

Introduction

Weeds are harmful for crop production but important for biodiversity. In order to design cropping systems that reconciles crop production and biodiversity, we need tools to help farmers to deal with this issue. The mechanistic weed dynamics model FLORSYS (Colbach *et al*., 2014) is a convenient tool to test management scenarios and evaluate both crop production and biodiversity in cropping systems. Our aim is to use this model as part of a decision support system (DSS). Here, we aimed to identify the needs of advisors to design and evaluate weed management strategies and the main expected uses of a DSS. For this purpose, it is crucial for the development and use of the tool that future users are engaged at an early stage (Cerf *et al*., 2012).

Materials and Methods

A survey was conducted via an online questionnaire sent to advisors from agricultural councils all over France; we obtained 24 responses. The survey included four parts in order to identify: (1) the interviewee; (2) the aims, contents and structure of the DSS (e.g. which rotations? which operation dates?): the criteria for evaluating cropping systems, the temporal scale (e.g. one year, one rotation) and the description of farming

Table 1. How much data are the users ready to provide for a decision-support system (DSS) depending on their difficulties for managing weeds. Percentage (%) of farm advisors answering to a web survey in France

Weed Management Issue	How Much Detail Needed For Crop Management?		
	Detailed (List Of Operations)	**Both**	**General** (Meta Decision Rules)
Lack Of Knowledge On Weed Biology	15	2	11
Constraining Species	13	0	6
Lack Of Solutions	12	0	0
Generated Costs	8	0	0
Competition With Crop	4	0	0
Dependence On The Weather	4	0	0
Lack Of Efficiency Of Practices	6	7	6
Multiannual Scale	0	37	0
Weed Diversity	4	7	0
Too Many Techniques To Choose And Combine	0	12	0
The Need To Diversify Crop Rotation	12	22	33
Weed Resistance To Herbicides	2	0	19
Poor Image The Weeds Give Of Farmer Because Of Field Infestation	3	0	3

Practices (e.g. list of operations, meta decision rules); (3) the constraints for model use, e.g. the availability and difficulty to fill in the different types of input variables; (4) the functionality and readability of inputs and outputs of the future model, the ability to understand why a given input leads to the resulting output.

Results and Discussion

The survey clearly identified two different issues where an advisor would work with a DSS to design and evaluate weed management strategies:

1. Major issue e.g. herbicide resistance - users confronted with a problem such as herbicide resistance would provide only meta decision rules (e.g. a plough every two years) for the DSS (Table 1) and would be ready to radically change their practices (e.g. diversification of crop succession) (Table 2);
2. Adaptive management - users ready to understand and modify their practices before reaching a dead-end (e.g. which practices, which mechanical weeding) would provide a detailed description of the practices (e.g. crop succession, list of operations) so that they could finely tune their system in terms of options and timings of operations (Table 2).

Table 2. How much data will users provide for a decision-support system (DSS) depending on decisions they would like to take with it. Percentage (%) of farm advisors answering to a web survey in France.

Which Decision Should A DSS Help To Take?	**How Much Detail Needed For Crop Management?**		
	Detailed (List Of Operations)	**Both**	**General** (Meta Decision Rules)
It Should Propose A Range Of Levers For Action	12	0	6
What Are The Risks For A Precise Cropping System	7	0	0
Which Type Of Mechanical Weeding	5	0	0
Which Crop Management Sequences	31	34	22
Which Management Alternatives To Previous Cropping System	4	12	0
Which Crops And Successions	19	29	33
Which Herbicide Solutions	18	12	19
How To Optimize Operation Dates	4	12	14
What Is The Best Management Option	1	0	6

Conclusions

Identifying the different profiles and needs for a decision support system will help us to propose different tools more adapted to the various needs. The interaction with future users during its construction is essential for a useful tool development.

Acknowledgements

The present work was financed by INRA (EA and MIA divisions), the French project CoSAC (ANR -14 -CE18CE18CE18 -0007) and the Burgundy Region.

References

Colbach N. – Biju-Duval L. – Gardarin A. – Granger S. – Guyot S.H.M., Mézière D. – Munier-Jolain N.M. – Petit S.: 2014. The role of models for multi-criteria evaluation and multi-objective design of cropping systems for managing weeds. *Weed Research,* **54**:541–555.

Cerf M.– Jeuffroy M.-H.– Prost L.– Meynard J.M., 2012: Participatory design of agricultural decision support tools: taking account of the use situations. *Agronomy for Sustainable Development,* **32**(4):899–910.

INTELLIGENT FLYING CAMERA SYSTEM FOR MOBILE CROP MONITORING AND ON-FARM BREEDING

G. VÁSÁRHELYI[1] – A. JUNG[2,4] – P. BÓNIS[3] – M. VRESAK[4] – G. SOMORJAI[1] – E. MONES [1]– T. ÁRENDÁS [3]– K. SÁRDI[5] – T. VICSEK[1,6] – D. DREXLER[4]

[1] MTA-ELTE Biological and Statistical Physics Research Group, Hungary
[2] Technical Department of the Horticultural Faculty of the Szent István University, Hungary
[3] Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, Hungary
[4] Hungarian Research Institute of Organic Agriculture, Hungary, Email: dora.drexler@biokutatas.hu
[5] Department of Crop Production and Soil Science, University of Pannonia, Georgikon Faculty, Hungary
[6] Department of Biological Physics, Eötvös University, Budapest, Hungary

Introduction

The real advantage of proximal- and remote sensing is the capability to characterize spatial or field variability that cannot be parameterized more effectively in any other way. The technical fineness of the spatially distributed spectral data depends on the applied sensor and platform. When the sensing distance is scaled down, the spatial and spectral resolution can be significantly increased (Lillesand *et al*., 2015); in practice this usually means reducing the altitude of the data-capturing platform. The aim of our study was to verify the applicability of a cheap but intelligent flying camera system in unmanned air-borne remote sensing for the detection of N-use-efficiency within and between winter wheat varieties. This will then allow the system to be used in on-farm variety tests and participatory breeding projects.

Materials and Methods

A multispectral sensor setup was created using two identical low-cost CMOS cameras (Mobius ActionCam), attached to each other and to a gimballed drone platform (Mikrokopter and 3DR quadcopters with DYS and Tarot gimbals). One camera measured the wide-band RGB spectrum, as designed originally. On the other camera, we replaced the Bayer-filter with a near-infrared filter that allowed the CMOS sensors to detect near infrared light (NIR), using its original red channel. We created a common powering mechanism for the two cameras so that image acquisition was always initialized in synchrony. We aligned the two cameras physically and calibrated them independently using software solutions to remove most of the camera distortions. A custom software solution was developed using OpenCV for the calibration/rectification and pixel-level matching of the RGB and NIR images, and to conduct automated image analysis on the matched images.

The system was applied to winter wheat in the Koltay long term N-fertilization trial of the Agricultural Research Center of the Hungarian Academy of Sciences, Martonvásár in 2014 and 2015. Image capturing flights were performed at anthesis (mid-late May, 130 DAE, Feekes 10.5.1-10.5.2) in both years. The trial contained 15 winter wheat varieties with eight N-treatment levels in four replications in a randomized block design. We compared most of the common wide-band vegetation indices (NDVI, RVI, DVI, SAVI, OSAVI, MSAVI2, IPVI, ENDVI, EVI) for the parcels and created detailed statistics of each image sample of individually treated parcels. To provide ground truthing of remote sensing data, SPAD measurements were carried out on two varieties (Mv Karizma, Mv Kolo) and at three N-levels (0, 80, 160 kg ha^{-1}) in parallel with the collection of spectral images. Results of Kjeldahl-N determination were also compared in random leaf and seed samples.

Results and Discussion

We could perform measurements quicker with the remote sensing setup than the traditional techniques, covering 100% of the trial area, with a much higher spatial resolution (< 1 cm). Traditional methods demanded much longer time and higher human input, while providing only point-wise data. We found strong correlations between remote sensing, proximal sensing (SPAD) and wet chemistry data (Figure 1), and also with respect to the final seed Kjeldahl-N results and measured yield. This can give a fairly exact prediction of expected yield quality and quantity at an early phase of plant development (Wang *et al*., 2004). Significant differences in N-use efficiency between the two varieties were also shown with both traditional and remote sensing data.

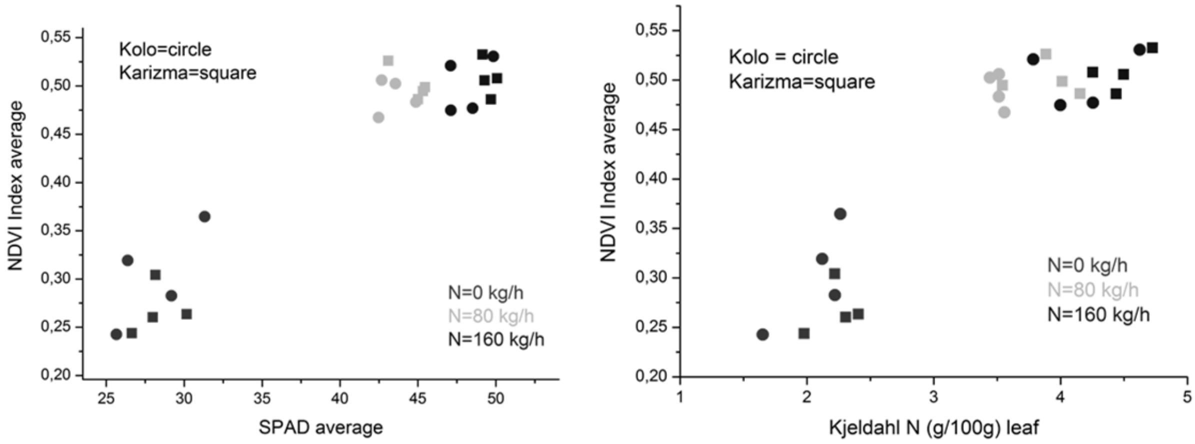

Figure 1: NDVI Index averages of the winter wheat parcels (varieties Mv Karizma and Mv Kolo) on three N-treatment levels in relation with SPAD parcel averages and Kjeldahl N-content of leaves.

Conclusions

Based on our results we conclude that the developed mobile crop monitoring application is of special benefit for the small-scale evaluation of plant N-heterogeneity, and the quick detection of nutrition-efficient individuals within a diverse population. In a next step it may foster on-farm variety testing and the participatory breeding of nutrient-efficient crop varieties, especially adapted to organic agriculture.

References

Lillesand Th.M. – Kiefer R.W. – Chipman J.W.: 2015. *Remote sensing and image interpretation*, 7th Edition. Hoboken NJ, USA: Wiley.

Wang Z.J. – Wang J.H. – Liu L.Y. –Huang W.J. – Zhao C.J. –Wang C.Z.: 2004. Prediction of grain protein content in winter wheat (*Triticum aestivum* L.) using plant pigment ratio (PPR). *Field Crops Research,* **90**(2–3):311–321.