SHOP: a herd dynamic model to simulate the interactions between batch farrowing systems of sow herds

Gilles Martel, Benoit Dedieu, Jean-Yves Dourmad

Farming Systems Design 2009

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Welcome to the Second Biennial International Symposium on Farming Systems Design. Your interest in this area will make this symposium a success and a major international effort among a number of scientific societies. On behalf of the cooperating scientific societies and the program committee, we thank you for your participation and your interactions with international colleagues on this important topic. The increasing interest in alternative farming systems and an effort to expand the capability and capacity of farming systems to provide food, feed, fuel, fiber, or flowers continues to raise questions about how this can be done in a sustainable manner.

This symposium was designed to address a number of themes which were identified by the Program Committee. The themes for this symposium cover a number of areas that cover broad-scale questions. These themes follow throughout the program and the papers are grouped according to these themes.

Theme 1. Regional-scale farm design and improvement

Subtheme 1.1 Lifecycle of Value Chains

Subtheme 1.2 Climate impacts on agricultural systems

Theme 2. Field-scale farm design and improvement

Theme 3. Alternative management systems

Subtheme 3.1 Systems for energy and water-use efficient farming

Subtheme 3.2 Systems for reducing greenhouse gas emissions and increasing carbon storage

Subtheme 3.3 Systems for biofuel production and production systems

Subtheme 3.4 Systems for alternative production

Theme 4. Model application and outcomes

Theme 5. Software Support for Farming Systems Design

This program was structured to allow for maximum amount of interaction among the participants. The tour that is associated with this symposium is designed to supplement the concepts discussed in the oral and poster sessions by allowing the participants to see the innovative systems that are being implemented but to also hear from the producers how they see the future challenges in terms of farming systems. We owe a special thanks to Mary Bianchi and Warren Hutchings for their efforts in organizing this tour for this symposium.

There remains much to be done in the exciting area of farming systems. The interactions among the scientific societies provide an impetus for continued dialog among researchers and technology transfer specialists to expand our understanding of farming systems. We are excited that you are willing to share your knowledge with us. We hope that you will find this symposium informative, enjoyable, and useful to your professional career.

Jerry L. Hatfield, Organizing Co-Chair   Jon D. Hanson, Organizing Co-Chair

This conference is made possible through the support of the following sponsors and societies. We are also indebted to the following individuals who have provided guidance, insight, and direction to make this conference a success.

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REDUCING HERBICIDE IN BANANA CROPPING SYSTEMS BY INTEGRATING COVER CROPS: EXPERIMENTAL AND MODELLING APPROACH

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INTRODUCTION

Banana cropping systems for export market were based on monocropping systems and on the massive used of fertilizer and pesticides. There is actually an important demand from society and policy-maker for more sustainable and environmentally friendly banana systems. Nowadays, the reintroduction of fallow and the use of in vitro plantlets constitute effective cultural strategies to reduce nematodes damages and nematicide uses. Herbicide use becomes the most important pesticide input in banana farms and developing herbicide free alternatives is a priority. Intercropping with cover crops constitute the main alternative to reduce herbicide used in banana fields. However, to maintain sufficient economical yield, the competition between the banana plant and the cover crop has to be evaluated and eventually compensated.

MATERIALS AND METHODS

A field experiment has been carried out in Martinique (French West Indies, 26°C average temperature, 2500 mm annual rainfall) to evaluate the impact of intercropping banana with two cover crops *Bracharia decumbens* and *Cynodon daclylon*, mechanically managed. These intercropping systems were compared to bare soil obtained with glyphosate spraying. Nitrogen fertilizer was applied monthly around the banana corm for a total amount of 200 UN/ha and 300 UN/ha, for the first and the second cycle. We measured banana growth, duration of crop cycle, and bunch number of finger, during two cropping cycles. We monitored the nitrogen nutrition status of plants by Chlorophyll meter SPAD 502 (Achard, 2006). Mineral nitrogen content in soil was measured at some key dates in the row and in the inter-row. We adapted the nitrogen balance model SIMBA-N (Dorel, 2007) to account for the effect of the cover crop. It includes cover crop growth, its nitrogen demand, and the competition with the banana plant.

RESULTS AND DISCUSSION

During the first cropping cycle **(table 1)**, four months after planting, banana plants intercropped with *Bracharia decumbens* and *Cynodon daclylon* had significant lower level of nitrogen (SPAD index) and growth (-25% of pseudostem high) than on bare soil. At flowering stage (six months after planting), growth and SPAD index were not significantly different between intercropped and bare soil treatments. However, the planting-flowering interval was 6 to 8 weeks significantly longer in the intercropped treatments. Furthermore, the bunch size was lower in intercropped treatments. These results show that cover crops induce nitrogen limitation during banana growth and reduce productivity for the first cycle.

During the second cropping cycle, 12 months after planting, the ratooning banana plants intercropped had significant lower growth (-20% of pseudostem high), but had similar nitrogen SPAD index and similar bunch weights. Compared to the bare soil, the flowering of intercropped banana was significantly delayed. For this cropping cycle, yield loses are mainly due to the later flowering that is not longer than in first cropping cycle. We hypothesize it is an heritage from the first cropping cycle and not due to competitions during the second cropping cycle.

The higher nitrogen competition occurred during the first cycle and is clearly link to the cover crop demand during its initial growth. This growth was 9 and 5 ton of dry matter in three months, corresponding to 110 and 55 UN/ha for *Bracharia decumbens* and *Cynodon daclylon*, respectively, After the initial growth of cover crops, mowing residues of cover crops mineralized and return in the nitrogen balance, similarly to *Brachiaria* pasture (Boddey, 2004). Intercropped banana my only require increased nitrogen fertilisation during the initial growth of the cover crop.

With these data and nitrogen content of soil (data not showed), we were able to set the parameters of the model. On this basis, for a mowing every three months and a 45UN/ha fertilization, the model represent well the depressive effect of the cover crop during the first cycle of the bananas (**figure 1**), a slight depressive effect in the second cycle, and show that for the following cycles no effect would be expected. The model also indicates that an increase of fertilisation from 45 to 145 UN/ha each two month is require to satisfy nitrogen demand during the vegetative growth of bananas plants in the first cycle and would avoid competition effects on yield and cycle duration.

Another promising use of the model consists in exploring new technical combination in time and in space of the cover crop, e.g. anticipate the cover crop establishment, and with other species of cover crops that could be less competitive and/or requiring less specific management. Future activities will deal with introducing legume cover as cover crop in banana cropping systems and with a more comprehensive evaluation of agronomic and environmental performances of these new banana cropping systems.

Table 1: Agronomic results for two banana first cropping cycles

Agronomic parameter	Vegetative growth (12& 52 weeks after plantation)		Growth at flowering		Cycle duration	Bunch size
Cycle /Treatment	Pseudostem high (cm)	Chlorophyl index SPAD	Pseudostem high (cm)	Chlorophyl index SPAD	WAP (weeks)	Finger number
First Cycle						
T0 Bare soil	180 A	57 A	264	55	26 A	171 A
T1 Cynondon cover	135 B	53 B	262	55	32 B	156 B
T2 Bracharia cover	120 B	52 B	271	57	34 B	164 AB
Statistics	HS	HS	NS	NS	S	S
Second cycle						
T0 Bare soil	262 A	55	296	56 B	62 A	216
T1 Cynondon cover	203 B	53	302	58 A	69 B	218
T2 Bracharia cover	213 B	53	301	56 B	69 B	213
Statistics	HS	NS	NS	S	HS	NS

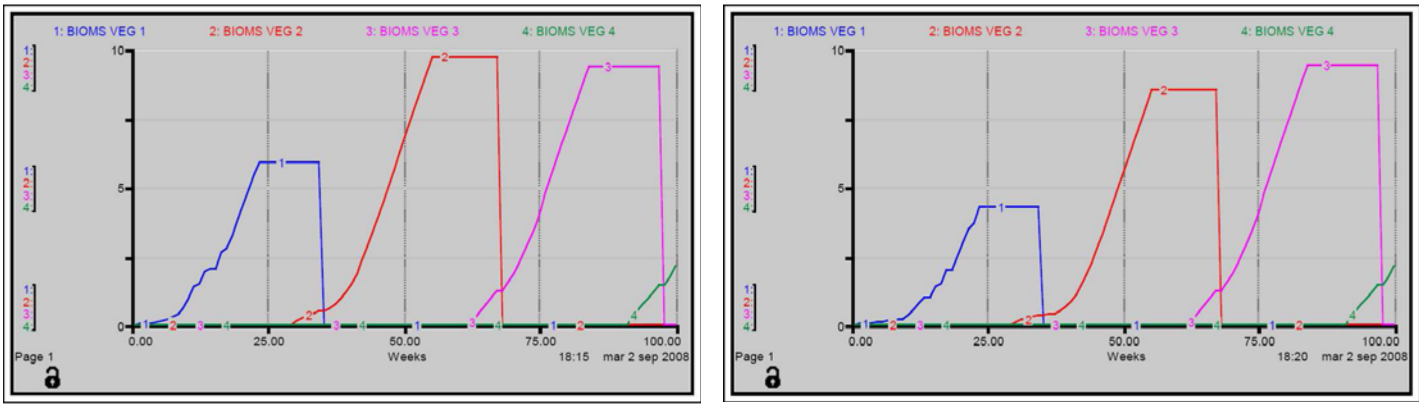

Figure 1: Growth simulation of bananas on bare soil (on the left) and with grass cover (right)

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THE USE OF REFERENCE VALUES IN LIFE CYCLE ASSESSMENT OF FARMING SYSTEMS

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INTRODUCTION

Life Cycle Assessment (LCA) is a tool that compiles and evaluates the inputs, outputs, and potential environmental impacts of a product system. When used to compare production modes, LCA can reveal which mode appears “environmentally better” but does not indicate whether it is environmentally sustainable. LCA also is predominantly site-generic, considering emissions independent of landscape characteristics (Finnveden and Nilsson 2005). Here, we define a sustainable farming activity as an activity in which “polluting emissions and use of natural resources can be supported in the long term by the natural environment” (Payraudeau and van der Werf 2005). Subsequently, we develop reference values (RVs) to assess whether production modes are environmentally sustainable in a specific environment.

MATERIALS AND METHODS

We assessed two impacts with different spatial scales: a global impact, climate change (CC), and a local impact, eutrophication (E, limited to its nitrate leaching component), for 45 dairy farms in Brittany (western France). Farms were assessed with EDEN-E, a LCA-based tool (Van der Werf, Kanyarushoki, and Corson Forthcoming). For both impacts, on a per-hectare basis, we defined relative and absolute RVs. Relative RVs were defined as the mean impacts of the “best” (i.e., having the lowest impacts) one-third of the population (here, 15 farms). Absolute RVs were founded on science-based political objectives and define thresholds of sustainability. For CC we considered the French government target: reducing greenhouse gas emissions by 20% by 2020 and by 75% by 2050; for E we considered the European Union Water Framework Directive, which aims for “good” water status using a nitrate (NO_3) standard of 50 mg/l. The other absolute RV for water quality, with respect to ecological health, is based on research in the bay of Lannion in northern Brittany (Ménesguen 2003). Strongly reducing algal blooms here would require a maximum concentration of 10 mg/l of NO_3 in the rivers. Since E is a local impact, two different absolute RVs were set based on a regional characteristic (1960-1990 mean annual drainage flow) and on-farm nitrate-nitrogen balances (after taking atmospheric depositions and gaseous losses into account) to estimate a theoretical mean annual concentration of nitrates under fields, a method developed in this region (Payraudeau, van der Werf, and Vertes 2006). An indicator of nutritional energy production was used to normalize differences among farms that produced different proportions of animal and crop products.

RESULTS AND DISCUSSION

For CC, the 45 farms’ mean, relative, and two absolute reference values were, respectively, 6107 (mean), 4862 (relative), 4885 (2020 goal) and 1526 (2050 goal) kg CO_2-equivalent per ha. For E the 45 farms’ mean, relative, and two absolute reference values were, respectively, 59 (mean), 31 (relative), 38 (50mg/l goal) and 8 (10mg/l goal) kg/ha of nitrogen as nitrate. Seven farms had impacts below the 2020 goal (CC) and 10 below the goal of 50 mg/l (E); 3 of these farms had impacts below RVs for both impacts (Figure 1). To determine whether groups above and below the RVs had significantly different characteristics, a $\chi 2$ test of independence was performed by comparing their distribution around the overall median of each characteristic. As shown in Table 1, these 14 unique farms differed significantly from the other farms in the proportion that produce organically, their agricultural area, milk production, greenhouse gas (GHG) and nitrate emissions, and potential impacts.

This study revealed a positive correlation between CC and E (Figure 1), which leads us to hope that reducing one will not increase the other. Interestingly, the "low-E" farms tend to produce less nutritional energy, in particular from crop products, per ha of land occupied, whereas the "low-CC" farms produce slightly more nutritional energy and with a larger proportion from crop products.

These preliminary results show the interest in developing and applying RVs and illustrate that absolute RVs currently remain unattainable for most farms. The major implications of defining RVs include: (i) guiding current farming systems to alternative forms by showing which stages of production have the largest environmental impacts, (ii) the possibility of indicating which impacts may most interest stakeholders, and (iii) considering multiple spatial scales based on local, regional, and global characteristics of the natural environment. Future work will explore management options leading to compliance with absolute RVs.

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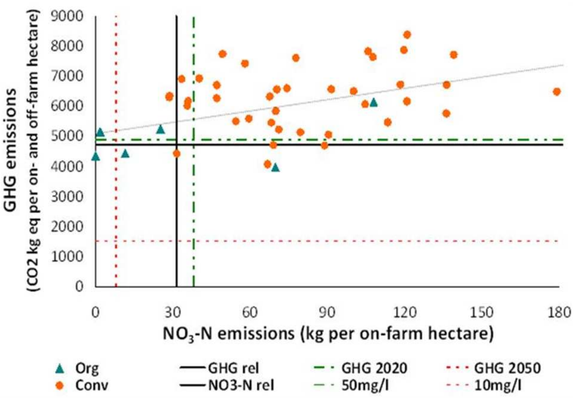

Figure 1. Distribution of farms by production mode (Org = organic, Conv = conventional) according to two impact indicators: greenhouse gas emissions (y-axis) and nitrate-N emissions (x-axis). One relative reference value (RV) and two absolute RVs are represented for each impact (dashed and solid lines for greenhouse gas and nitrate-N emissions, respectively).

Table 1. Annual median characteristics, emissions and impacts of the 45 farms grouped by those whose impacts did (E or CC) or did not (Others) remain below each reference value. Differences are significant at $p<0.1$ (*) and $p<0.05$ (**).

Characteristic	Unit	E (n=10)	Others (n=35)	CC (n=7)	Others (n=38)
% organic farms	%	40**	6	43**	8
Useable Agricultural Area (UAA)	ha	64**	54	67**	55
On- and Off-farm Agricultural Area (OOA)	ha	71*	65	77*	66
Sold fat and protein-corrected milk	kg FCPM ha^{-1} FCGA yr^{-1}	5594*	6868	5302*	6901
Total nutritional (nutr.) energy produced	GJ ha^{-1} UAA	21.3*	37.2	32.8	31.6
Nutr. energy from animal products	GJ ha^{-1} UAA	12.3	14.9	12.0	15.3
Nutr. energy from crop products	GJ ha^{-1} UAA	9.0**	22.3	20.8**	16.3

Emissions and Impacts	Unit	E (n=10)	Others (n=35)	CC (n=7)	Others (n=38)
CO_2 emitted	kg CO_2 ha^{-1} OOA	802*	941	790*	939
N_2O emitted	kg CO_2 equiv. ha^{-1} OOA	1563**	1843	1450**	1839
CH_4 emitted	kg CO_2 equiv. ha^{-1} OOA	3491	3467	2252**	3557
Nitrate leaching	kg N ha^{-1} UAA	29**	79	67*	79
Total eutrophication	kg PO_4 equiv. OOA	19**	40	31*	40
Total climate change	kg CO_2 equiv. ha^{-1} OOA	5856**	6251	4492**	6335

A COVIABILITY MODEL TO ASSESS THE LONG TERM DYNAMICS OF MIXED FARMING SYSTEMS UNDER CLIMATIC UNCERTAINTY

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INTRODUCTION

In arid regions, agro pastoralists develop complex strategies in order to anticipate losses caused by drought. Asset diversification, based on the combination of crop and livestock, is one such strategy that allows coping with climate uncertainty. During the last ten years, international demand for quinoa (*Chenopodium quinoa*) has multiplied its price by a factor of 15 (Acosta-Alba 2007) maintaining high prices for this product. In southwestern Bolivia, large areas of rangelands were converted into arable land, upsetting the balance between quinoa crop and llama stocks (*Lama glama*), llama products are exclusively sold on local markets. We develop a coviability model to assess the long term dynamics of mixed farming systems under climatic uncertainty. The model represents two assets which are compared in order to find out the effect of yield variance on decision-making. The model is used to identify the viable combination of quinoa crop and livestock, minimizing climatic effects on mixed farming systems.

DESCRIPTION OF MODEL

The model represents a general problem of land use allocation under constraints. It relies on a state-space representation. The state variable is the total farmer's wealth divided into two land uses: a grazing llama flock and a cropping system based on quinoa. Each land use is characterized by its sale price and by its annual yield depending on a climatic parameter. It is assumed that the climatic parameter can fluctuate along time within two extreme values. This climatic parameter accounts for good and bad agricultural or livestock years. Quinoa production is the asset with high variance in average yields between year types and high price fixed annually (75 Euros per ton); whereas llama stock is the asset with similar low average yields between years and low market prices. A control variable stands for the proportion of wealth allocated to each land use. It represents the farmer's management strategy in terms of number of llamas and amount of quinoa cultivated. Furthermore, the farmer needs to secure a minimum income at all times. This minimum income is taken as a viability constraint; it represents the cash value needed to secure the annual family's subsistence requirements. It is a fixed value, estimated for a reference family (Tichit, Hubert, Doyen, and Genin 2004). State and control variables define a geometrical space within which there are wealth levels and decisions maintaining long term wealth viability while ensuring minimum income despite climatic uncertainty.

The mathematical framework of viable control theory (VCT) (De Lara and Doyen 2008) is used to analyse the compatibility between wealth dynamics and constraints. This framework makes it possible to identify land use allocation decisions and wealth levels that ensure the satisfaction of viability constraints at all times, despite uncertainties that may exist. The model is not limited by the need to provide any statistical data on the distribution of the climatic variable. The need for that is eliminated by the adoption of a worst case and totally risk-averse approach related to robust viability (De Lara and Doyen 2008). The computation of the viability kernel is the set of initial wealth levels from which there exists decisions that yield wealth evolutions such that the viability constraint holds true for every time. However due to the presence of exogenous uncertainty, careful attention has to be paid to the strategy used in the control variables. Here, non-anticipative strategies are considered, which means that current decisions depend on the past and present realisation of uncertainty, but not on its future values, which are unknown and unpredictable.

RESULTS AND DISCUSSION

Specialized strategies either on quinoa or on llama stock were not viable for any climatic scenarios. Specialized strategies based on quinoa are extremely risky and in many years, they do not make it possible to ensure a farmer's minimum income (Fig 1a). However, in good years, they will ensure a quick increase in wealth. If based on llama stock only, viable specialized strategies require a higher wealth level in order to secure minimum income whatever the climatic conditions (results not shown). Different mixed strategies combining both livestock and crop in varying proportion were simulated. Results show that combining 30% quinoa with 70% llama stock is a robust strategy, ensuring the mixed farming system viability in any climatic scenario (Fig 1b). Due to their ability to thrive during environmental perturbation, livestock are a stabilising component of the mixed farming system, whereas quinoa crop makes it possible to achieve quick recovery after drought years.

These first results have highlighted the agricultural component of mixed farming systems. However, livelihood strategies, in particular those based on off-farm income and migration, are likely to play an important role in risk mitigation strategies. Integration of such social and economic issues is needed to design alternative farming systems. Further model development will integrate off-farm income and prices variation. Agro pastoralist societies have to face new sources of risk because they are no longer isolated. Markets, NGOs, research and development institutes, and governments generate links that are pressures but also are sources of innovative information that induce changes in management practices, changes that usually go unnoticed. Thus, studying agro pastoral systems requires looking beyond the agricultural production system. The sustainability of livestock production systems should be considered as a whole by including socio-economic factors in multi-criteria analyses.

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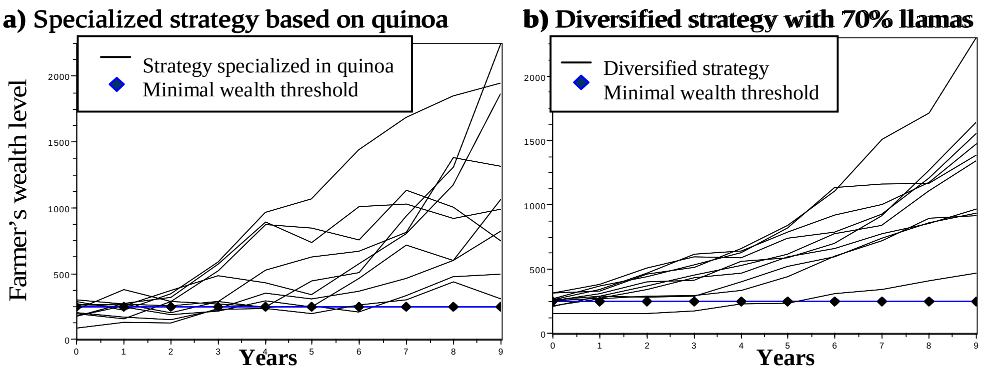

Figure 1. Change over time of farmer's wealth for two contrasted land use strategies. a) Specialized strategy based on quinoa production only; b) mixed strategy based on 30% quinoa and 70% llamas. In both figures, blue threshold represent minimum income.

Evaluation of ratooning ability of NERICA lowland rice as an option for triple cropping in inland valley without irrigation in derived savannah

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INTRODUCTION

Under the prevailing traditional farming in inland valley of Southwestern Nigeria, one crop of rice is grown per year because swamps are not developed and water flow is not controlled (WARDA, 1993). Most farmers practice double cropping in the inland valleys (i.e. lowland rice-dry season vegetable sequence). Considerable opportunity exists for growing the third crop between the lowland rice and the dry season cropping. The period of soil moisture availability in this niche is not only too short to accommodate second lowland rice but will not be sufficient to support it. Earlier study showed that early maturing upland rice dibbled into the niche decreased the overall benefit/cost ratio of triple cropping rather than increasing it (Adigbo *et al.,* 2007). However, this period could accommodate ratooned rice crop because it matures early and requires less water. Ratooned rice crop could therefore be a veritable option. The objectives of this study were 1) to evaluate the performance of main crop of lowland rice of the New Rice for Africa (NERICA) varieties and 2) to evaluate the performance of ratooned rice crop of NERICA lowland rice varieties in the existing niche.

Materials and Methods

The experiment was conducted in 2007/2008–2008/2009 cropping seasons in an inland valley (IV) of the University of Agriculture, Abeokuta, Nigeria. The experiment was laid out in Randomize Complete Block Design (RCBD) in three replicates. Ten lowland rice varieties of NERICA were planted in May and harvested in September. The harvested rice shoots were cut to 5cm above the soil level to stimulate ratoon growth and harvested in November. The plot size was 3 m x 2 m and spacing of 20 x 20 cm apart. Fluted pumpkin (*Telfaria occedentalis*) was planted in December and harvested in April.

Data collection and analysis for main and ratooned rice crops

Stand count, number of days to 50% flowering, grains panicle^{-1}, plant height and Grain yield (t ha^{-1}). The data collected were subjected to analysis of variance and means were separated using DMRT.

Results and discussion

NERICA-L 22 and 25 had the lowest number of ratooned tillers plot^{-1} while those of NERICA-L 19, 20, 26, 44 and 47 were the highest. The number of days to flowering ranged between 88 and 98 days after planting (DAP) for main rice and 27 and 38 DAP for ratooned rice crop. The main rice crop had significantly higher average grain yield (6.49 t ha^{-1}) than ratoon rice crop (2.93 t ha^{-1}). The total grain yields of the two rice crops in 7 months were similar (9.38 t ha^{-1} and 9.46 t ha^{-1} in 2007/2008 and 2008/2009 cropping seasons, respectively). The grain yields of main rice crop ranged between 4.97 and 7.31 t ha^{-1} while those of ratooned crop ranged between 0.97 and 4.66 t ha^{-1}.in 2007/2008 cropping season (Table 1). In 2008/2009 cropping season, the grain yields of main rice crop range between 4.1 and 9.4 t ha^{-1} while the ratoon rice ranged between 1.2 and 3.4 t ha^{-1} (Table 2). The fresh leaf of fluted pumpkin gave of 15.51 t ha^{-1}. Ratooned rice crop in this niche gave substantial grain yields of rice compared to the obtainable yield of upland rice {1.5 t ha^{-1} (IITA, 1990) and 1.38 t ha^{-1} (Africa Rice Center, 2008)} in the upland ecology. Thus, ratooned rice appeared to be viable technology capable of boosting rice production in the niche and consequently increase the productivity of inland valley.

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Table 1: Agronomic performance of main and ratooned crop of (NERICA-L) variety in 2007 cropping season.

	Main rice crop			Ratooned rice			
Variety	**50% heading**	**Grains panicle^{-1}**	**Grain yield t ha^{-1}**	**Ratoon emergence**	**50% heading**	**Grains panicle^{-1}**	**Grain yield t ha^{-1}**
NERICA-L 19	92cd	211bcd	5.28bc	129a	34abc	85de	3.97abc
NERICA-L 20	90d	112e	5.97abc	134a	34abc	95cd	4.08abc
NERICA-L 22	93bc	191d	5.54bc	72c	34abc	95cd	1.10e
NERICA-L 24	93bc	236ab	6.25abc	87bc	32c	109bc	2.24d
NERICA-L 25	94b	239ab	6.23abc	76c	27d	119ab	0.97e
NERICA-L 26	98a	249a	6.42ab	141a	37ab	69e	4.66a
NERICA-L 41	91d	232abc	7.31a	100b	38a	129a	4.26ab
NERICA-L 42	92cd	233abc	7.05a	92bc	37ab	97cd	3.61bc
NERICA-L 44	93bc	194cd	6.31abc	143a	33bc	89d	4.09abc
NERICA-L 47	88d	192d	4.97c	133a	32c	89d	3.38c
*F test	0.0001	0.0241	0.048	0.0001	0.036	0.0040	0.0000
SE	0.7802	16.41	0.46	9.896	2.023	8.4164	0.48

+ = Data was not collected because of lodging, * Significance (p value), Values with the same alphabet vertically are not significantly different from each other

Table 2: Agronomic performance of main and ratooned crop of lowland rice variety in 2008/2009 cropping season.

	Main rice crop			Ratooned rice			
Variety	**50% heading**	**Grains panicle^{-1}**	**Grain yield t ha^{-1}**	**Ratoon emergence**	**50% heading**	**Grains panicle^{-1}**	**Grain yield t ha^{-1}**
NERICA-L 19	96ab	142a	6.5de	128bc	41bc	109cde	2.7ab
NERICA-L 20	94cd	159a	6.5de	137abc	40bc	123bc	3.4a
NERICA-L 22	95bc	140a	7.3cd	79d	38cd	84f	1.6c
NERICA-L 24	91d	163a	9.4a	110c	42b	125bc	3.2ab
*OFADA	94cd	163a	4.1g	135abc	29e	132b	1.2c
NERICA-L 26	99a	180a	7.7	152ab	33de	93ef	2.6b
NERICA-L 41	93cd	186a	7.7	144ab	43b	128b	3.4ab
NERICA-L 42	95bc	158a	9.1ab	56d	48a	114cd	1.8c
NERICA-L 44	95bc	166a	7.9	151ab	37cd	101def	3.0ab
NERICA-L 47	88e	178a	4.5fg	159a	42b	165a	3.3ab
*F-Test	0.002	NS	0.0000	0.0004	0.0002	0.0003	0.003
SE	1.3	0.5	0.57	13.1	1.9	8.8	0.38

+ = Data was not collected because of lodging, * Significance (p value), Values with the same alphabet vertically are not significantly different from each other. *OFADA was used to replace NERICA-L 25 because of lodging.

MODELLING CROP ALLOCATION DECISION-MAKING PROCESSES TO SIMULATE DYNAMICS OF AGRICULTURAL LAND USES AT FARM AND LANDSCAPE LEVEL

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INTRODUCTION

Agriculture, as the largest land user in Europe, is increasingly questioned about its impacts on the environment. The mutual relationship between land and farmer practices is an important factor to consider for studying land use decisions. Land management is part of the whole technical management of agricultural production at farm level and partly determines farm profitability. The collective dynamics generated by all individual farm land use choices impacts on ecological processes occurring on larger space. Therefore, to improve resource use efficiency at farm level (e.g. land, water) and to better manage environmental resources at landscape level (e.g. erosion), one needs to consider processes of crop allocation to land.

In the past, modelling crop allocation has been extensively addressed (Aubry et al., 1998), but most of the approaches used were static (Dogliotti et al., 2003). The cropping plan choices were usually summarized as a single decision occurring once a year. The dynamic processes, ie modelling the allocation choices as a succession of reactive and planned decisions along annual and long term horizons, were rarely used. Crop allocation choices involve an important part of uncertainty and risk (e.g. price, weather) that have to be accounted for. Further, in most existing modelling approaches, the latter was not spatially represented and was usually summarized as single crop acreage distributions across land types.

Although modelling agricultural decision-making is not new, it has never been carried out into details on crop allocation decisions at farm scale. Based on three complementary PhD works we propose to model these crop allocation decisions at farm scale, in order to: i) understand and model the relationships between different types of decision and the time farmers take them, ii) support farmers in their annual and long term crop allocation strategies and iii) support the design of environmental public policies by simulating their effects on individual land use decisions and their environmental impacts at landscape level through a bottom up approach.

MATERIALS AND METHODS

In order to explore the variability of crop choices and crop allocation on the farm territory in relation with farmers' objectives, we carried out two different sets of farmer interviews in France. We focused on farm constraints (spatial organization of the farm territory, climate and soils characteristics, labour organization), and on regional and larger scale constraints (socio-economic context, CAP requirements). In set 1 (11 farms in the "Niort Plain" region), we sought to formalize the links between crops and animal production and its impact on cash-crop surfaces vs. forage surfaces choices on farm, considering the variable annual forage needs for livestock. In set 2 (30 farms scattered into Midi-Pyrénées, Poitou-Charentes and Centre) we focused on the effect of water availability and irrigation rules on crop choices in arable farms. In this survey, parts of the questionnaire aimed at assessing farmers' aversion towards risk.

Based on collected information completed by a literature review, we sketched towards a conceptual model which includes spatial and temporal dynamics of the crop allocation decision-making processes at farm scale.

RESULTS AND DISCUSSION

Preliminary data analysis showed that farmers' decisions to chose crops, define acreage and allocate them to land are strongly dependant on each other and can hardly be solve independently. Further there are strong relationships between annual and long term thinking while farmers take these decisions.

Some farm specific constraints which drive the crop allocation decision-making process are hardly manageable on short term perspective. Field characteristics (e.g. area, shape, soil type, water accessibility) and their spatial distribution into the territory (distance, access) are the first structural constraints that strongly affect the decision-making process. Based on these constraints, farmers organize their farming territory into homogeneous land units in relation to their own production objectives (e.g. cash crop, forage for animal). This spatial organization implies annual and/or long term plot division strategies that appear to be dependant on the farm territory structure and the nature of production. The management units receive different crop rotations or perennial crops (e.g. grasslands) generating different and complementary crop management systems. These crop management systems are relatively stable in time but are very likely to evolve when important changes of the context and/or farmers' objectives occur. Understanding how farmers organize the farm territory is therefore a key element for modelling crop allocation decision-making processes because it structures crop productions.

Annual scheduling of decision-making processes leading to the cropping plan are very different from farm to farm and strongly depends on farmers' strategies, socio-economical context and available information. However, in all cases, the decision-making process is a succession of embedded anticipatory and reactive phases (Garcia et al., 2005). The different phases can be identified in relation to specific farmers' strategies, constraints and events (e.g. price change, water attribution), and can therefore be incorporated into a generic modelling framework.

Modelling the crop allocation decision-making processes requires to explicit the interactions between a set of constraints from very different natures fitted into different time scale dynamics and integrated into various spatial entities within the farm territory. At this stage, the paper has just sketched the basic needs for modelling crop allocation processes. The model has not been implemented yet, since it first requires a translation of the decisional-model into formalisms usable in combination with biophysical crop models. Using modelling and simulation platform (RECORD, DYPAL), these formalisms will be coupled with biophysical models and optimization algorithm to simulate crop management strategies.

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Middle East farm management model application on South-West part of Azerbaijan

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Abstract

This model application from Israel of new agricultural technologies and practices under real-world conditions of Azerbaijan. Farm takes the area about 4000 ha on South West part of the country.

Key words: Carbon Sequestration, Crop Production**,** Implications for Plant Growth of Irrigation, Agricultural Offsets, Environmental change.

Introduction

Farm destination is latitude 39° 37' 30'' N, longitude 048° 08' 42'' E, altitude maximum 73 m, minimum 0 m above sea level, plateau with a poor soil quality. Underground water level close to surface on 0.5-12 m.

Crop production in the Agriculture Farm Bilasuvar is winter wheat, corn, sugar beet, industrial tomato, greenhouse tomato, vegetables and orchards.

MATERIALS AND METHODS

Agriculture Technology Transferring method, allow to economy of money to the research and development of projects. Developing improved nutrient, tillage, and crop management practices that will enhance productivity without negative off-site consequences

Education farmers and agronomists for familiarity with drip irrigation, pivot system, fertigation, seedlings, net house crop production, greenhouse and others resources.

RESULTS

Our experience shown, that a most of the farmers in the world have not familiarity with hi-tech methods on agriculture crop production. Education of the agriculture experts in Israel from different countries confirm our assumptions, that most farmers and agronomists not familiarity with drip irrigation, pivot system, fertigation, seedlings, net house crop production, greenhouse and others resources show quick economic return. Best soil and water management for the food production and increase a carbon sequestration. Crop production affected and increasing impact of climate change will our ability to efficiently crops produce. Every plants species is important agriculture crop or growing of halophytes for the biofuel.

CONCLUSIONS

Education of agriculture experts from different countries is important. Most farmers and agronomists not familiarity with drip irrigation, pivot system irrigation, fertigation, seedlings, net house crop production, and others resources consider to increase biomass , consequence enhance carbon sequestration.

What will do? Make wide ways for the transferring agronomic knowledge and advanced technology to agriculture farms, agronomist and managers. Impact of agricultural research from Israel to Azerbaijan by: better understanding learning and adoption pathways of farmers and agricultural industries.

We also are assessing the roles and effectiveness of decision support systems, and developing, evaluating and designing the implementation of action research cycles for to produce food, feed, and fiber by methods to evaluate water-use efficiency and comparison among farming systems to determine optimum management strategies. Every plants species is important!

One of the outcomes is to increase the information sharing among the different farmers and enhance agriculture throughout then all regions of Azerbaijan.

REDUCING NITRATE AND WATER LOSS USING MICROBIAL COMMUNITY FERMENTATION TECHNOLOGY

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INTRODUCTION

Nitrate contamination of ground and surface waters from agricultural sources is a serious problem and significant efforts have been made to identify and control factors contributing to this pollution (Power et al., 2001; Spalding et al., 2001; Dinnes et al., 2002). In the reviews by Power et al. (2001) and Dinnes et al. (2002) acknowledgement was made of the role of soil microorganisms in N-cycling, however; no information was presented on the potential for utilizing or enhancing microbiological functions as a method to reduce nitrate leaching from the soil. Mulvaney et al. (2006) showed that yield-based recommendations for N fertilization could lead to excessive amounts of N applied to corn and that accounting for microbial immobilization and mineralization of N could lead to a more efficient prediction of corn crop N requirements. The microbial decomposition of organic matter, especially corn crop residue in the soil, can also help to stabilize N (Liang et al., 2007). Microbial inoculants have been shown to increase the growth, yield and N content of field corn (Adesemoye et al., 2008). To further evaluate the role of microbial inoculants on reducing N loss in corn, Advanced Microbial Solutions (AMS) has begun a multi-year study using field lysimeters. Data are presented from the first year's field evaluations.

MATERIALS AND METHODS

A replicated corn study was conducted in field lysimeters by Arise Research & Discovery, Inc., Martinsville, IL in 2008. Each lysimeter treatment included 4 rows (replicates) of field corn (Tristler T7N88CB) 18.3 m long. Row spacing was 76 cm with a seed rate of 74,130/ha. The soil type is a Piasa silty clay loam (fine, smectitic, mesic Mollic Natraqualfs). Water was supplied by seasonal rain only (average 96 cm, for 2008 rainfall was 147 cm). Water leaching down to 1.06 m under each row was measured and captured in wells. The four treatments consisted of two N application rates (207 or 187 kgN/ha) with or without concentrated SoilBuilder (9.3 L/ha applied with UAN-28 as a sidedress at planting). N application rates were adjusted at a second UAN-28 sidedress application 18 days after planting to provide the full and 90% N rates indicated above. The volumes of leachate water and NO_3-N concentrations were determined six times during the season following pumping of the lysimeter wells. Leachate volumes, NO_3 concentration, total NO_3-N leached, and yield data were statistically analyzed using an ANOVA with mean separations at $P<0.05$ (Student-Newman-Keuls).

RESULTS AND DISCUSSION

By the third pumping, 30 days after planting, and continuing through the subsequent pumpings, there were significant reductions in the amount of water and/or N retained in lysimeter wells in the SoilBuilder treatments compared to the controls (Table 1). By the end of the season, SoilBuilder significantly reduced the total amount of water and NO_3 leached to the lysimeter wells and significantly increased grain yield. The 3rd lysimeter pumping (12 d after the second sidedress UAN application) showed a large increase in N leached in the controls but not in the SoilBuilder treatments. This indicated a SoilBuilder enhancement of crop N uptake or increased N immobilization. Plant health evaluations and photos (data not shown) indicated the SoilBuilder treatments were significantly greener. The time period for the 3rd and 4th lysimeter water evaluations, where the largest effect of SoilBuilder was shown, correspond to the developmental stage of corn where a rapid increase in root growth occurs (Mengel, 1995). Thus the timing of corn root development, increased plant health, decreased N in leachates and increased yield all indicate that SoilBuilder treatment increased root growth and N uptake. Increased root growth has been documented in several university studies with SoilBuilder (AMS, unpublished) and with another AMS product, Ag Blend, which is SoilBuilder plus additives (Burkett-Cadena et al., 2008). Based on the data from this study, SoilBuilder can help to reduce water and N loss through field drainage tiles under corn crop production.

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Table 1. Yield, water and nitrogen leaching from corn in a field lysimeter trial with SoilBuilder.

Parameter	Growth / dap[1]	Treatment				$LSD_{.05}$
		Standard N (207 kg/ha)		Reduced N (187 kg/ha)		
		Control	SoilBuilder	Control	SoilBuilder	
Lys. volume (L)	planting	870 a[2]	870 a	870 a	870 a	0
Lys. volume (L)	V-2 /15	870 a	816 b	870 a	771 c	19.97
Lys. volume (L)	V-6 / 30	834 a	752 b	814 a	741 b	46.81
Lys. volume (L)	V-10 / 45	750 a	654 bc	696 ab	606 c	86.69
Lys. volume (L)	R-1 / 76	658 a	230 b	633 a	234 b	78.85
Lys. volume (L)	R-2 / 107	224 a	224 a	284 a	198 a	115.3
Ttl vol leached (L)	-	4207 a	3547 b	4168 a	3420 b	165.1
NO_3 conc. (mg/L)	planting	9.8 a	9.5 a	9.8 a	9.8 a	2.33
NO_3 conc. (mg/L)	V-2 /15	12.0 a	10.0 a	9.3 a	9.3 a	2.51
NO_3 conc. (mg/L)	V-6 / 30	16.8 a	9.8 b	17.0 a	11.3 b	2.53
NO_3 conc. (mg/L)	V-10 / 45	13.0 a	6.5 b	11.0 a	7.5 b	2.44
NO_3 conc. (mg/L)	R-1 / 76	10.3 a	7.3 b	11.0 a	7.0 b	2.78
NO_3 conc. (mg/L)	R-2 / 107	10.3 a	6.0 b	8.8 a	5.0 b	1.77
Total N lost (kg/ha)	-	80.6 a	54.9 c	74.8 b	55.8 c	9.78
Yield (kg/ha)	123 dap	9431 b	9996 a	9337 b	10074 a	307

[1]dap = days after planting.
[2]Values within rows not sharing the same letter are significantly different @ $P<0.05$.

IMPROVING RESOURCE USE EFFICIENCY OF FORAGE PRODUCTION SYSTEM BY INTERCROPPING SYSTEMS

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INTRODUCTION

Sustainability of agriculture is a major concern in the Southern High Plains, where demand for good quality forages by the large dairy industry and declining water resources are threatening the future of irrigated crop production. The lower water use of forage sorghum (*Sorghum bicolor* (L.) Moench) compared to corn (*Zea mays* L.), makes it a better alternative for the region. Typically sorghum is grown at row spacing wider than 75 cm, in which the inter-row space is not occupied by the crop for the major part of vegetative growth. Research has also indicated that biomass productivity increases with mixing of diverse species (Szumigalski and VanAcker, 2006).

Intercropping is a system of growing two diverse species of crops on a piece of land at the same time with the assumption that they improve the use of both above ground and below ground resources more efficiently compared to growing them separately (Zhang and Li, 2003). Component crops in an intercropping system can also compliment each other (Hauggard-Nielsen and Jensen, 2005), which can also contribute to increased productivity per unit area. Inability to harvest intercropping systems for grain production by mechanical means is limiting intercropping systems to developing countries. However, in a forage production system both crops can be harvested together for silage.

Selection of a crop for intercropping systems depends on the goals for developing the system. For forage production systems in the region, crops that improve biomass production, resource use efficiency, forage quality, and fit well in the rotation system are suitable. Legumes are a group of crops that are rich in proteins, have wide adaptability, and possess the unique ability to fix atmospheric nitrogen. They have been recognized for their role in supplying nitrogen to the ecosystem and also improve phosphorous solubility.

Competition in an intercropping system can be for sunlight, nutrients and water. A legume crop that can tolerate lower light intensity or that can climb on the main sorghum crop to receive its share of radiation will be of great benefit. The objective of this field study was to understand radiation use pattern and radiation use efficiency of legume based intercropping systems compared to a monocrop of forage sorghum.

MATERIALS AND METHODS

A field trial was conducted at the New Mexico State University Agricultural Science Center at Clovis, NM during summer of 2008. Fertilizer was applied based on soil test results for forage sorghum. A two row plot planter with seed cones for each row was used to plant forage sorghum (cv. FS-5) at 75 cm row spacing and 3 cm deep. Legumes [*Lablab vulgaris* Savi cv. Rongai and Pole bean (*Phaseolus vulgaris*) cv. Genuine cornfield], were planted halfway between sorghum rows. Forage sorghums were planted at the recommended population density of 250,000 plants ha^{-1}, while legumes were planted at 150,000 plants ha^{-1}. A surface drip irrigation system with water meters for regulating amount of water applied was used to maintain crops relatively water stress free condition.

Biomass accumulation patterns of all crops were observed by harvesting 0.5 m of row length of both main and intercrops every 7-10 days. Sensors were installed to continuously monitor the microclimate parameters of wind, solar radiation, soil and air temperature. Leaf area index and interception of solar radiation was observed with Sunscan equipment. Periodic photosynthesis of crops in both systems was recorded using a photosynthesis unit (Li 6400, LiCor Inc).

RESULTS AND DISCUSSION

Intercropping systems developed leaf area faster and intercepted solar radiation more in the beginning of the season when it needed to use greater proportion of radiation (Fig. 1a). The advantage gradually decreased and by 60 days after planting there was no difference. Legume contribution to total biomass gradually decreased. At the termination of the trial, intercropping increased total biomass production by 15% (Fig. 1b). Net photosynthesis by legumes gradually decreased (data not presented), suggesting shading and/or competition for resources that reduced legume productivity. Lablab was more indeterminate and had longer duration compared to pole bean used, suggesting it may be better suited for the intercropping systems. A series of trials are being conducted to identify suitable legume crops, planting patterns and understanding of resource use patterns. Results may help in designing intercropping systems that increase resource use efficiencies and forage productivity.

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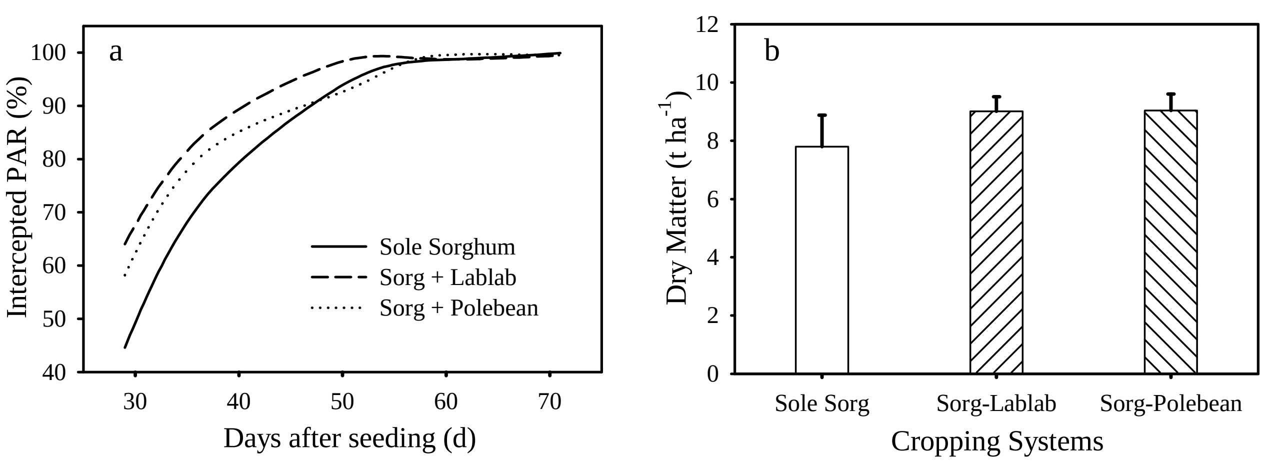

Figure 1. Seasonal radiation interception pattern of forage sorghum and legume intercropping systems in comparison to sole forage sorghum (a) and biomass production by sole and intercropped forage sorghum at the end of the trial (b) at Clovis, NM during 2008. Vertical bars are standard error of means.

ECONOMIC RISK ANALYSIS OF EXPERIMENTAL CROPPING SYSTEMS USING THE SMART RISK TOOL

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INTRODUCTION

This study uses the SMART (Screening and Multivariate Analysis for Risk and Tradeoffs) web-based software tool to analyze conventional and conservation tillage systems using 14 years (1990-2003) of economic budget data collected from 36 plots at the Iowa State University Northeast Research Station near Nashua, Iowa, USA. Specifically, stochastic efficiency with respect to a function (SERF) methodology is implemented and utilized within SMART to stochastically evaluate which of three different tillage system alternatives (chisel plow, no-till, and ridge till) on continuous corn and corn-soybean rotation cropping systems maximize economic profitability (net return) for corn across a range of risk aversion preferences.

MATERIALS AND METHODS

Data for our study were obtained from 36, 0.4-ha plots located at the Iowa State University Northeast Research Station near Nashua, Iowa (43.0°N, 92.5°W), USA. Various experimental phases using different tillage treatments and cropping systems (continuous corn and both phases of a corn-soybean rotation) were conducted from 1978-2003. Economic budgets for 1990-2003 were developed as part of the web-based USDA Natural Resources Conservation Service (NRCS) – EconDoc exchange tool. The economic budget approach was used to summarize per unit (hectare) revenue and net return (revenue – total costs), resulting in 504 plot-years (36 plots x 14 years) of enterprise budget data. The net return data were discounted to reflect the net present values.

The SERF method orders a set of risky alternatives in terms of certainty equivalents (CE) calculated for specified ranges of risk attitudes (Hardaker et al. 2004). A CE is equal to the amount of certain payoff an individual would require to be indifferent between that payoff and a risky investment. SERF calculates CE values over a range of absolute risk aversion coefficients (ARACs), representing a decision maker's degree of risk aversion. Decision makers are risk averse if ARAC > 0, risk neutral if ARAC = 0, and risk preferring if ARAC < 0. The ARAC values used in this analysis were positive (since farmers are rarely risk preferring), and ranged from 0.0 (risk neutral) to 0.004 (strongly risk averse). The SERF model utilizing different functions (e.g., power, negative exponential) was programmed in the C# programming language and calculations verified against examples presented in the Simetar© 2006 User Manual (Richardson et al., 2006).

The SMART web-based tool is divided into six sections: Introduction, Input, Multivariate Monte Carlo Simulation, SERF, Stop Light, and Tradeoff. The Introduction section provides information on how to set up Internet browsing tools to use SMART, an overview of SMART, and general help for the section. The Input section facilitates data input into a flexible and customized spreadsheet tool. Data may be entered manually or loaded from an Excel 2003-compatible spreadsheet. Both economic and environmental information (required for tradeoff purposes) can be input, and a detailed statistical analysis can be performed on the input data. SMART has the ability to generate multivariate empirical distributions (MVEs) (up to 5,000 Monte Carlo iterations) for each input variable. An MVE distribution simulates random values from a frequency distribution made up of actual historical data and has been shown to appropriately correlate random variables based on their historical correlation (Richardson et al., 2006). In the SMART SERF section, the minimum and maximum ARAC and initial wealth for each input variable are required as inputs to the SERF simulation. The user also must select the type of utility function used for the SERF calculations and the number of CE values calculated (in order to define the CE curve across a range of risk preference). In addition to the above sections, SMART also contains "probability of target value" or Stop Light and Tradeoff Analysis sections, however, these are not discussed due to space limitations.

RESULTS AND DISCUSSION

The SMART economic analysis for the Nashua tillage system alternatives is presented in Figure 1, and shows that the no-till and chisel plow tillage systems had the highest mean net return for corn, while the ridge till and no-till plow tillage systems had the lowest standard deviation. There was no tillage system alternative that had the largest mean and smallest standard deviation. The no-till system had the largest mean net return, but also had a much higher standard deviation and CV than the ridge till tillage system. Figure 2 shows the net return CE results for all ARAC's for the tillage system alternatives under corn. The results show that the rankings do not change as risk aversion increases and that the no-till tillage system is preferred across the entire range of risk aversion. For a risk neutral decision maker, the overall difference in the net return of the tillage system alternatives is ~ $60/ha. This indicates a risk neutral farmer in ridge till will need to receive ~ $60/ha to be indifferent between the no-till tillage system (highest ranked) and the ridge till system (lowest ranked), and approximately $15/ha for the chisel plow and ridge till systems (ranked second and third, respectively). The difference in net return between the tillage system alternatives decreases slightly as the risk aversion increases (Figure 2).

Commonly advocated risk methods (e.g., mean-variance or stochastic dominance analysis) typically lack a systematic way to accommodate risk aversion. The SERF method of tillage system assessment by CEs demonstrated here helps to overcome these limitations. However, a SERF approach for ranking tillage system alternatives based solely upon economics may not tell the whole story. Furthermore, a focus on economic outcomes such as net return alone when ranking tillage systems may also be misleading, since environmental or other externalities may render certain systems unsustainable in the long run. It should be emphasized that this analysis has not taken into account differences in externalities for tillage system alternatives, and it would be possible to extend this study by valuing and including any externalities. The SMART web-based tool may be accessed at http://arsagsoftware.ars.usda.gov/smart/.

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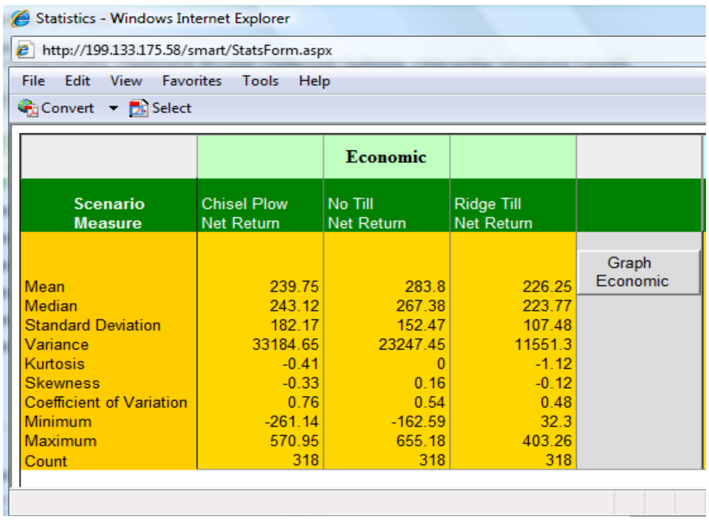
Statistics - Windows Internet Explorer
http://199.133.175.58/smart/StatsForm.aspx

		Economic		
Scenario Measure	Chisel Plow Net Return	No Till Net Return	Ridge Till Net Return	Graph Economic
Mean	239.75	283.8	226.25	
Median	243.12	267.38	223.77	
Standard Deviation	182.17	152.47	107.48	
Variance	33184.65	23247.45	11551.3	
Kurtosis	-0.41	0	-1.12	
Skewness	-0.33	0.16	-0.12	
Coefficient of Variation	0.76	0.54	0.48	
Minimum	-261.14	-162.59	32.3	
Maximum	570.95	655.18	403.26	
Count	318	318	318	

Figure 1. SMART economic analysis for the Nashua tillage system alternatives.

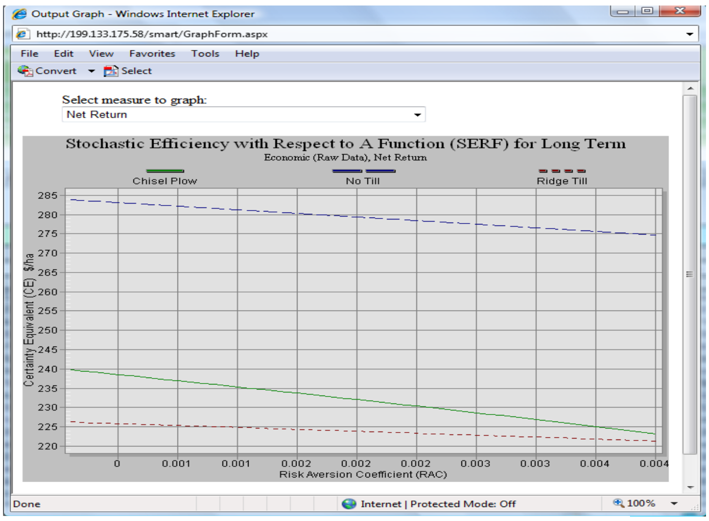

Figure 2. SMART SERF analysis for the Nashua tillage system alternatives.

A COMPONENT-BASED DISTRIBUTED WATERSHED MODEL FOR THE USDA CEAP WATERSHED ASSESSMENT STUDY

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INTRODUCTION

The specific objectives of this study were to: 1) implement hydrological modeling components under the Object Modeling System (OMS), 2) assemble a new prototype watershed scale model for fully distributed transfer of water between land units and stream channels, and 3) evaluate the accuracy and applicability of the modular watershed prototype model for estimating stream flow. The watershed selected for application of the prototype watershed model was the Cedar Creek watershed (CCW) in northeastern Indiana, USA. The prototype model was applied without calibration, thus eliminating any ambiguities pertaining to the use of different optimized model parameter values. The study is unique in that it represents the first attempt to develop and apply a complex natural resource system model using the OMS.

OBJECT MODELING SYSTEM (OMS)

The Object Modeling System (OMS) is a comprehensive modeling framework that helps streamline the development of integrated natural resource system models for current and future model delivery (David et al. 2002) using a component-oriented modeling approach. OMS is implemented in the Java programming language on top on the NetBeans application platform. OMS modeling components can be characterized as system and scientific components. System tools such as a Component Builder and Model Builder support model development where various scientific components can be assembled into a complex model. The model can then be executed using the OMS Runtime Environment. Modular frameworks for model development like OMS are well-suited for studies such as this requiring complex simulation component technology integrated into a common, collaborative, and flexible system.

OMS-BASED CEAP PROTOTYPE WATERSHED MODEL

The J2K modeling system (Krause et al., 2006) was used for the simulation of the hydrological dynamics of the Cedar Creek Watershed in Indiana. J2K is a modular, spatially distributed hydrological system which implements hydrological processes as encapsulated process components. J2K operates at various temporal and spatial aggregation levels throughout the watershed. For example, runoff is generated at the Hydrologic Response Unit (HRU) level with subsequent calculation of runoff concentration processes (through a lateral routing scheme) and flood routing in the channel network. HRUs for the CCW were delineated by GIS overlay techniques using spatial data layers (e.g., elevation, slope, aspect, land use, soil type, and hydrogeology), thus creating a topologically connected pattern of single land units with similar data features. The J2K model had previously been implemented only in the JAMS (Jena Adaptable Modelling System) modular modeling framework (Kralisch and Krause, 2006). Therefore, the following J2K modeling resources were transferred to the OMS framework: 1) 40+ J2K Java scientific source components for watershed scale hydrological processes including overland flow, infiltration, ET, soil water movement, groundwater storage, and flood routing; and 2) ASCII data input files for hydrogeology, soils, land use, HRU routing, and channel reach routing that are referenced from the J2K model XML (Extensible Markup Language) input file.

RESULTS AND DISCUSSION

Two input parameter sets were developed for OMS-J2K evaluation: 1) a "base parameter set" with parameter values taken from previous simulation studies where J2K was applied to watersheds with characteristics similar to the CCW; and 2) an "adjusted parameter set" with modifications to input parameters related to ET, soil water storage, and soil water lateral flow. Table 1 shows model performance for daily, monthly, and annual stream flow response using both parameter sets and the following model evaluation statistics: Nash-Sutcliffe model efficiency (E_{NS}), coefficient of determination (R^2), Root Mean Square Error (RMSE), and percent bias (PBIAS). Comparisons of daily, average monthly, and annual average simulated and observed flows for the 1997-2005 simulation period using the base parameter set resulted in evaluation coefficients ranging from 16 to 20% for PBIAS, 1.98 to 8.23 m^3 s^{-1} for RMSE, and 0.47 to 0.55 for E_{NS}. All statistical evaluation coefficients for daily, average monthly, and average annual stream flow improved substantially for the adjusted parameter set (e.g., PBIAS, RMSE, and E_{NS} coefficients ranged from 9 to 10% for PBIAS, 1.02 to 6.06 m^3 s^{-1} for RMSE, and 0.62 to 0.65 for E_{NS}). The range of relative error (e.g., PBIAS) and E_{NS} values for uncalibrated stream flow predictions in this study were similar (base parameter set) or better (adjusted parameter set) than others reported in the literature. The study is unique in that it represents the first attempt to develop and apply a complex natural resource system model under the OMS. In addition, this study represents the first time that J2K hydrological process components have been evaluated on a watershed in the United States. The results show that the prototype OMS-J2K watershed model was able to reproduce the hydrological dynamics of the Cedar Creek Watershed with sufficient quality, and should serve as a foundation on which to build a more comprehensive model to better assess water quantity and quality at the watershed scale.

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Table 1. Statistical evaluation for OMS-J2K simulated daily, average monthly, and average annual Cedar Creek Watershed stream flow (January, 1997 to December, 2005).

	OMS-J2K statistical evaluation – base parameter set			OMS-J2K statistical evaluation – adjusted parameter set		
Evaluation coefficient	Daily	Average monthly	Average annual	Daily	Average monthly	Average annual
E_{NS}	0.47	0.53	0.55	0.62	0.64	0.65
R^2	0.51	0.53	0.54	0.61	0.63	0.64
RMSE	8.23	4.01	1.98	6.06	2.77	1.02
PBIAS	20.21	16.49	15.67	10.17	10.13	9.40

Note: E_{NS} = Nash-Sutcliffe efficiency; R^2 = coefficient of determination; RMSE = root mean square error (m^3 s^{-1}); PBIAS = bias or relative error (%).

DEVELOPMENT OF DECISION SUPPORT SYSTEM FOR SUSTAINABLE AGRICULTURAL PLANNING IN UPLAND AND RAINFED AREAS

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INTRODUCTION

An integrated computer program called Cropping System and Water Management Model (CSWM) with a three-step feature (i.e. expert system-simulation-optimization) was developed to address a range of questions for rainfed and dryland agriculture. The system was used to design more sustainable production systems in the rainfed areas through the use of water harvesting system called small farm water reservoir for increase production and resource conservation and management.

MATERIAL AND METHODS

The model was applied using crop, soil, and climate and water resource data from the Philippines. Primarily, four sets of data representing the different rainfall classification of the country were collected, analyzed, and used as input in the model. Simulations were also done on date of planting, probabilities of wet and dry period and with various capacities of the water reservoir used for supplemental irrigation. Optimization techniques were used to determine the best crop combination and area allocation.

To evaluate the effects of planting dates on irrigation water requirements, area coverage and income, specific data inputs were the following: 1) 30 years of rainfall data; 2) Reservoir volume is 1,800 cu. meters; 3) Crop Pattern is rice – vegetable – legume; 4) Service area is 1.6 hectares. In practice, non-rice crops could be grown after the rice season beginning October. To supplement the little rainfall expected in the second crop season, irrigation water is sourced-out from the small farm reservoir located on-farm. Simulation of this scheme was done on two planting dates – October 1 and 20. Result on irrigation water requirement, percent of crop area covered and income were determined and analyzed.

RESULTS AND DISCUSSION

As expected, Oct. 20 planting requires higher amount of water for irrigation. Garlic being a long season crop has the highest water use on the list registering 160mm and 100mm of irrigation water requirement for October 20 and October 1 planting dates, respectively. Obtaining best income by optimizing area allocation of crops is of special interest to farmers since normally reservoir water is not enough to support the whole farming area during the dry season. The model output indicated that only the legume vegetable crops due to their short duration characteristics can be planted in the whole area for October 1-20 planting dates. For garlic and tomato, only 75% and 65% of the area respectively can be utilized if the planting date falls on October 20. Garlic however, is the most interesting crop in terms of income due to its high and stable market value. Income would be highest for October 1 planting at 4,000 USD level as compared to 2,500 USD when the crop is planted on October 20.

Likewise, the model was applied for agricultural planning. Parameter for planning was based on rainfall patterns under Corona's four climatic classifications in the Philippines i.e.

Types I to IV. The information was considered the major factor for rainfed agriculture planning in this study. *Type I climate* is unimodal in nature with most of the rain comes in May to October. Only one rice crop can be grown during the season from June to September. If a farmer owns an on-farm reservoir with the capacity of 1000 cu. meter for every hectare (which is the average capacity), a second non-rice crop could be grown using water from the reservoir. *Type II climate* is characterized by wet periods throughout the year. Areas covered by this type of climate environment are located mostly in the eastern part of the country facing the Pacific ocean. The model indicated that a rice crop can be grown without irrigation from July to February, but only short duration non-rice crops like soybean and mungbean can be grown as a third crop for short period. The recommended cropping pattern was limited to rice-rice-soybean and rice-rice-mungbean. *Type III* climate is similar to Type I, with a less pronounced dry period. Available rice growing period is shorter, from July until October. Likewise, this type of pattern needs supplemental irrigation for a second, non-rice crop to grow. Areas under *Type IV* climate are mostly located in the southern provinces of the country where there is an even distribution of rain throughout the year. Simulation result suggests that rice cannot be grown in this area without supplemental irrigation but any non-rice crops are feasible throughout the year without irrigation.

Evaluation of seasonal climate impacts on crop production was also done using the model. In this study, the dependable rainfall rain approach was used as index for climate change due to its good advantage for irrigation planning application and its relative ease to use in terms of data requirement and calculation procedures. For this purpose, the same 30-year set of rainfall data from Central Luzon was chosen for analysis and input in the model. Under Corona's classification, this set of data falls under the Type I climate. It is also in this area where farmers are using small farm reservoir for irrigation. The first simulation run was done with the following data inputs: a) actual reservoir volume of 1,800 cu. meters, b) a service area of 1.6 hectares and; c) rainfall probabilities of 20%, 50% and 80%. The second run was done to establish a relationship between reservoir volume and rain probabilities and their effect to income, crop intensity and irrigation requirement for a 1 hectare of farmland. An important result from the simulations and sensitivity analysis are: 1) The garlic-peanut combination is the highest consumer of water at around 400 mm irrigation requirement during a dry year; 2) At different levels of drought, the income derived from the top five crop combination does not vary significantly and; 3) If wet year is expected and planting commence on October 1, optimum yield and cropping intensity will be realized provided that a minimum of 2000 cu meters of reservoir water is available for supplemental irrigation.

Through the analysis, useful information was obtained to determine cropping schedule and pattern appropriate to the specific climate conditions. In addition, optimization of the use of the land and water resources can be achieved in areas partly irrigated by small reservoirs.

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FARMBIRD – AN INTERDISCIPLINARY MODELLING PROJECT ON THE COVIABILITY OF FARMING SYSTEMS AND BIRD BIODIVERSITY

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INTRODUCTION

Intensification of European agriculture induced sharp decline of biodiversity, common bird populations being particularly affected. This erosion of biodiversity is mainly due to decrease in habitat quality and homogenisation of agro-landscapes (Benton et al., 2003). Heterogeneity, defined as the spatial configuration of a habitat mosaic, determines the carrying capacity for several species using different habitats. It is generated by the spatial and temporal distribution of management intensity. In the FarmBird project, we develop an interdisciplinary modelling framework to analyze the coviability between agricultural production and biodiversity conservation in heterogeneous agro-landscapes. This framework links different scales (field, farm, landscape) and combines ecological, agronomic and economic knowledge We present the first framework developed for a grassland farm in which grazing and mowing influence bird population dynamics in the long term. Several studies have demonstrated that some grazing or mowing regimes can create suitable grass structure for birds. They also showed that these management regimes directly impact bird life traits due to nest and chick destruction. To date, no study has examined the joint and interacting effects of grazing and mowing regimes on bird populations. The farm scale is the first level at which both management regimes interact. It is therefore a relevant scale, to analyse the trade-off between agricultural production and biodiversity conservation in different livestock farming systems differing in their overall intensity.

DESCRIPTION OF MODEL

The dynamic model is a spatially implicit extension of that proposed by Tichit et al. (2007) for an homogeneous grassland. It considers a grassland farm which combines three management regimes: (i) “ecological grazing” providing a suitable habitat for birds (ii) “productive grazing” maximising the harvest and (iii) mowing for cattle winter feeding. These management regimes produce the feeding resources for suckling cattle and they also induce the level of habitat quality for two ground nesting bird species: lapwings and redshanks. The model comprises two interactive sub models describing the dynamics of (1) three grassland fields controlled through grazing or mowing and (2) the bird populations. Grass dynamics and management regimes influence either indirectly or directly bird life traits. Grazing intensity and mowing periods have direct impact on bird fecundity. Both management regimes determine the habitat quality i.e. grass height, which is a variation factor of chicks’ survival. Another important feature of the model is that different strategies of bird movement are formalized between the three grassland fields. This feature makes it possible to account for an impact of the proportion of the three management regimes on bird population dynamics at farm scale.

The mathematical framework of viable control theory (VCT) (De Lara and Doyen, 2008) is used to analyse long-term grassland dynamics. The VCT deals with the control of uncertain dynamic systems under state and control constraints. It first requires the identification of a set of constraints that represents the "good health" of a system: here ecological and production constraints. Ecological constraints are defined by specifying, at key periods of bird life cycle, minimal and maximal grass heights as well as maximal stocking densities for each bird species. Production constraints include considerations on livestock feeding requirements. The viability of the grassland farm is related to the maintenance of these conditions at all times, including both present and future. We use VCT to determine the viable proportion of management regimes at farm scale as well as the viable grazing strategies (i.e. timing and intensity). For any given amount of “ecological grazing”, the model computes the viable proportions of mowing and productive grazing i.e. those maximising the harvest of dry matter.

RESULTS AND DISCUSSION

Figure 1a shows the trade-off between production and conservation in extensive and intensive farms. Each point of the trade-off curve stands for a grassland farm composed with different amount of the three management regimes. For the same amount of ecological pasture, the quantity of harvested biomass was always slightly higher in intensive farms (up to 5%) but bird populations were smaller after ten years. In order to maintain bird populations in intensive farms, it was thus necessary to allocate a larger proportion of farmland to “ecological grazing”. For instance, 30% of “ecological grazing” were enough to maintain bird populations in extensive farms which was not the case for intensive farms (Fig. 1b). The coviable proportions of management regimes ensuring bird population maintenance while maximising the harvest of dry matter were 25%, 50%, 35% (respectively for “ecological grazing”, “productive grazing” and mowing) in extensive farms whereas they reached 35%, 40%, 35% in intensive farms (results not shown). Interestingly, for such viable proportions, the biomass harvest was higher in extensive farms (Fig 1a, dotted lines). This was due to the lower proportion of ecological grazing and the higher proportion of productive grazing. Consequently, extensive farms had a higher grassland self sufficiency than intensive ones.

Our model enables to compute the proportion of management regimes and their intensity leading to the production/conservation coviability in a grassland farm. It underlines the need to consider the overall farm intensity when determining such coviable strategies. Further research in the FarmBird project will extend this approach to arable farming systems as well as to landscape scales. Future models will take into account public policies as drivers of farmers’ land use decisions. Such models will be used as support for the design and evaluation of policies aimed at supporting the diffusion of biodiversity friendly farming systems.

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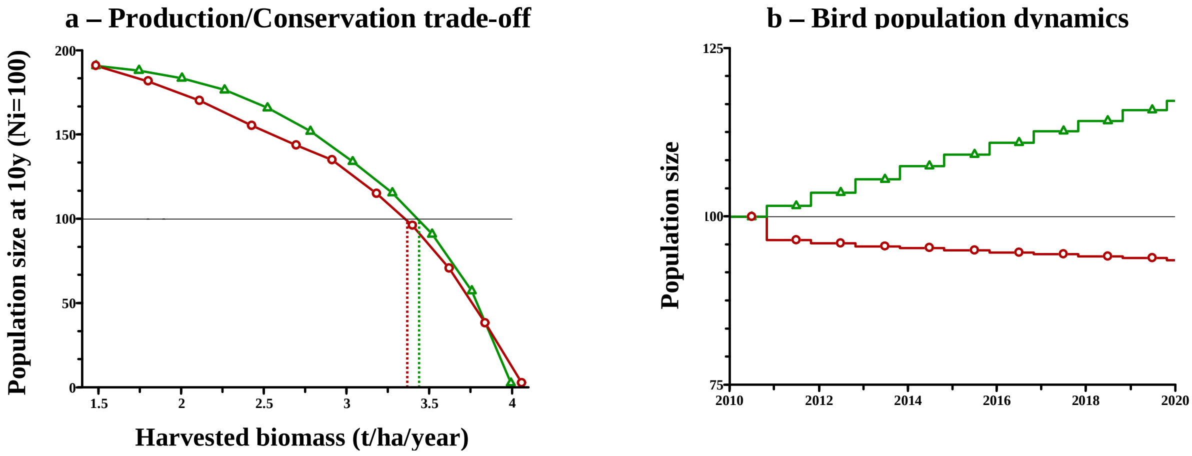

Fig. 1 Conservation and production values of extensive (green triangles) and intensive farms (red circles). (a) Trade-off between production and ecological performances. (b) Bird populations’ dynamics in farms with 30% of “ecological grazing”.

ASSESSMENT OF DAIRY FARM SUSTAINABILITY IN QUEBEC: A TOOL BASED ON INDICATORS AT THE FARM LEVEL

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INTRODUCTION

There is a wide consensus at policy level that agricultural performance should be evaluated with the triple-bottom-line approach that recognizes economic, environmental and social aspects of sustainability. However, the assessment of sustainability at the farm level is far from well-established. The assessment of sustainability in agriculture needs a multidisciplinary approach. Few assessment tools exist that can span the 'triple bottom line' of sustainability (Halberg et al., 2005; von Wirén-Lehr, 2001). Our objective was to develop indicators for the three aspects to assess dairy farm sustainability in a complete diagnosis tool at the farm-level.

MATERIALS AND METHODS

Several authors have proposed frameworks for the assessment of sustainability in agriculture including the development of indicators or attributes (Meul et al., 2008; Mitchell et al., 1995). The framework for the selection of indicators in this project consisted of five steps: (1) define the concept of dairying sustainability at the farm-level, (2) identify goals and principles to achieve in the assessment, (3) select components for each aspect of sustainability, (4) select indicators for each component and (5) establish threshold values to compare indicators results.

Indicators were developed using a Delphi technique approach that involves a series of consecutive steps using a bottom-up approach. First, a panel of 25 experts (farmers, stakeholders, researchers) was asked to list all the possible indicators that could be measured to evaluate each aspect of farm sustainability. The potential indicators were compiled and submitted to the same 25 experts who rated them according to their relevance and easiness of on-farm acquisition. This first step does not require face to face meetings of the participants, protecting their anonymity (Delbecq, 1975) and limiting travel costs.

Second, the top-rated indicators were brought for discussion in a focus group (12 of the 25 experts) to determine : (1) which indicators should be kept, (2) each indicator threshold or target values for farms to be considered sustainable and (3) their relative weight on a scale of 100 points. This recommended participatory process (King et al., 2000) enables the discussion between experts in their goal to develop the indicators (Krueger, 1988).

RESULTS AND DISCUSSION

These processes produced three sets of indicators for assessing sustainability, one containing 13 indicators for environmental measurements, a second one with eight indicators for technical-economic assessment, and a third one with 20 indicators designed to measure social aspects (table 1). Once determined, the indicators were tested to assess the sustainability of 40 farms, split between two contrasting agricultural regions of the province of Quebec. This farm assessment is a test to know if selected indicators answered critical characteristics of indicators who are: easy to implement, comprehensible immediately, sensitive to variations, reproducible, adapted to the objectives, relevant for the user, able to reflect the field reality (von Wirén-Lehr, 2001). This is not use as a validation of the tool.

At the end of the assessment, each producer received his farm sustainability score and a radar diagram illustrated his global score. With this type of diagram we can easily identify the strengths and weaknesses of the farm. The assessment tool will be used to measure the evolution of farm sustainability due to modifications in agricultural practices induced by the farmers. An innovative aspect of this research is the methodological approach used to obtain the best results by the end-users and the appropriate choice of indicators enabled to reflect agricultural realities at the farm-level.

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Table 1 Components and indicators in each sustainability aspect

Aspects	Components	Indicators
Environmental sustainability	Soil quality	Organic matter content, Phosphorus saturation
	Cropping practices	Perennial forage crops, Soil tillage practices, Green manure, Crop rotations, Integrated pest management
	Fertilization management	Manure storage structure, Manure management, Nitrogen balance, Phosphorus balance
	Farm land management	Watercourse protection, Land drainage, Windbreaks, Field slope, On-farm woodlot
Economic sustainability	Technical Management	Milk yield, Milk from forage
	Economic viability	Security margin, Debt per hL
	Expense control	Operational expense/income, Machinery expenses per hL
	Labor efficiency	Milk per worker
	Self-sufficiency	Forage self-sufficiency
Social sustainability	Quality of life	Work and workload, Holidays, Satisfaction, Social support, Health and stress, Social and professional relationships
	Social integration	Contribution in local services, Agricultural neighborhood, Quality of non-agricultural relationships, Social contribution, Regional presence of agriculture
	Farm succession	Continuity value, Presence of farm succession, Preparation for retirement, Farm succession integration
	Entrepreneurship	Formation, Use of advisory services, Vision, Human resources management, Entrepreneurial abilities

Crop diversity indicators: literature review and applications at farm level

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INTRODUCTION

The effects of intensification and specialisation at farm and regional levels are often mentioned as leading to standardize both landscapes and agricultural practices, with subsequent losses in terms of biodiversity. Crop diversity is increasingly considered as a component of the sustainability of agroecosystems (Moonen and Barberi, 2008). Enhancing crop diversity would contribute to regulate pest populations, to reduce farmers' reliance on external chemical inputs, to foster risk aversion strategies, etc. Various methods appear in literature to assess crop diversity and its determinants. Indicators would provide an option to take into account the various dimensions included in biodiversity conservation. In this paper, we review selected references and test candidate indicators on a data set at farmland level for a whole region.

MATERIALS AND METHODS

First, a bibliometric approach (based on CAB and WOS database) was used to identify articles and reviews on crop diversity assessment, based on a set of queries[1]. 198 references were collated using citation manager tools (CiteSpace and EndNote). A short list comprising of 42 references was then selected through consensus building among the authors, representing various disciplines (agronomy, ecology and social sciences) as suggested by Jackson *et al*. (2007). Major research fields related to crop diversity were identified. A state of the art on crop diversity indicators was derived, according to these major research fields. The Shannon index (H') was elected, due to its multi-level coverage.
Second, using a unique GIS annual database on land use (25 to 50 cultural classes at plot level in 3 districts of Provence region –Nuts2- for 2000-2007), we estimated a set of crop diversity indices at various scales (farm, municipality, district). Our GIS also includes databases on farm characteristics (size, employment, and profit) and socio-economic data at communal level. Scale sensibility and agricultural and socio-economic determinants of crop diversity were studied for year 2007.

RESULTS AND DISCUSSION

Use of crop diversity indicators

Based on our bibliometric approach, crop diversity indicators fall into three main categories. First, they can be used as a component of broader agri-environmental assessments (Bockstaller, 1997), with a view to elaborate aggregated indicators usually represented as amoeba-type diagrams. They are mostly based on Shannon index or its adaptations, and can be tested on hypothetical agroecosystems (Gliessman, 2007). A second approach consists in using indicators as revealing different production patterns (e.g. organic versus conventional) or their relative intensity at various temporal and spatial scales. In this situation, indicators used include: biotic indicators (Buchs, 2003), adaptive capability of crops to inter-annual variations (Chloupek, 2004), intensity index (Herzog et al, 2006). In a third category of papers, indicators are intermediate variables which contribute to focus agri-environmental schemes toward specific areas or farm types (Piorr, 2003), based on the understanding of the determinants of farmers' behaviour (Cutforth, 2001). Indeed some authors cover a wide range of functions, whereas others give priority to the effect of crop diversity on specific environmental compartments. Most of the papers deal with the effects of agriculture on biodiversity, whereas studies of the effects of biodiversity on agriculture are scarce.

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[1] For example, : TS=(agri* OR agro* OR "food product*" OR cultivated OR crop* OR intercrop* OR mono-culture OR tillage* OR plowing OR ploughing OR arable OR cultivation* OR tillage* OR farm* OR dairy OR grassland* OR rangeland* OR pasture* OR meadow* OR pastoral* OR grazing system* OR grazier* OR fodder* OR livestock* OR breed* OR herd* OR cattle* OR grower* OR gardening* OR grape* OR vine* OR "rural system*" OR agrar* OR horticult* OR arboricultur* OR "fruit product*" OR orchard* OR agrobiolog* OR fallow OR "field margin*" OR "field boundar*" OR pesticide* OR herbicide* OR insecticide* OR fertili*)
AND TS=("bio diversity" OR biodiversity OR "biological diversity" OR "plant diversity" OR "vegetation* diversity" OR "weed diversity" OR "animal diversity" OR "faunal diversity" OR "invertebrate diversity" OR "insect diversity" OR "microbial diversity" OR "bacterial diversity" OR "species diversity" OR "species richness")
ANDTI=(indicator* OR index* OR indice* OR indicateu* OR bioindic* OR bio-indic* OR "bio indic*") NOT TS=(fish* OR ocean* OR marine* OR sea$ OR genom* OR lake* OR coastline* OR fresh water*)

Measurements and scaling issues

Most of empirical works are data driven: crop diversity indexes often use national or county data on crops (Harish 1998), sometimes coupled with socio-economic Census data (Jaskulki 2007), a scale at which a simple richness index may be sufficient. However, spatial distribution of crop diversity can lead to different results between local crop diversity and global measure of crop diversity; the use of more complex composition index like Shannon or Simpson indexes does not solve this issue. Sensibility to scale of diversity index based on land cover is a well documented field in ecology, but needs to be adapted to farm crop data. Dinh Van (2003) proposed an analysis of crop diversity measurement and its socio-economic determinants at farm level. We did not identify studies focussing on the evolution of crop diversity at farm level for a region.

Contribution of case studies

Case studies have been engaged for a district where vector map of land registry is integrally available (Vaucluse). A comparison between farm, municipality or district level has been implemented for year 2007. Results are largely divergent between theses 3 scales. Shannon diversity index at municipality (or district) level is unable to take into account the high number of farms with only one crop. Crop diversity at municipality or district level depends on the spatial distribution of farms with one or two crops, i.e. those having low crop diversity at farm scale. Hence, a stratification based on farm size is necessary to have consistent results at both levels. An index of dominance may be a useful complementary index. Spatial autocorrelation of these small farms with only one crop could also help to assess potential differences between diversity index at farm and at communal or regional level. Structural determinants (farm structure, type of main crop, distance to Central Business District…) and spatial distribution of this diversity are introduced.

In a dynamic perspective, preliminary results for 2000-2007 period clearly show that cessation of farming (and to a smaller extent, entry to farming) plays a major role on crop diversity, whereas crop diversification at farm level has a minor effect, at least in our study area.

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ECO-DESIGN AND CO-DESIGN: APPLICATION TO FRUIT PRODUCTION IN EUROPE

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INTRODUCTION

The design issue is explicitly raised in several proposals aiming at "ecologizing" horticulture. Due to a recurrent use of pesticides, fruit production is at stake; albeit some approaches such as Integrated Pest Management (IPM) and biological control contribute to fulfill the objectives of integrated or organic fruit production (Lescourret and Sauphanor, 2008). What can be learned from such production models in order to design orchards less dependent from external inputs to achieve plant protection? We present the first results of a working group including agricultural scientists, ecologists, extension workers and fruit producers. This group enables to share scattered knowledge and skills into a co-design approach. This approach is consistent with frameworks issuing from expert-based knowledge and system prototyping. However, such proposals have not been implemented in fruit production: as perennial crops and multi-strata systems, orchards create complex designs to be modulated for agronomic purposes.

MATERIALS AND METHODS

Based on transition pathways towards sustainable agriculture, a framework was derived from the field of crop protection and extended to food systems (Hill, 1985). This framework discerns three types of innovations: (i) increase the efficiency of practices in order to reduce the use of costly, scarce and environmentally damaging inputs; (ii) substitute conventional inputs with alternative practices and biological methods; (iii) redesign an agroecosystem so that it functions on the basis of a wider set of ecological processes. It was used as a guide for orchards eco-design. The approach of our working group was to (i) define the expected properties of a sustainable orchard, (ii) identify and combine the bio-technical components of an ecologically-based orchard redesign, (iii) propose relevant criteria to assess the performances of such orchards.

RESULTS AND DISCUSSION

Three targeted properties for such orchards are: self-sufficiency, through minimizing external inputs and maximizing the use of natural resources; connectivity among vegetation layers to enhance beneficials; adaptability and reversibility in management options. Components for orchard redesign were identified, based on participants' practical and methodological experience.

Currently, a few number of apple cultivars are commercially grown in the world and practically all of them are highly susceptible to scab which is the most serious apple disease. Therefore the main breeding programmes are focused on scab resistance. Monogenic sources of resistance, specifically the *Vf* gene, were the most used by the breeders. However, the breakdown of *Vf* resistance by at least three scab races emphasizes the importance to broaden the genetic diversity of scab resistance including quantitative resistance. Very different selection pressures occurred in the past that created a large diversity of apple cultivars. Many of these were grown formerly in extensive high stem standard trees orchards and expressed too many unexploited quantitative traits. Interesting traits were such as: high tolerance to most diseases, long natural maintenance ability, low fertilizer requirements, diversity of tree architecture …Rescue surveys pointed out that many landraces are still present in old orchards or gardens and may be used either as cultivated varieties or as parent in breeding programmes (Lateur, 2003). Non-chemical sanitation practices against apple scab have been first reasoned in the frame of the orchard eco-design: (i) the inoculum reduction by leaf litter management in the previous autumn and/or the following early spring, (ii) the respect and the use of antagonists suppressing conidial and ascospore productions, (iii) the mixed apple cultivars orchards and (iv) sheep or birds breeding integrations. Besides, various environmentally safe methods were discussed in order to reduce the amount of fungicides applied in orchards including strategies involving spraying during the infection process (Jamar *et al*., 2008), screenings of alternative control input and new adapted sprayers for treatment applications.

In the multiscale paradigm we define the tree itself is likely to be a first and key step to design. Beginning with seminal research works developed on apple in the 1960's at INRA France, a large amount of studies have shown that tree architecture and fruiting behaviour are related in many ways (Lauri *et al*., 2009). Indeed a low branching density is generally related to higher branch length which is in turn positively related to higher regularity of fruiting. These features which vary greatly among apple genotypes also indicated new training and pruning strategies. A high canopy porosity obtained through precise pruning cuts (spur extinction) is proposed as a way to better control branching density, return-bloom and fruit quality. Tree architecture management also impacts pest and disease epidemics indicating innovative, albeit partial, ways to control bio-aggressors in the orchard. We propose to focus on the following orchard traits and management to enhance ecosystem functions: (i) decrease the spatial monotony (linear arrangements) of orchard systems and increase boundary effects; (ii) emphasise a functional multi-strata design, i.e. through the introduction of a missing bush layer; (iii) increase plant diversity within and outside the orchard; (iv) pay specific attention to the soil organic status and to the role of scavengers at the basis of food-webs.

Fruit production patterns enhancing orchards' nutritional and environmental performances are thus identified. A relationship appears between tree vigor – as determined by training and pruning strategies – and fruit quality. Low-input fertilization practices entail higher concentrations in secondary metabolites (Fauriel *et al*., 2007). Organic fruit production patterns are candidate for such performances. However, their productivity is still too low for the current marketing standards.

Partnerships among actors involved in a redesign process enabled us to identify research topics: relationships between training systems and pest and disease pressure; consistency between crop protection efficiency and ecological value of orchards; relevant levels of organization (spatial and temporal) to promote such orchards and their integration into sustainable food systems.

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EFFECT OF CROP ROTATION AND FERTILISATION ON MAIZE AND WHEAT YIELDS AND YIELD STABILITY

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INTRODUCTION

Long-term experiments can help develop leading indicators of sustainability and serve as an early warning system to detect problems that threaten future productivity. A stable or increasing trend in yield is necessary to call a system sustainable. The stability of yield is also an important characteristic to be considered when judging the value of a cropping system relative to others. Crop sequences represent a system approach in crop production research, enabling the available natural resources to be preserved and more efficiently utilised (Karlen et al., 1994).

MATERIALS AND METHODS

In a long-term crop rotation experiment set up at Martonvásár (47° 21′ N, 18°49′ E), Hungary in 1961, the effects of seven crop sequences and five fertilisation treatments on the yields and yield stability of maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) were studied. The soil of the experimental area was a humous loam of the chernozem type with forest residues, slightly acidic in the ploughed layer, with poor supplies of available phosphorus and good supplies of potassium. The annual precipitation for the study period (1961-2000) averaged 539 mm. In the two-factorial split-plot experiment the main plots consisted of seven crop sequences: maize monoculture, wheat monoculture, 3 yrs alfalfa – 5 yrs maize (MA), 3 yrs alfalfa – 5 yrs wheat (WA), 2 yrs wheat – 2 yrs maize (WM), 3 yrs alfalfa – 3 yrs maize – 2 yrs wheat (WAM) and Norfolk crop rotation (maize-spring barley-peas-wheat) (NF). The proportions of maize and wheat were 25, 37.5, 50, 62.5 and 100% depending on the type of crop sequence. The subplots in the experiment represented five different fertilisation treatments: A: control, without fertiliser; B: 60 t ha^{-1} farmyard manure every 4 yrs + NPK; C: 5 t ha^{-1} straw or 7 t ha^{-1} maize stalks each year + NPK; D: NPK fertiliser equivalent to that extracted by the crop; E: NPK for a yield of 15 t ha^{-1} maize and 10.5 t ha^{-1} wheat. Stability analysis on the experimental treatments was carried out using univariate (variance and regression parameters) and multivariate [Additive Main Effect and Multiplicative Interaction (AMMI) model] methods (Kang, 1995; Crossa, 1990).

RESULTS AND DISCUSSION

The yields of maize and wheat were lower in all cases in a monoculture than in crop rotation (Figs. 1-2). The extent of yield loss was greater in wheat than in maize. Reductions in maize yield in a monoculture were chiefly recorded after a dry winter, particularly if the summer was also dry. The reduction in wheat yield in a monoculture could be attributed mainly to pathogenic factors (take-all of wheat, caused by *Gaeumannomyces graminis var. tritici*) stimulated by the weather (Berzsenyi et al., 2000). The yield-increasing effect of crop rotation was inversely proportional to the ratio of maize or wheat in the sequence and was greatest in the Norfolk rotation (0.904 t ha^{-1} for maize and 1.646 t ha^{-1} for wheat), followed by the alfalfa – maize – wheat triculture (0.853 t ha^{-1} for maize and 1.223 t ha^{-1} for wheat), and the wheat – maize (0.490 t ha^{-1} for maize and 0.732 t ha^{-1} for wheat), alfalfa – maize (0.376 t ha^{-1}) and alfalfa – wheat (0.471 t ha^{-1}) rotations. Without fertilisation the yield-increasing effect of rotation (t ha^{-1}) was significantly higher (for maize: 0.715 in MW, 1.254 in MA, 1.401 in WAM, 1.357 in NF; for wheat: 0.375 in WM, 0.446 in WA, 0.923 in WAM, 1.666 in NF). Maize is a good forecrop for wheat, and this is important since wheat and maize are the two major crops in Hungarian crop production. Farmyard manure and the recycling of crop residues (maize stalks, wheat straw) with NPK supplementation are efficient ways of fertilising maize and wheat. Significantly higher yields were obtained at high levels of NPK fertilisation, especially in rotations where the proportion of maize or wheat was 50% or higher. The yield-increasing effect of crop sequences compared to the wheat monoculture was not affected by fertilisation. In maize crop sequences, however, fertilisation reduced the rotation effect by almost half. Further research will be required to determine the biological explanation of this phenomenon.

Various methods of stability analysis showed that the stability of crop sequences differed significantly from that of monocultures. The variance parameters (CV%, σ^2, YS) and the interaction principal component scores (IPCA) tended to be higher in maize and wheat monocultures than in crop sequences (Table 1). According to the regression methods of stability analysis the difference in the stability of various crop sequences vs. monoculture can be attributed to significant differences between the intercepts. Stability analysis suggested that recycled crop residues had an increasingly greater effect in monoculture and in low-yielding environments (<4 t ha^{-1}). The NF and WAM rotations provided especially favourable conditions for the manifestation of the effect of farmyard manure and recycled crop residues. The results show that stability analysis is a suitable approach for understanding treatment × environment interactions and assessing the mean performance and yield stability of treatments in a long-term crop rotation experiment.

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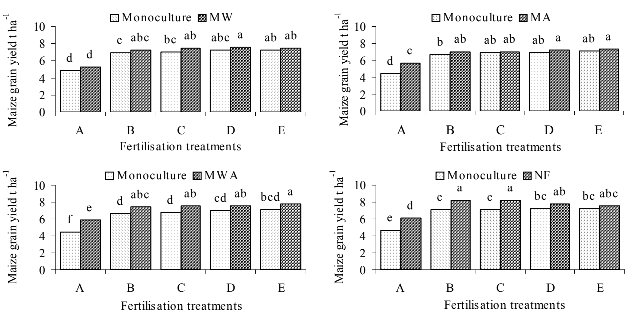

Fig. 1. Effect of crop rotation and fertilisation on maize grain yield compared with a monoculture (1961-2000). Within each rotation and fertilisation the same letter indicates non-significant differences at P< 0.05 according to LSD.

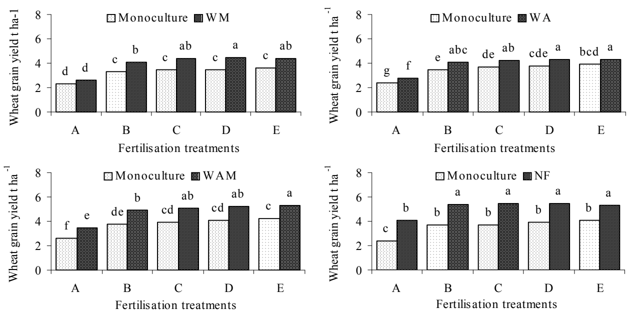

Fig. 2. Effect of crop rotation and fertilisation on wheat grain yield compared with a monoculture (1961-2000). Within each rotation and fertilisation the same letter indicates non-significant differences at P< 0.05 according to LSD.

Table 1. Stability parameters of maize and wheat monocultures vs. Norfolk rotation in various fertilisation treatments

Fertilisation treatments	Yield t ha^{-1}	CV%	σ^2	YS	IPCA(1)	Yield t ha^{-1}	CV%	σ^2	YS	IPCA(1)
	Maize monoculture					Wheat monoculture				
A	4.715	15.5	5.48**		-1.59	2.441	22.6	1.20**		1.00
B	7.092	5.0	0.20^{NS}	+	0.27	3.702	11.8	0.19^{NS}	+	-0.18
C	7.145	9.2	1.48**		0.62	3.728	14.8	0.45**		0.14
D	7.220	6.1	0.14^{NS}	+	0.29	3.934	7.9	0.21^{NS}	+	-0.36
E	7.200	8.2	1.30**		0.41	4.075	6.7	0.45**	+	-0.61
LSD (0.05)	0.237					0.141				
	Norfolk crop rotation					Norfolk crop rotation				
A	6.072	8.8	2.50**		-1.29	4.055	13.4	§.79**		-0.96
B	8.199	5.4	0.33^{NS}	+	0.18	5.360	4.5	0.13^{NS}	+	0.46
C	8.208	5.8	0.40^{NS}	+	0.28	5.470	6.6	0.13^{NS}	+	0.40
D	7.821	3.7	0.08^{NS}	+	0.21	5.487	8.2	0.19^{NS}	+	0.17
E	7.576	6.0	0.72^{NS}		0.63	5.338	7.8	0.32^{NS}	+	-0.08
LSD (0.05)	0.260					0.159				

CV%: coefficient of variation, σ^2: stability variance, YS: yield stability, +: selected treatments, IPCA: interaction principal component analysis scores. ** Significant at P≤ 0.01, ^{NS} Non-significant at P>0.05.

BRIDGING THE GAP BETWEEN ADAPTATION AND MITIGATION: BEST PRACTICES TO REDUCE GREEN HOUSE GAS EMISSION IN AGRICULTURE WHILE COPING TO CLIMATE CHANGE

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INTRODUCTION

Agricultural cropping and animal production systems are important sources of atmospheric GHGs, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) which globally account for approximately one-fifth of the annual increase in radiative forcing.

Accordingly, a number of mitigation strategies have been proposed to lower the contribution of agriculture on GHGs emissions. For instance, the use of less intensive, organic production systems has been proposed as a reliable measure to reduce of emission of GHGs while low tillage techniques may reduce CO_2 contribution from the soil. On the other hand, climate change is expected to have significant impacts on crop growth and yield. Under normal conditions, these are largely determined by weather during the growing season and even with minor deviations from the normal weather, management practices and yield are seriously threaded. As a consequence, understanding the potential impacts of climate change on the agriculture has become increasingly important and is of a main concern for the economic viability of this sector. Adaptation is certainly an important component of any policy response to climate change (Mizina et al. 1999) and simulations indicate the strategies will vary with agricultural systems, location, and scenarios of climate change considered. Simple farm-level techniques, such as early planting and the use of cultivars better adapted to warmer climates compared to those currently grown at specific locations have been indicated as a realistic adaptation to climate change at many northern agricultural sites (Olesen and Bindi, 2002). Accordingly, the best combination of adaptation and mitigation strategies for future periods is required for reducing the impact of a warmer climate on crop yield, lowering at the same time the emission in CO_2, N_2O and nitrogen leaching.

In this work, a number of alternative farming system strategies have been tested and evaluated for the efficiency in both mitigation and adaptation. For such a purpose, the results of a crop growth simulation models (Cropsyst) were coupled to a bio-geochemical model (DNDC) to assess maize crop yield and the relevant GHGs emissions in Tuscany region (central Italy) for the present period 1976-2005 and in a +2°C warmer climate. Conventional farming system (based on the massive use of inorganic fertilizers to maximize yield), and organic farming system (based on the use of low impact management practices, such as the use of manure) performances were compared. Alternative timing of fertilization, sowing time, residue management and maize variety were tested within these farming systems.

MATERIALS AND METHODS

Aiming at assessing the possible impact of climate change on both crop yield, GHG emissions and nitrogen leaching, the performances of alternative crop managements and adaptation strategies in a warmer climate were tested in a framework including Cropsyst and DNDC models. In particular, Cropsyst was used to estimate the impact of climate change on crop yield which in turn was used as input data of DNDC to simulate the relevant changes in GHG emission and nitrogen balance.

Irrigated maize crop cultivated in South Tuscany area (Lat. 42.88°, Lon. 11.07°) and the relevant management practices were used as case study of this work. Daily observed values of minimum and maximum temperatures and precipitation, for the present period (1976-2005), were extracted from the E-Obs database (spatial scale at 25 Km) provided by the FP6 European Project

ENSEMBLES. Soil properties were extracted from the Tuscany soil database (1km x 1 km) considering the most frequent soil type (sandy clay loam) as representative of the case study area.

Future climate was created by increasing daily temperature by 2°C and reducing rainfall by 10%. Atmospheric CO_2 concentration level was set to 350 and 550 ppm for present and future period respectively. While for the present period, only the current conventional crop management was used for the simulations, in a +2°C environment, five different farming system strategies, five sowing dates and three different varieties were combined in order to find the best combination of adaptation and mitigation strategies for future periods. The farming systems included: Standard management (STD) using 240 kg N ha^{-1} y^{-1} as ammonium nitrate and leaving 15% of crop residue in field; (ORG) using 240 kg N ha^{-1} y^{-1} as manure and leaving 15% of crop residue in field; (MIX) using 120 kg N ha^{-1} y^{-1} as ammonium nitrate, 120 kg N ha^{-1} y^{-1} as manure and leaving 15% of crop residue in field; (LWO) using 120 kg N ha^{-1} y^{-1} as manure and leaving 80% of crop residue in field; (LWC) using 120 kg N ha^{-1} y^{-1} as ammonium nitrate and leaving 80% of crop residue in field. Five considered sowing dates included: ±15 days and ±30 days with respect to the first of April, which is the current sowing dates. Late (class 700), medium (current variety, class 500) and early (class 300) maize varieties were considered.

Maximum potential crop yield was estimated by Cropsyst considering only changes in sowing dates and maize varieties. These values were included in DNDC to derive the actual yield as reduced by the combined effects of crop management, sowing dates and varieties, the GHG field emission (N_2O, CO_2) and nitrogen leaching relevant to each combination.

RESULTS AND DISCUSSION

In standard conditions (i.e. standard variety and management), a +2°C warmer climate resulted in a +11% crop yield with respect to the present period while CO_2 from the soil increased by 14% as well as N_2O. In contrast, nitrogen leaching decreased by 20%.

With reference to different farming systems, some common trends may be highlighted. MIX, ORG and STD resulted in increased yield (+8% on average) as well as in CO_2 emissions (+35%). On the other hand N leaching resulted almost unchanged (-5% on average) while the N_2O emissions increased by 73% (average). The low impact managements (LWC and LWO) resulted in decreased yield (-4% on average), and increased CO_2 emissions (+35%). In contrast, both N_2O and N leaching highly decreased (-70% and -67%, respectively).

In general yield was not affected by sowing date showing a general increase, with respect to present period, but the latest sowing date (+30 days) which exhibited a reduced yield (-4%). CO_2 and N_2O emissions, although higher than present period, tend to decrease with delay in planting time, while N leaching decreased in all considered sowing dates (-24%).

Longer cycle varieties enhanced biomass accumulation, increased CO_2 emissions, but highly reduced N leaching (-40%) and limited N_2O emissions (+2%). Shorter crop growth cycle resulted in decreased yields (-8%) and lesser CO_2 emissions, while both N_2O emissions and N leaching were higher than the other varieties.

As a conclusion we can state that the combination of longer cycle varieties with high input crop management (high N fertilizer inputs and lower crop residues in the field) may guarantee increases in crop yield with respect to present period, with correspondent increasing GHG emissions. By the other hand, low input practices (low N inputs and residues incorporation), although maintaining or slight reducing yield, highly lower N_2O emissions as well as N leaching.

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TESTING ADAPTATION OPTIONS IN A +2°C WARMER CLIMATE

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INTRODUCTION

The results of recent global climate monitoring as well as the simulations of general and regional circulation models stressed out that the future climate will be significantly different than that experienced in the past, resulting in impacts on different economic sectors.

Accordingly, EU's policy, consistent with the spirit of the United Nations Framework Convention on Climate Change (UNFCCC), aims to curb global warming at the level below 2°C above the pre-industrial mean for the turn of this century (EU, 2007). The EU policy goal implies the evolution of mitigation and adaptation solutions for a tolerable transition ("soft landing") to a warmer climate including the identification of their associated costs and effectiveness. It follows that impact assessment corresponding to the +2°C scenario is a critical point to develop any future response strategies in different sectors and systems.

Since agricultural practices are climate-dependent and yields vary from year to year depending on the weather, understanding the potential impacts of climate change on agriculture has become increasingly important and is of main concern especially for the sustainability of agricultural system and for policy-making purposes. Many studies aimed at assessing crop development shifts and yield variations under changes in mean climate conditions. Other studies, stressed out that change in climate variability, as expected in a warmer climate, may have even a more profound effect on yield than changes in mean climate and that policy analysis should not rely on scenarios involving only changes in means (Hanson et al., 2007). Additionally, the changes in the frequency of extreme climatic events centred at sensitive growth stages have been recognized as a major yield-determining factor for some regions in the future.

Building on these premises, this work aims at assessing the impact of climate change as well as the effect of different adaptation strategies in a +2°C warmer climate at European level considering changes in both mean climate and extreme events frequency.

MATERIALS AND METHODS

Climate future data simulated by a HadCM3 General Circulation Model (GCM) for a period corresponding to a + 2ºC global warming with respect to pre-industrial level, were used as input of Cropsyst model. A GCM statistical downscaling software (LARS WG) was applied to observed data to reproduce both present and future climate (Tmin, Tmax, rainfall and global radiation) at a spatial resolution suitable for impact assessment on a regional scale (50 x 50 Km).

According to LARS WG procedure (Semenov and Barrow, 1997), available observed daily weather data for a given site were used to determine a set of parameters for probability distributions of weather variables as well as correlations between them (calibration stage). This set of parameters was then used to generate both the synthetic weather time series describing the present period and as a baseline to be perturbed using forcing factors derived from the GCM.

In this work observed daily data (including Tmin, Tmax, rainfall and radiation) for the period 1975-2005 spatially interpolated at a resolution 50 x 50 Km over EU (provided by MARS project) were used in the calibration phase of the stochastic weather generator. After calibration, 100 years of synthetic daily weather data were produced for each grid point to represent the current baseline 1975-2005.

The results of HadCM3 for A2 scenario in 2030-2060, over the European domain, were used to derive the forcing factors corresponding to a +2°C scenario (New, 2005), for the downscaling procedure. These factors were computed for each GCM grid point as monthly average differences of

Tmin, Tmax, rainfall and radiation with respect to the reference period (1975-2005). The relative changes in standard deviation of temperature and in the duration of wet and dry spell were also calculated in order to simulate change in extreme events frequency.

Cropsyst model was run for +2°C scenario to simulate growth and development of barley, wheat (winter and spring), sunflower, soybean and maize using common agricultural practices (business as usual treatment, BAU), i.e. sowing dates, fertilization, rainfed conditions, and using different adaptation strategies. These included early and late sowing date (-15 and +15 dd with respect to BAU), shorter and longer cycle variety (-20% and +20% with respect to BAU) and the use of irrigation. CO_2 air concentration was set to 550 ppm for the considered period and consequently crop biomass accumulation in Cropsyst was set to increase by +18% and +10% with respect to present conditions (350 ppm) for C3 and C4 species, respectively.

RESULTS AND DISCUSSION

HadCM3 GCM for a +2°C warmer climate showed a clear pattern in the change of rainfall distribution across Europe, with a general annual rainfall increase above 55° Lat N, no or slight changes between 45° and 55° Lat N and a sensible decrease over the Mediterranean basin. Annual maximum and minimum temperature increased following a strong longitudinal gradient from –10° to 40° Lon E.

Both changes in mean climate and climate variability affected crop growth resulting in different crop fitting capacity to cope with climate change. This capacity mainly depended on the crop type (i.e. winter and summer crops) and on the geographical area (i.e. Southern or Northern Europe). In a BAU scenario, the Northern regions experienced some beneficial effects of climatic change in terms of increased crop yield for all the considered crops but soybean that was slightly negatively affected. By contrast, in the southern areas, yield of summer crops decreased in the range between –5% (spring wheat and sunflower) and -13% (soybean) whereas yield of winter crops (winter wheat) resulted increased. The autonomous adaptation strategies proposed reduced or emphasized the impact of climate change. The use of irrigation increased crop yield with respect to BAU, especially at lower latitudes where the decrease in rainfall was more evident. Generally, the use of longer cycle varieties resulted in an increased yield due to the lengthening of time for biomass accumulation. This strategy resulted more effective in Northern Europe, where no changes or even increase in rainfall rate were simulated. By contrast, at lower latitudes the projected decrease in rainfall, especially in summer, limited the effectiveness of this strategy. Shorter cycle varieties resulted in a decreased yield. This was especially true in Northern Europe, where the shorter growth cycle cancelled out possible positive effect of increased rainfall. Changing sowing dates gave not significant results across Europe but in Southern Europe where an earlier sowing date allowed the crops to advance their growth cycle and to escape the spring-summer drought.

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Sustainable Use of Dairy Slurry on Crops: Dual Manure Stream Concept

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INTRODUCTION

Liquid slurry manure from dairy feeding operations is an important potential source of crop nutrients that should be exploited as fully as possible to replace manufactured fertilizer. One of the most intractable problems for sustainable use of manure as the main nutrient source is the excessive ratio of P:N compared to crop needs, leading often to over-application of P on soils near livestock operations. Accumulation of P in soils is a waste of resource and an environmental concern while transporting liquid manure, which contains 90- 98% water, away from source is costly. The simplest way to reduce transportation cost is to remove some of the nutrient-rich solids from the manure so that more of the thinner fraction can be spread near source, and the nutrient rich solids transported further to nutrient deficient fields.

The solid fraction of manure consists of faeces, bedding and waste feed whereas the liquid portion is mainly urine and waste water. Manure solids contain the majority of the organic N and P (also divalent cations and several micronutrients) so the liquid fraction that remains after removal of solids often has both less nutrients and lower P:N ratio. Removing solids also removes organic matter and organic carbon, altering C:N, but leaving behind soluble carbon, including volatile fatty acids, which can serve as a ready substrate for denitrification which emits N_2O. Hence, removing the solids from slurry produces two products with different nutrient, chemical, and physical profiles, that have agronomic implications. For example, removing solids decreases viscosity and improves rate of infiltration after field application which serves to reduce ammonia loss and conserve N, and thereby improving the effective N:P ratio compared to whole manure (Stevens and Laughlin, 1997). Workers in Quebec recently showed that increasingly efficient removal of solids from pig slurry (settling, anaerobic digestion, filtration and flocculation) progressively reduced emissions N_2O and NH_3 and substantially increased uptake of N by grass (Chantigny et al., 2007).

The objective of our study was to advance sustainable use of dairy slurry by developing strategies for use the solids-rich and liquid streams obtained with a simple, low-cost method (settling) of separating dairy slurry.

MATERIALS AND METHODS

The research was conducted in the maritime climate of south coastal B.C., Canada. Slurry (typically 6.3% DM and 4.6 N:P) from a local dairy was settled for several months in a 2.5 m deep tank with an open roof. We decanted the upper portion (2.1% DM, 7.7 N:P) and applied to bare soil in spring, summer and fall; emissions of NH_3 were measured with wind tunnels and N_2O with vented chambers. We also tested repeated applications of decanted slurry from a local dairy farm on grass (*Festuca arundinacea* Schep.) using surface banding. The settled sludge (8% DM, 2.0 N:P) was tested as replacement for banded P fertilizer by injecting at 30 kg P ha^{-1} at 75-cm spacing to match corn-rows (*Zea maize* L.). The corn was planted several days later (to allow time for soaking and nitrification) at various distances (5-15cm) from the manure furrow, and sampled 3 times over the season.

RESULTS AND DISCUSSION

Sampling of on-farm storages revealed that most dairy slurries had >5% DM and N:P ratios ranging from 4:1 to 6:1. Higher N:P ratios found in samples with <2% DM were associated with the thin fraction of passively separated slurries.

In a multi-year grass trial, separated liquid obtained from a dairy farm produced better yield (~1.2 t ha^{-1}) and N uptake (~40 kg N ha^{-1}) than whole slurry at equivalent applications rates of mineral N (~300 kg N ha^{-1}). The higher yield from decanted manure may be due in part to lower NH_3 emission, due to faster infiltration, although this was not measured. The advantage for the decanted fraction was even greater based on total applied N because whole slurry had a higher concentration of less-available organic-N compared to the decanted fraction. Yield and N uptake per applied P was much greater for the decanted fraction, hence the decanted fraction can be applied at greater volumes than whole slurry.

Decanted slurry fraction applied to bare land reduced emission NH_3 under cool conditions when the soil was relatively dry, but not under very hot or wet conditions (Bhandral et al., 2009). Emissions of N_2O from the decanted manure was similar to the whole slurry based on similar rates of applied mineral N, but lower based on applied total N.

Corn planted near furrows injected with the sludge separated from dairy slurry performed well. Populations were not diminished by proximity to sludge furrows, and the sludge did not affect early growth of roots or colonization of roots with arbuscular mycorrhizae (AM). At the 6-leaf stage, the corn treated with sludge had more biomass and P uptake than corn receiving just N as fertilizer, showing that the sludge provided starter P for the juvenile corn plants. The degree of AM colonization of corn roots did not alter the response of corn to sludge. The efficacy of the sludge improved with proximity to the injection furrow both at 6 leaves and at final harvest: 5cm > 10cm > 15cm. Sludge-treated corn and corn treated with both N and P fertilizers had similar growth and P-uptake at all growth stages, and similar maturity and harvest index at harvest.

CONCLUSION

Our work demonstrated that settling and decanting is a low-cost slurry separation technique that can help farmers manage manure nutrients. The decanted liquid fraction is a very effective N source for perennial grass production causing less P accumulation in soils and less emission of NH_3, than whole slurry. Therefore application volumes of decanted liquid manure can be set according crop N requirement rather than crop P requirement, permitting greater manure application rates near the barn, and thus reducing hauling costs. The sludge settled in the lower third of the tank can be injected at typical corn P rates at 75cm (corn crow) spacing. Allowing several days for soaking into soil and nitrification of ammonia, corn can be planted safely within 10 cm of the manure injection furrow with no P fertilizer. Since the sludge contains less water it can be transported to corn fields further from the barn avoiding build-up of soil nutrients, esp. P, near the barn. Information is needed on improving separation efficiency by settling and the long term effects of applying the separated products.

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A METHOD FOR EX ANTE MODELLING OF ADOPTION OF ALTERNATIVE CROP MANAGEMENT SYSTEMS

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INTRODUCTION

In the perspective of developping methodologies to design and assess *ex ante* alternative agricultural systems, an increasing attention is given to the use of models. Nevertheless few attention has been given to the *ex ante* modelling of the process of adoption of innovation by farmers. Farmers however often fail to follow extension advice and do not always adopt innovations because they are not compatible with their personal constraints and preferences. We developped an original interdisciplinary method aimed at modelling *ex ante* the adoption of alternative crop management systems. The objective of the communication is to present the method and the results obtained from its application to the *ex ante* modelling of adoption of five innovative crop management systems for banana production in the French West Indies (FWI).

DESCRIPTION OF THE METHOD

The method is based on the combination of the use of several agronomic and economic models and is made of three steps (Figure 1). The first step is aimed at modelling farm diversity at regional level in terms of crop management systems, soil and climate conditions, and economic ressources. This is based on a farm survey on a sample of farm representative of the regional diversity. A farm typology is then obtained and can be used to help experts to design alternative prototypes of management systems aimed at improving the sustainability of current systems (Blazy *et al.*, 2009a). In the second step a bio-economic farm model is designed in order to assess the agronomic, environmental and economic impacts of adoption of prototypes in the different farm types. This model is made of the linkage of a biotechnical crop model to simulate, at field level, the impacts of innovations and of an economic farm model to assess the economic impacts of adoption at farm level. The results of the simulations are then used in the third step to design a questionnaire in which farmers are asked if they would adopt the prototypes given their potential impacts and under different policy and market outlook. The data collected - farmers decisions to adopt and their personal characteristics - are then used to estimate an adoption model with a random utility econometric model. A mixed logit model makes it possible to model the decision to adopt as a function of innovation and farmers characteristics and their potential interactions.

RESULTS AND DISCUSSION

The application of the method to the case of banana systems in FWI lead to the identification of six contrasted farm types from a survey on a sample of 67 banana growers. Five innovative crop management systems involving new pest resistant cultivars, intercropping techniques, improved fallow and organic fertilization were defined. The simulations of the impacts of the prototypes across farm types revealed contrasted and ambivalent impacts (Blazy *et al.*, 2009b). The survey on adoption determinants was done on an original sample of 607 banana growers and revealed adoption rate varying between 30% for organic integrated systems to 76% for intercropping system according to the farm type. Estimates of parameters of the adoption model revealed that the willingness to adopt depends largely on aversion to change and farmers expectations about future pesticide regulation, as well as on ability to substitute pesticides uses by larger labor amount. This study confirmed that the role of innovation traits and policy attributes can be strongly affected by interactions with farmer's personal attitudes, in particular expectations on future environmental and agricultural policy, and economic outlook. A cross-sectional view at innovations performances and adoption determinants make it then possible to propose several policy and agronomic recommendations to promote environmental adoption.

By linking a farm typology with agronomic and economic models the method make it possible to evaluate *ex ante* new agricultural technologies and practices under real-world conditions. Although a considerable amount of data and modelling techniques are mobilized and required to implement the method, this last one helps a better understanding of innovations impacts and adoption pathways. This *ex ante* approach could be useful to help agronomist researchers and policy makers to improve the sustainability of agricultural systems by promoting innovations and policy that are more consistent with farmer's personal constraints and preferences and therefore more easily adopted.

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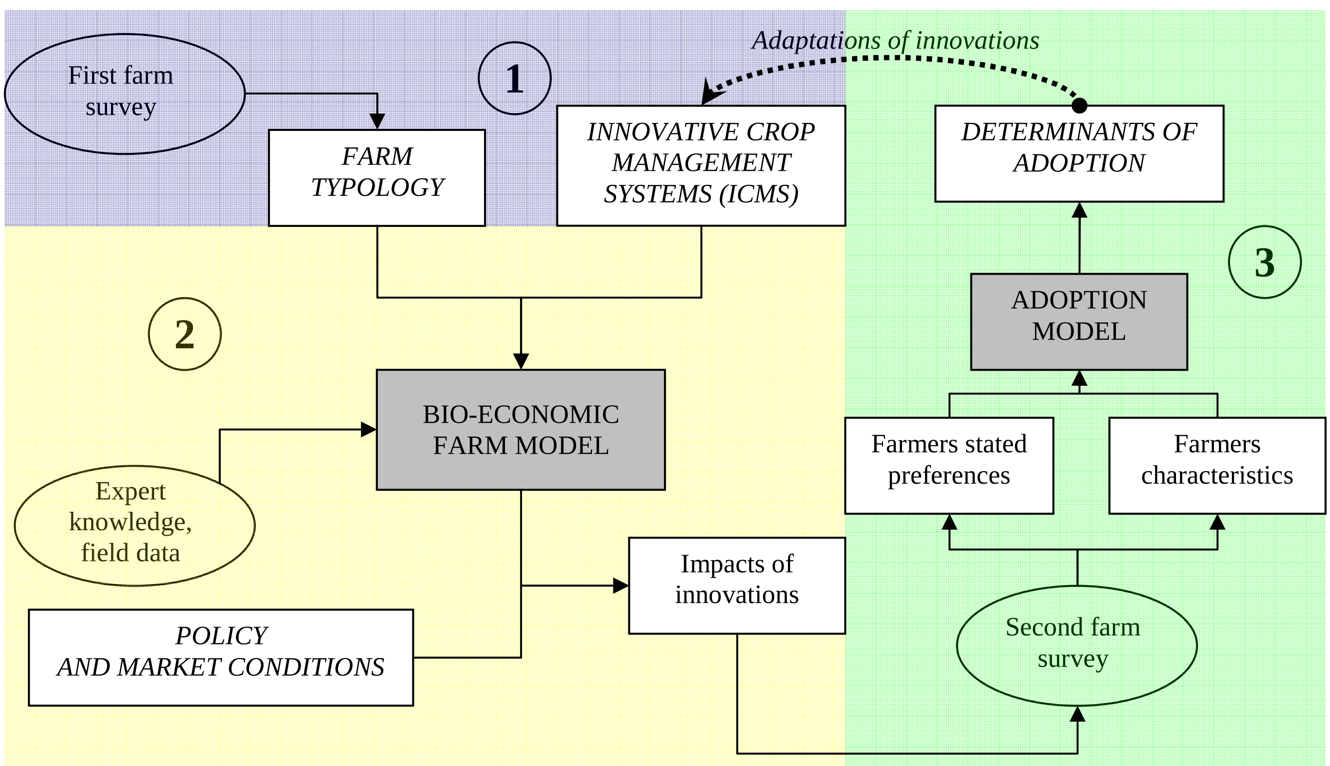

Figure 1. The three-steps method for *ex ante* modelling of adoption of innovative crop management systems.

TESTING AND PARAMETERIZING CROP MODELS FOR RESPONSE TO CLIMATE CHANGE FACTORS

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INTRODUCTION: Climate change may include increased day and/or night temperature, increased carbon dioxide, altered rainfall frequency and intensity, as well as extended growing season. Simulation models for different crops can be used as strategic tools to evaluate the consequences of climate change on production for given regions, as well to evaluate shifts in species, sowing date, cultivars, irrigation, and fertility management practices for adapting to climate change. Prior to successful use of crop models as tools for such strategic tests, it is important to determine whether the crop models are accurately parameterized as to climatic effects on growth and development. The modeling community has not sufficiently tested and improved crop models for these climatic effects, especially considering the latest scientific literature. The goals of this paper are: 1) to discuss the need to test the parameterization of crop models for sensitivity to climatic variables, 2) to discuss the nature of the data needed for testing, and 3) to illustrate examples of such evaluations.

METHODS, RESULTS, AND DISCUSSION: Crop simulation models include relationships that provide for sensitivities of photosynthesis, leaf area expansion, growth, reproductive processes and grain yield to CO_2, temperature, and other climatic factors; however, the quality of those relationships has not adequately been tested. Crop growth models that use the simpler radiation-use-efficiency approach to predict daily dry matter growth are particularly vulnerable to inadequate parameterization and testing. For example, the CO_2 sensitivities for the CERES models (C-4 maize, sorghum, and millet, and C-3 wheat, barley, and rice) and an old (but still available) daily "canopy" C-version of the CROPGRO model in the DSSAT were based on relationships developed in 1990 (Adams et al., 1990; Curry et al., 1990). The more recent leaf-level (L) version of CROPGRO (Pickering et al., 1995) scales from leaf to canopy assimilation. Its leaf-level equations are more mechanistic, capturing sensitivity to CO_2 and temperature using rubisco kinetics of Farquhar et al. (1980).

Over the past 20 years, considerable data on CO_2 and temperature responses have become available from studies conducted in sunlit-controlled-environment chambers, open-top chambers, free-air CO_2 enrichment (FACE) studies, and to a limited extent, high-light phytotron studies. It is important to appreciate that most of these data should be used only for the relative responses of photosynthesis, biomass and yield. FACE can provide data that have more realism for absolute yields but only *if* plot yields of several m^2 land area are used. An advantage of sunlit-controlled-environment chambers and phytotrons is that they can provide data on temperature response. A good source of information for temperature response is from field studies conducted over different elevations, latitudes, and sowing dates. Crop models can be used with these data in an inverse solving mode, to derive correct temperature relationships over elevations, latitudes, and sowing dates.

Such experimental data were used to develop the 2008 climate change assessment report for agriculture (Hatfield et al., 2008). Tables in that report describe the optimal temperature for grain yield and the upper failure temperatures of important crops, as well as the percent yield response to increase in CO_2 from 380 to 440 ppm and 1.2°C increase in temperature for major production regions in the USA. The projections for this report were based strictly on published experimental data, not on crop model predictions.

We re-evaluated the DSSAT crop models for yield response to CO_2 (compared to literature reports). For the C-4 species, recent data indicate less response to CO_2 than was summarized by the earlier reviews. As a result, we reduced the responsiveness of the CERES-Maize, Sorghum, and Millet models to CO_2 (effective in DSSAT V4.5). The CO_2 sensitivity function for the CERES models is a two-variable lookup function that describes relative effect on daily dry matter accumulation that is normalized around 330 ppm and is a multiplier on the radiation-use-efficiency. Above 330 ppm, the new C-4 function is about 50% less responsive than the old function, causing percent yield response to doubling CO_2 from 330 to 660 ppm to be reduced from 8.3 to 4.6%. The function used for CERES C-3 crops gave responses (27% yield increase for wheat and 31% for rice with doubling CO_2) that are close to metadata reports so those functions were not changed. For CROPGRO, the L version with hourly leaf-to-canopy assimilation was sufficiently close to reported data and was not modified. However, the C version (old daily photosynthesis option) of CROPGRO, having been parameterized by data summarized prior to 1990, was found too responsive to CO_2 and was re-calibrated. It uses a three-parameter asymptotic function described by an asymptote, initial slope, and a "whole crop" compensation point. Daily crop transpiration in the models is reduced as a function of rising CO_2, using a function developed in1990. The responses of daily transpiration for both C-3 and C-4 crops in DSSAT mostly mimic observed transpiration reductions, with greater reductions for C-4 crops. The responses were more realistic for crops that had low LAI responses to CO_2 like the cereals. For crops that increased LAI with rising CO_2, the effect of increasing LAI often more than offset the transpiration reductions caused by rising CO_2. Model simulations, theory, and experimental data show that response to CO_2 is greater under water-limitation than under irrigation.

Sensitivities of DSSAT crop models to temperature were evaluated and compared to literature. Temperature sensitivities of simulated processes such as leaf appearance, leaf photosynthesis, fruit set, and single seed growth rate, can be set from controlled-environment experiments and solved from simulations against data collected under a wide range of adverse temperatures. The crop models must have good soil temperature prediction, as well as code to mimic frost or freeze susceptibility and reduced pollination under elevated temperature. Models lacking these features are poorly suited to evaluate sowing dates as mitigations to escape effects of hot temperatures or drought.

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EFFECTS OF LANDSCAPE POSITION ON GROWTH AND WATER USE OF TREES INTEGRATED INTO ANNUAL PRODUCTION SYSTEMS IN THE WESTERN AUSTRALIAN DRY-LAND AGRICULTURAL ZONE.

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INTRODUCTION

In the wheatbelt of Western Australia, attempts are being made to address a hydrological imbalance – brought about by broad-scale clearing for agriculture - by replanting trees. The degree to which tree growth may be enhanced by additional water supplies (e.g. groundwater) will be dependent on the accessibility of such water and the efficiency with which trees are able to utilize it. Trees that invest more in root development in order to access deep groundwater may be less efficient in accumulating above ground biomass with respect to trees that have access to shallower groundwater. Additionally, trees that are capable of hydraulically redistributing water from depth may overcome or, to some degree, offset the limitations to growth associated with less accessible groundwater. Implications for the efficacy of strategic tree plantings will be better informed with a greater understanding of tree responses to groundwater depth and the role of hydraulic redistribution.

This study aimed to investigate water use patterns of trees of trees with a close water table (2 m - SGW), trees with a deeper water table (4.5 m - DGW) and trees with no access to groundwater (NGW).

MATERIALS AND METHODS

The research took place on Calecono Springs farm (30°02’28”S, 116°13’00”E), approximately 30 km south east of the town of Coorow in Western Australia. The study commenced in 2003 when the trees were just over four years old. The study site has a Mediterranean climate characterised by a hot dry season and cool wet season. The mean annual rainfall (1899-2003) is 350 mm, more than 80% of which falls between April and October. Annual potential evaporation is 2340 mm with a monthly peak of more than 350 mm in January.

Sap flow was monitored for 12 months in the three landscape positions described earlier, then seasonal data was extracted to compare flows under different conditions. Probes were installed in two tap roots, two lateral roots and one stem from each tree. Sapflow data is presented as a single diurnal curve which is a mean of 14 days data. Above ground biomass data was also collected in the three landscape positions.

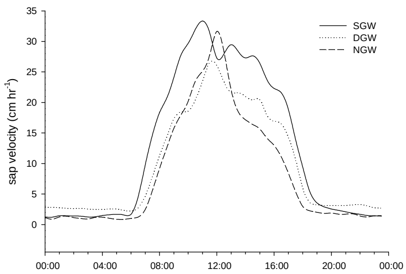
RESULTS AND DISCUSSION

Variations in water availability appeared to have little effect on basic root architecture with trees in the two extreme landscape positions (shallow ground water and no ground water) possessing the same proportion of taps roots and lateral roots. Night time sap flow was observed in roots in all three landscape position, confirming that hydraulic redistribution is occurring in this species across a range of soil moisture pattern scenarios. Although higher rates of hydraulic redistribution were measured in the deep ground water and no ground water plots, complex root architecture may have masked the extent of nocturnal flow in the two plots where a water table was present.

Water availability had a profound effect on tree growth with a doubling of the depth to groundwater effectively halving biomass accumulation over the first four years, while trees with deeper groundwater grew to four times the size of trees surviving on annual rainfall over the same period. Compounding this effect was an increase in water use efficiency when water was more easily accessible meaning well watered trees were able to fix more carbon per unit water use.

Sap flux density patterns in the dry season reached similar peaks in all three plots, but rates were less sustained over the course of the day where water was more limited. This amplified the difference in water use per tree as stem cross sectional areas also decreased as water availability reduced.

The presence of a water table allowing the maintenance of surface soil moisture has the potential to appreciably increase total stand water use, and consequently tree growth so this should be taken into account when planning placement of trees if either of these outcomes are drivers. Well targeted plantings will therefore enable land managers to maximize the benefits of re-integrating trees into their existing farming systems while minimizing the area of land required to be taken out of annual crop production.

a. 

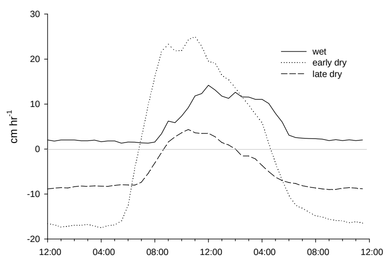
b. 

Figure 1 (a) Stem Sap flux density patterns in three landscape positions late in the dry season. Each trace is the stem mean for the plot over 14 days. (b) Average diurnal sap flux density (n=3) over a ten day period in lateral roots in no ground water landscape position for 3 seasons 2003-2004.

Table 1. Plot mean heights, volumes, sapwood area, leaf area, sapwood area/leaf area ratios and transpiration efficiency in terms of grams of dry matter accumulation per litre of water transpired with standard errors.

	Height (m)	Vol (m^3) x10^{-3}	SA (cm^2)	LA (m^2)	SA:LA	WUE (g/kg)
SGW	4.31 (±0.16)	18.3 (±2.2)	82.8 (± 11.1)	38.2 (± 5.3)	2.2 (± 0.03)	1.33 (±0.15)
DGW	3.18 (±0.18)	7.8 (±0.7)	47.9 (± 5.0)	20.8 (± 2.2)	2.3 (± 0.03)	1.16 (±0.15)
NGW	1.68 (±0.10)	1.5 (± 0.17)	16.1 (± 1.6)	5.9 (± .67)	2.8 (± 0.05)	0.88 (±0.22)

A Multi-Scale Methodological Procedure for the Characterization and Identification of High Nature Value Farmlands

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INTRODUCTION

High Nature Value Farmland (HNVF) was proposed to emphasise the crucial role of low-intensity farming in European biodiversity conservation (Baldock et al.,1993) and is considered an important issue to promote multifunctional agriculture among the European Environmental and Agricultural Policy (Rural Development Programme, 2007-13). Low-intensity farming still covers broad areas of Europe's more marginal regions; on this respect, the HNVF concept is useful to support a range of habitats and wildlife species, especially when they includes a high proportion of semi-natural vegetation such as grass, scrub and woodland (Bignal & McCracken, 2000).

Three types of HNVF are generally recognized: 1) mostly with grazed semi-natural vegetation; 2) a mosaic of semi-natural vegetation, arable and/or permanent crops; 3) more intensive farming systems which nevertheless still support species of conservation concern (Andersen et al. 2003). At the same time there are three different approaches which can be used for their identification (Andersen et al. 2003): 1) land cover; 2) farming system; 3) species.

This work elaborates a methodological procedure to identify and characterize HNVF; it was applied to the geographical area of "Monti Dauni" (Apulia Region, Southern Italy) of approximately 200,000 hectares; both *land cover* and *farming system* approaches were employed.

DESCRIPTION OF MODEL

The *land cover approach* (*Fig.1*) was carried out using a Geographic Information System software (ArcGis 9.2). Starting from the *Land Use/Cover map* (1:10.000 in scale) a *Biotope Map* was derived through a proper land cover class aggregation. A "natural value" score, ranging from 0 to 1 (minimum and maximum value respectively), was assigned to each biotope (15 as a whole), according to a cardinal ranking procedure (Berthoud et al., 1989). With respect to this score (if lower or higher then 0.29), the map was split into two complementary units: an *Anthropization* and *Naturality maps*. Buffers (of increasing size in relation to the natural value of the biotopes) were traced out along the border of the patches on the *Naturality map*. All those buffers were then summed up to get the *Transition Map* which was added to the *Anthropization map*. In this way, the *Interference map* was finally generated, soon after a score reclassification (5 class levels). This final map highlights those sectors or zones where a marked spatial closeness or inter-dispersion between high natural and high anthropization areas is detected. Those areas should be the first candidates to be evaluated as HNVF.

The *farming system approach* was consequently applied to a restricted area (1,500 hectares wide) characterized by high *interference* values; information related to three farms inside this area were collected by direct inspections and farmers interviews. Crop rotation and yield, fertilizers and pesticides, dairy and cattle breeding, farm management, natural and semi-natural vegetation, extension and shape of crop fields and of ecological infrastructures were fully detected.

RESULTS AND DISCUSSION

A top-down and a bottom-up methodologies for the identification and characterization of HNVF were proposed. The *land cover approach* is a top-down methodology, performed at a broad scale, suitable for the geographical identification of potential HNVF, such as the highest classes patches of the

Interference map, corresponding to those landscapes where farming is strictly influenced by natural or semi-natural ecosystems. A coexistence of *agriculture* and *high species and habitat diversity* (Andersen et al., 2003) is observed. We labeled these patches as "potential" HNVF because no direct information are available about farming system management and agro-ecological sustainability.

Therefore, at a finer scale, a bottom-up methodology was applied to a sample area, consisting in the *farming system approach*. The three farms are characterized by a high proportion of natural and semi-natural vegetation, like pasture and natural grassland, bush and garrigue, woodland. Crop cultivation consist mainly in cereals (above all *Triticum durum* and *Hordeum vulgare* L.) and meadows. The high proportion of natural vegetation is mostly the result of a marginalization of these rural areas where a high-input farming system is not profitable.

The detected sample areas can be actually assigned to a HNVF between types 1 and 2. Results state the absolute need of both approaches to characterize and identify HNVF and promote their correct management and ecological improvement. Generally, the interviewed farmers were not fully aware of the importance of these residual natural habitats and of the environmental services those habitats can deliver. As a consequence, farmers must be assisted and supported to promote the full achievement of a well designed multifunctional role of agriculture.

The present study must be considered a first attempt to set up a methodological approach to characterize and identify HNVF; the starting point for further investigations.

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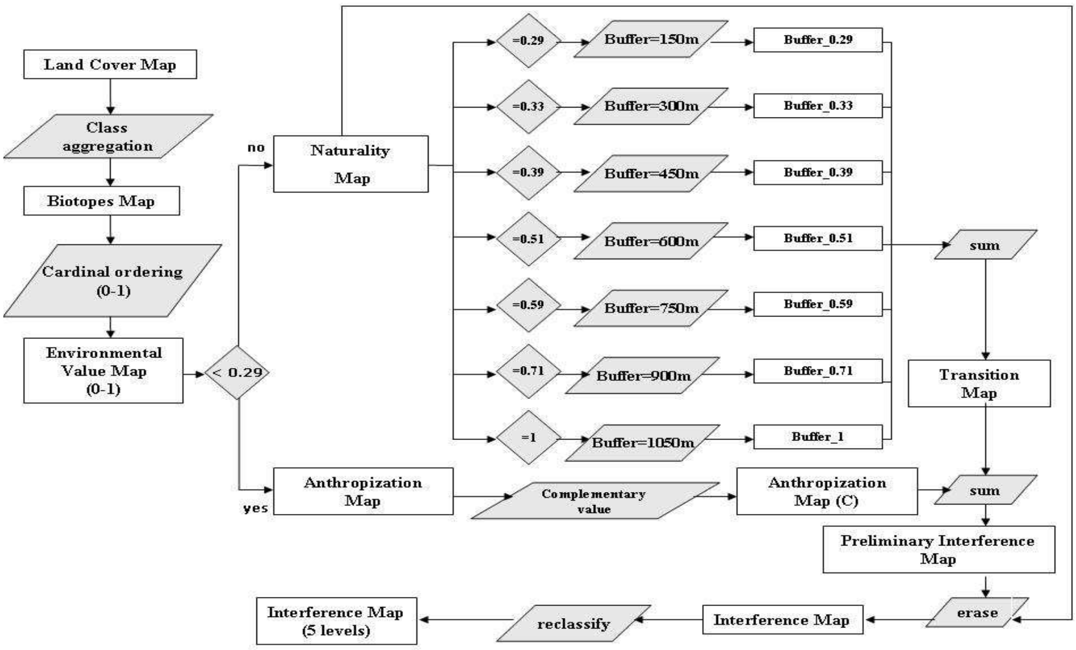

Fig. 1 – Flow-chart of the methodological procedure relative to the land cover approach

SYSTEMS RESEARCH IN AUSTRALIAN AGRICULTURE - THE APSRU EXPERIENCE

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INTRODUCTION

The Agricultural Production Systems Research Unit (APSRU) was established in 1990 as a partnership born out of competition between research agencies in north-east Australia – the Queensland Department of Primary Industries and CSIRO. Almost two decades later, APSRU has established a reputation in Australia, and internationally, as being amongst the leaders in farming systems research and the application of systems analysis and modelling tools in agriculture. This paper briefly documents some of APSRU's achievements of the past 19 years and draws some lessons from this collective effort.

SCIENCE AND INTERVENTION

APSRU's core technology is the APSIM model (Keating et al., 2003). Prior to forming APSRU, each agency had undertaken model development and application, either developing their own models or building on the models of others. However, the design and development of APSIM has been our key innovation in this field, not only in providing a true systems simulation capacity but also in adopting rigorous software engineering practices. Accordingly, much of the science of APSRU has been manifest over the years in adding to and improving the functional simulation capability of APSIM (Robertson et al., 1992). Today, APSIM is regarded as the standard for the modelling of crops and cropping systems in Australia – for example, since 1992, APSIM has been used in 17% of all papers (75% of papers with modelling included) presented at the Australian Agronomy Conference (Robertson per com).

For model applications, APSRU designed and developed tools to support the characterisation and monitoring of soil resources, including soil coring equipment, the 'HOWWET?' software and 'Soil Matters', a manual describing how to take soil samples and analyse results. Concomitant with this concerted effort to create soil resource data for modelling, farmers and advisers throughout Australia recognised the importance of monitoring soil water and nutrients as an integral component of dryland crop management. Today, the APSOIL national database of soil properties, being APSIM-ready, can be downloaded from Google Earth.

APSRU has been a leading participant in the development and application of seasonal climate forecasting systems relevant to Australian industry and internationally (Meinke and Stone, 2005). The Southern Oscillation Index phase system was developed and promoted by APSRU as a management tool throughout Australia. This work on climate prediction has helped make this phenomenon part of everyday language in Australia such that farmers nationally are acutely aware of the implications of SOI trends on their enterprises' potential productivity.

Being both a developer of decision support systems and their harsh critic (McCown et al., 2002), APSRU has been an active contributor to both the theory and practice of systems research in Australia. As a consequence of such reflection, APSRU has pioneered participatory action research as an approach to intervening in farming systems, particularly in using APSIM as a tool to explore farmer and adviser responses to alternative management options (Carberry et al., 2002). Today, Yield Prophet® offers farmers in Australia access to APSIM on-line as a subscriber service designed with theory and history's learnings in mind (Hochman et al., 2009).

Current innovations being progressed within APSRU include both model up-scaling to whole-farm (Rodriguez et al., 2009) and regional analyses, broadening modelling scope to encompass ecological performance of alternative land use systems and developing crop modelling potential to link with molecular genetics in novel integrated approaches to plant breeding (Hammer et al., 2005).

LESSONS LEARNED

APSRU's history, its achievements and its continued existence are tangible evidence for the 'partner or perish' maxim. By creating a critical mass of scientists with a common challenge – to demonstrate to our agencies and industries value from science investment into simulation modelling – we have created a well supported and acknowledged domain for systems analysis and modelling. Our unifying focus has been largely to progress the science and software of APSIM. The challenge in this task has been to foster creativity and accommodate diverse views whilst at the same time benefit from the efficiencies of a concerted and coordinated effort. Whilst the APSIM architecture largely enabled this duality, we judged early on that the latter necessity took primacy in order to create a manageable and sustainable platform for systems modelling into the future.

The oft-voiced criticism of APSRU has been our protection of APSIM IP through licensing agreements rather than making it open-source – also a point of strong internal debate. While the benefits of science integrity, software maintainability and return on investment fully justify our past position, the downside of access restrictions to potential users is acknowledged. Today, APSIM and its science are open to any user as community-source software downloadable from www.apsim.info.

Whilst a unified focus was important, the other key contributor to APSRU's success was that individual scientists largely accommodated their own science interests; we essentially 'divided the turf' of issues between a set of strong-willed scientists! Fortunately, APSRU started at an opportune time (or maybe even created the opportunity) for serious investigation into climate risk analysis in dryland farming in Australia. Thus, scientists took the lead on different imperatives in this multi-faceted issue – crop physiology, soil resource monitoring, seasonal climate forecasting, participatory on-farm research, model and DSS development, theory guiding practice – and the sum of their efforts equated to an impressive catalogue of science and on-ground impacts.

APSRU started locally, by genuinely engaging farmers in our research inquiries. A participatory approach has become a characteristic of our research, but distinguished by seeing models as essential to providing rigour and by the belief that such interventions are legitimate research activities, whereby learnings of both farmers and scientists are reported in the science literature. A strong local track record facilitated APSRU's approach and influence to be replicated nationally and internationally.

A challenge to the current generation of scientists in APSRU, and elsewhere, is to continue to innovate our systems research in order to meet the significant challenges of today and tomorrow.

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FARMING SYSTEMS MODELING USING THE OBJECT MODELING SYSTEM (OMS): OVERVIEW, APPLICATIONS, AND FUTURE PLANS

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INTRODUCTION

The United States Department of Agriculture (USDA) delivers technical assistance to operators of approximately two million farms and ranches through a network of about 2,800 county level field service center offices. USDA field consultants must understand the producer’s farming system, and the technical assistance they provide usually involves proposed enhancements to the system. The consultant and producer identify the concerns or opportunities to be addressed, inventory the existing system, and formulate solution alternatives and modifications to the current system. Two analytical approaches can be employed. The consultant and producer may add practices to the current system and then model (estimate) the effects of the enhancements on the identified concerns or opportunities, continuing to plug-and-play until suitable alternatives emerge. Or, in somewhat reverse order they can model the desired state and select from a suite of management options that satisfy the criteria for the expected outcome.

USDA field consultants currently use an array of analytical tools when providing technical assistance, including Web Soil Survey, Revised Universal Soil Loss Equation, Wind Erosion Equation, Nutrition Balance Analyzer, Soil Quality Index, Pesticide Screening Tool, Phosphorus Index, Energy Estimators, Cost and Returns Estimator, among several others. They increasingly will use more comprehensive tools, such as the Agricultural Policy Extender (APEX) and the Agricultural Nonpoint Source (AnnAGNPS) models, or at least the technology contained within them, for on-farm system analysis. Unfortunately, each tool comes with its own data provisioning requirements, unique user interface, and processing requirements. Field consultants hit a wall of complexity and resource constraints, and the tools are not used to their full potential.

To remedy the problem, the Natural Resource Conservation Service (NRCS) has initiated a Conservation Delivery Streamlining Initiative (CDSI) to integrate technology components with the workflows of the field consultant (USDA-NRCS, 2009). CDSI provides the framework and common user interface for the field consultant. The Agricultural Research Service (ARS) led the development of the Object Modeling System (OMS) to integrate the science components across models and tools into model bases (USDA-ARS et al, 2009), one of which will integrate with the CDSI framework. The purpose of the model base is to deliver science deployed as services available to the CDSI workflow.

OBJECT MODELING SYSTEM (OMS)

Using OMS 2.2 USDA and Colorado State University scientists are building a new USDA Conservation Effects Assessment Project (CEAP) watershed level model, and integrating the Precipitation and Runoff Modeling System (PRMS) in annual water supply forecasting by NRCS for 600 locations. OMS is being expanded to include data provisioning, production run-time, and knowledge base platforms, infrastructural enhancements to satisfy anticipated greater demand for model services by USDA programs, including CDSI. The OMS team has developed a new standard to remove framework invasiveness from component code, employed the use of annotations, and added multi-language support. These enhancements make it easier to integrate legacy models and components into model bases supporting CDSI and other initiatives.

FARMING SYSTEM MODEL BASE

The new field level farming system model base supporting CDSI will include climate, hydrology, crop/plant growth, nutrient fate/transport, pesticide fate/transport, erosion, soil quality, economic analysis, and other biophysical components. The sources for these components are the models listed in the introduction above, as well as new science as it is certified for technology transfer and becomes available. The model base will contain several model instances, primarily instances for different physiographic regions. In certain cases, it will make sense to deploy a model instance limited to a particular concern, for example, erosion estimation deployed as a model service supporting heavy user load during an agency program sign-up period.

RESULTS AND DISCUSSION

The farming system model base is proceeding through a requirements phase. Core concepts for CDSI have been documented in an ontology using Protégé 4.0 (oms.javaforge.com). The primary purpose of ontologies is to maintain core domain knowledge in a transparent and structured state, rather than buried in code and partially represented in data models. CDSI ontology concepts relating to the farming or ranching operation include area of interest, problem area, management concern, treatment unit, management system, management practice, structural practice, management period, crop/plant cover, management operation, response unit, and management effect. Inputs to a model instance supporting a CDSI workflow usually will include management practice, structural practice, management period, and crop/plant cover data. Output of a model run produces one or more management effects. Conversely, desired management effects may be inputs, with outputs containing various combinations of management practices and cropping options. As the effort moves forward, other ontologies will be leveraged as feasible, including those from CUAHSI (http://his.cuahsi.org) and SEAMLESS (Athanasiadis et al, 2009).

The farming system model base will be deployed to the OMS production run-time platform, which leverages cloud computing technology. The platform has been successfully tested and prototyped on the Amazon Elastic Computing Cloud (EC2) with multi-threaded model runs enabled by Terracotta network attached memory (NAM) technology.

Data provisioning and model calibration currently are the primary constraints to rapid progress towards an operational model base for CDSI. The model base must serve offices across the U.S., including Alaska, the Caribbean, and Pacific Basin. Several tools are being added to the OMS framework to facilitate model calibration, sensitivity, and uncertainty analysis. Data provisioning mostly involves re-orienting existing resources and data assets to create the data marts and access services to support the model base.

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GLOBAL WARMING POTENTIAL OF ORGANIC AND CONVENTIONAL GRAIN CROPPING SYSTEMS IN THE MID-ATLANTIC REGION OF THE U.S.

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INTRODUCTION

The global warming potential (GWP) of a cropping system is the balance between the net exchange of the greenhouse gases CO_2, N_2O and CH_4 that result from on-farm practices and the production and transport of inputs. While no-till cropping systems are often considered an effective means of decreasing GWP by sequestering C in soil, there is increasing evidence that this may not always be the case (e.g. Baker et al., 2007). Systems in which organic materials are buried using tillage, for example, can increase soil C at depth compared to no-till systems (e.g. Angers et al., 1997), and N_2O fluxes for no-till systems can be greater than for tilled systems (Robertson and Grace, 2004). We report here on GWP calculations for no-till (NT), chisel till (CT) and organic (Org3) cropping systems at the long-term USDA-ARS Beltsville Farming Systems Project (FSP) in Maryland, USA.

MATERIALS AND METHODS

The three cropping systems are three-year corn (*Zea mays* L.)-rye (*Secale cereale* L.) cover/soybean [*Glycine max* (L.) Merr.]-winter wheat (*Triticum aestivum* L.)/legume rotations. The legume in NT and CT is double-cropped soybean; in Org3 it is hairy vetch (*Vicia villosa* Roth). We estimated annual GWP by summing the net exchange of CO_2 equivalents from 1) changes in soil C, 2) N_2O fluxes, and 3) energy used on farm and in the production and transport of material inputs. We collected soil to 1 m depth in 2006, 11 years after plot establishment, and analyzed samples for total C using dry combustion. N_2O fluxes were measured for corn from 2005 to 2008 and for wheat and soybean in 2008. Energy use CO_{2eqvts} were determined using published values for individual operations and materials and FSP management records. We also calculated greenhouse gas intensity (GHGI, i.e., GWP per unit of grain yield) using crop yield data from the site.

RESULTS AND DISCUSSION

Soil C (in Mg C ha^{-1}) was greater in Org3 (60.8) than in CT (51.7) and NT (54.9) ($P<0.05$). Since the site had been in NT during the 11 years prior to plot establishment and had presumably approached equilibrium, we assumed that all systems had an initial soil C content of 54.9 Mg C ha^{-1}. The average rate of change in soil C, based on that assumption, was 533 kg C ha^{-1} y^{-1} in Org3 and -295 kg C ha^{-1} y^{-1} in CT (see Table 1 for CO_{2eqvts}).

We found differences in N_2O flux among systems in two cases: In 2006 N_2O flux (kg N_2O-N ha^{-1} y^{-1}) in corn was greater in NT (4.2) and CT (3.5) than in Org3 (1.7) ($P<0.05$) and in 2008 N_2O flux in wheat was greater in Org3 (2.4) than in NT (0.6) and CT (0.8) ($P<0.05$). This latter difference resulted in significantly greater N_2O flux CO_{2eqvts} in Org3 than in NT both for wheat and for the full rotation (Table 1).

Energy use CO_{2eqvt} in Org3 was substantially lower than in CT and NT (Table 1), largely due to the high energy cost of producing and transporting N fertilizers, which are not used in Org3. We assumed that poultry litter in Org3 is produced on-farm. If poultry litter is transported to the farm, however, it can only be transported 42 km for wheat production and 114 to 127 km for corn production before the CO_{2eqvt} for energy use in Org3 is equivalent to that in NT and CT.

GWP was negative in Org3, positive in CT and NT, and greater in CT than NT for all crops and for the full rotation (Table 1). These differences were driven primarily by differences in soil C among systems and secondarily by lower energy use in Org3 than in CT and NT. Despite relatively low crop yields in Org3, GHGI for all crops and the full rotation was also negative and significantly lower than for NT and CT. Greater N_2O flux in Org3 than in CT and NT wheat did not account for sufficient GWP to alter GWP or GHGI rankings.

Results indicate that Org3 was a net sink, while CT and NT were net sources, of CO_2 equivalents. Practices common in organic systems—including soil incorporation of legume cover crops and animal manures—can result in mitigation of GWP and GHGI relative to CT and NT systems, primarily due to increased soil C.

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Table 1. Relative GWP and GHGI for three cropping systems based on change in soil C, N_2O flux, energy use, and crop yield. Negative values indicate a global warming mitigation potential†.

Crop	System	ΔSoil C	N_2O	Energy‡	GWP§	Crop Yield¶	GHGI#
		----------- kg CO_{2eqvt} ha^{-1} y^{-1}			-----------	Mg ha^{-1} y^{-1}	kg CO_{2eqvt} Mg $grain^{-1}$
Corn	CT	1080 a	493	1250	2822 a	9.94 a	288 a
	NT	0 b	443	1162	1605 b	10.4 a	154 a
	Org3	-1953 c	627	458	-868 c	7.80 b	-110 b
rye/Soybean	CT	1080 a	354	576	2010 a	3.45	586 a
	NT	0 b	187	506	693 b	3.60	193 b
	Org3	-1953 c	452	403	-1098 c	2.95	-355 c
Wheat/legume	CT	1080 a	372 b	759	2211 a	5.63 a/2.39	274 a
	NT	0 b	279 b	752	1031 b	5.51 a/2.26	132 b
	Org3	-1953 c	1133 a	172	-648 c	4.63 b	-144 c
Full rotation	CT	1080 a	406 ab	862	2348 a	7.14 a	330 a
	NT	0 b	303 b	807	1110 b	7.25 a	153 a
	Org3	-1953 c	540 a	344	-1069 c	5.12 b	-207 b

† Means for a given crop within a column followed by the same letter or no letter do not differ significantly at $p < 0.05$.
‡ Energy used for on-farm operations, and production and transport of input materials.
§ Sum of CO_2 equivalents from 1) change in soil C, 2) N_2O flux, and 3) energy use.
¶ Mean yield for years with average precipitation between 2002 and 2008. Wheat/legume yields for CT and NT are for wheat and double-cropped soybean.
#GWP divided by crop yield.

CO-DESIGNING FARMING SYSTEMS AND DECISION SUPPORT TOOLS: A GENERIC FRAMEWORK

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KEY WORDS : Participation, Co-design, Reflexivity, Conceptual Framework

INTRODUCTION

Farming systems design is mainly addressed through approaches combining modelling, field experiments and a sometimes end users participation (Pretty, 1995, Novak, 2008). End users participation allows to take into account their concerns (Stoorvogel *et al.*, 2004), their knowledge (Cardoso *et al.*, 2001), or to validate the feasibility of new systems under on-farm conditions (Vayssières *et al.*, 2007). Co-design is used here to give account of design processes which involves active participation of end users.

For us, active participation of end users is required to take on board the complexity of innovation processes. Much can be gained when the design process is shared among co-designers, e.g. researchers and various users, in order to address the uncertainty about the value and the vision of what should be designed as well as the feasibility of the system under design. The conditions and constraints to achieve active participation during the co-design process also need to be specified. This paper presents the results of a study carried out by a group of social scientists and agronomists to develop an conceptual framework which points out stages and key points to be taken on board to monitoring a design process enabling active participation of the co-designers

MATERIALS AND METHODS

The co-design process was analyzed in seven on-going research projects in which design and innovation processes were intertwined. The analysis was carried on from the point of view of the researchers in charge of monitoring the process. In each case, end users were mostly involved in the specifications and in the testing phase of a prototype of the designed system. The projects differed with respect to the system being designed (softwares to support decisions , a new animal breed, a new cropping system) the nature of the involved partners (farmers, advisers, breeders, etc.), and the geographical location (5 were in France, 2 in developing countries).

Cross-analysis of the 7 projects served to identify generic features which project managers have to address to allow users' active participation. The coordination team facilitated this cross-analysis by enabling the researchers involved in this study to (i) produce comparable data on their respective projects which could be used to abstract these generic features, (ii) share and carry out collectively the cross-analysis. Researchers produced narratives describing the partnership, the steps followed during the design process, and the problems faced along it. They were also interviewed by the coordination team to reflect critically on their involvement and role in the process, and to describe in details selected relevant co-design events, e.g. events held between researchers and end users. Iterative data analysis was conducted between individual project researchers and the coordination team to identify generic features of the co-design process.

RESULTS AND DISCUSSION

Two main results were obtained. The first one is a generic conceptual framework for monitoring a co-design process as summarized below (without examples from the 7 projects)

A conceptual framework to support the monitoring of a co-design process

Step 1: acquiring cognitive and material resources to build a 1st version of a prototype

Purpose : to learn about acceptable and possible changes in work situations and to design a 1st rough prototype
Agency : each participant has to become aware of the various knowledge sources and to identify the scope of the process.
Means : diagnosis on the local situation : how do users invent some solutions to achieve change in work situations ? Which knowledge (from all co-designers) has to be embedded in the prototype ? Which knowledge (scientific, technical, local) has to be made available for all the co-designers ?

Step 2 : organizing successive loops around the prototype

Purpose : enabling joint development of the prototype and of the acceptable changes within the work situations
Agency : participants are involved in testing the prototype and building scenarios in which to test it. They discuss the consequences and the changes required on the prototype and in the local work situations
Means : establishing a framework in which each participant can be confident in the way others are engaged in the process. Highlighting controversies and common agreement on required change whether at prototype level or at local work situations one.

Step 3 : Ending a co-design cycle

Purpose : Stabilizing an acceptable version of the designed object
Agency : participants agree on the relevance of the prototype regarding the changes which have been achieved in the work situations
Means : assessing what will be gained by further development of the prototype. Assessing if little changes in the work situations will imply deep redesign of the prototype.

The second result addresses the ability of the researchers involved in co-design process to become reflexive practitioners (Schön 1983). This was achieved by the coordination work based on the building of narratives and their collective analysis. Reflexivity here aims at developing awareness about the context of the co-design process and at providing conceptual resources to co-design managers in order to orient their action.The framework is by no means a fixed package which can be applied mechanically to each and every co-design situation. For those who want to start co-design processes, it can be used as a check list of the main points to which attention should be paid to allow active participation of end-users. For those already involved in such project, it can be used to contribute to reflexivity and to assess how active participation has been achieved and how to enhance it if needed. In both cases, using the framework may offer the opportunity to improve it further and to feed it with more examples.

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ROUTES OF CHANGE ANALYSIS TO SHOW THE DIVERSITY OF FARMERS' LEARNING PROCESSES: THE REDUCTION OF INPUT USE IN FIELD CROP FARMS

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INTRODUCTION

To enable agriculture to maintain a high productivity level and decrease its negative environmental impact on a long-term basis, one approach is to promote learning processes among farmers. Some agronomists have already pointed out that learning processes are part of farming system leeway (Navarrete et al., 2006) or flexibility (Dedieu et al., 2008). While learning processes are seen as key factors in decision support (McCown, 2002), they have not yet been characterized. Hence, our research aims at analyzing the diversity of farmers' learning processes when farmers change their practices (decreasing the use of chemical inputs: fertilizers, pesticides and fuel) during their professional career.

MATERIALS AND METHODS

Our hypothesis is that there is a diversity of routes of change to reduce the use of inputs on the one hand and a diversity of learning processes on the other. Routes of change are meant to give an account of the temporality and of the complex combination of changes in practices occurring during the farmer's career. For each change, we have highlighted the learning processes which occurred. Learning processes encompass training, social learning and learning in action. We acknowledge them by identifying the nature of what was learnt, the resources mobilized and the different steps followed to learn, e.g. the state of alert (problem, idea, go click), the experimentation, the validation. Finally, to quantify the input reduction, based on recordings made by farmers, we calculate a series of indicators at different periods and at different scales (crops and farm).

We carried out farm surveys (20 in Champagne Berrichonne, France, territory of field crops) among farmers who now perform low-input agriculture. Interviews dealt with the technical, agronomic, economic and informative dimensions of farm work for a period covering the professional career of the farmer (6 hours of survey/farmer in two sessions).

RESULTS AND DISCUSSION

In this paper, we have chosen to present two routes of change for two different farmers: both of the two farms are located on similar brown soil types (40mm< soil water reserve < 100mm) and both of the two farms use 60 $L.ha^{-1}$ of fuel for their crops in 2008, but their practices are different. We calculated indicators for nitrogen and pesticide utilization, average wheat yield and, to illustrate the learning processes, we show only the experimentation step to simplify.

Table 1 shows that if the reduction of nitrogen fertilization on wheat appears in both cases (meanwhile the average yield has not changed), it has not occurred at the same period and it does not have the same final results. For soil tillage or pesticide use we noticed differences in the nature, the dynamics and the intensity of practices over the period. Few changes in practice are stimulated by a change in environmental regulations (for nitrate and water). Our data however shows that the one farmer (farmer 1 in Table1) has used this change as an opportunity for him as well as for his development group to reduce nitrogen use to below the norm while maintaining the same level of income. The learning processes are also different. Indeed, the experimentation step can take different forms according to the way of appealing to the individual (shown in Table

1) as well as to the way of controlling the results of the experimentation. Experimentation is mainly carried out within a group or with a neighbour, and one farmer can have diverse ways of experimentation. The development group of the first farmer started reducing the input doses three or four years before the second one. If both farmers evoked their recent concern for the environment, they did not translate it into practice in the same way.

These first results encourage us to consider that our methodology is relevant to analyzing and identifying the diversity of learning processes as well as that of route of change within a given territory. The treatment of all data will make it possible for us to show specific connections between certain routes of change and certain learning processes in farmers' careers. Such an analysis, based on grounded surveys, will provide new insights to guide changes of practice. It can also complement approaches that aim at designing or improving farming systems.

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Table 1: Two routes of change for two different farmers.

Headings	Route of change for Farmer 1			
Time periods	1985–1990	1990–1995	1995–2000	2000–2008
Highlights of the farm	Adjustment of the practices to the neighbours	Reduction of the operating costs (inputs)	Environmental awareness and economic viability	Signing up an environmental contract
UAA per AWU (AWU)	80 (1)	80 (1)	105 (1)	115 (1)
Rotation	WR or S/ WW / WB			WR or S / WW / SB or WB or WW
% of tilled area	65	65	25	50
Seeding	Decrease in density / More resistant varieties (in 2008, wheat density is 200-250 grain.m^{-2})			
Fertilization Average N on wheat (unit.ha^{-1})	160 →	150 →		140
Herbicides, Fungicides, Insecticides.		Dose reduction		
Growth regulator	Never used			
TFI: % of the 2008 regional reference	Farm-scale TFI for herbicides in 2008: 73 % Farm-scale TFI for other pesticides in2008 : 25 %			
Wheat Yield (average 5 yrs)	5,5 Mg.ha^{-1} Regional average is 6,2 Mg.ha^{-1}			

Headings	Route of change for Farmer 2			
Time periods	1988–1990	1990–1995	1995–2000	2000–2008
Highlights of the farm	Introduction Of Irrigation	Reduction of the operating costs (inputs)	Sharing of equipment and manpower	No-till seeding
UAA per AWU (AWU)	217 (1)		200 (5)	
Rotation	C / SB / WW / P / Se B		C / SB / WW	R / WW / C / SB
% of tilled area	70		0	0
Seeding	Decrease in density (in 2008, wheat density is 250 grain.m^{-2})			
Fertilization Average N on wheat (unit.ha^{-1})	200	200 →	170	170
Herbicides, Fungicides, Insecticides.			Dose reduction	
Growth regulator	Used	Stopped using		
TFI: % of the 2008 regional reference	Farm-scale TFI for herbicide in 2008: 92 % Farm-scale TFI for other pesticides in 2008: 84%			
Wheat Yield (average 5 yrs)	7 Mg.ha^{-1} (irrigation).			

Caption			
UAA, AWU	Usable Agricultural Area (Hectares), Annual Work Unit		
Crops in the rotation	C: corn; P: peas; W R: Winter Rapeseed; S: Sunflower; SB: Spring Barley; Se B: Seed-bearing; WW: Winter Wheat; WB: Winter barley; For example, "R / W" stands for a rotation of Rapeseed the first year and wheat the second year.		
N	Nitrogen (unit. Ha^{-1})		
TFI	Treatment Frequency Index: this index posts the number of standard doses of pesticides applied on one hectare for one agricultural year. The standard dose is the efficient dose applied on one culture for one pest or one weed. TFI can be calculated at the scale of a crop, as well as the scale of a farm. Here we distinguish the TFI for herbicide and TFI for the other pesticides.		
	Experimentation alone		Experimentation with a peer
	Experimentation with a development group		No experimentation
	Change due to the regulations impacting practices:		

USE OF MIXED MODELS TO ESTIMATE BIOLOGICAL AND ECONOMICAL PERFORMANCE OF URUGUAYAN DAIRY FARMS UNDER DIFFERENT ECONOMICAL SCENARIOS.

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INTRODUCTION

Milk production in Uruguay has been growing in the last 20 year at an annual rate of around 7% (DIEA, 2007). This trend has been based in larger dairy farms with higher stocking rate and higher productivity per cow (DIEA, 2007). Although directly grazed pasture still constitute the main source of feed to dairy cows a significantly increase on the use of supplements like cereal grains, byproducts and conserved forage like silage and hay has been observed. Over 65 % of the produced milk is sold in the international market as milk powder, cheese and butter. There are no direct or indirect governmental subsidies to regulate milk price at farm level, thus prices show large variations throughout years. In this context it’s become strategic the availability of predictive functions to forecast biological and economical performance of dairy farms under different economical scenarios.

MATERIAL AND METHODS

In the context of a large project being carried out by CONAPROLE the main Dairy Industry of Uruguay, over 70 individual dairy farms were monitored during 5 consecutive years and a complete set of physical, biological and economical events were recorded.

Mixed models with repeated measurements in time were estimated for the variables net income, total production cost, gross income after feeding and individual milk production For all variables the repeatedly measured subject was the farm and an autoregressive first order covariance structure was used. The estimation method was ML and de degree of freedom estimated by the KR method (Kenward and Roger, 1997). For each one of the four independent variables a complete model was run as a first step. Afterwards, non significant variables were removed and the goodness of fit of the reduced model *vs* the complete model was assessed based on the maximum likelihood ratio test (LRT, Casella and Berger, 1990) and AIC, AICC and BIC parameters (Verbeke, 1997). Finally, for the group of dairy farms out of the 20 dairy farms used to derive the models (n=53), the gross income after feeding was predicted based on the complete and the selected reduced models and compared by linear regression against the observed values. Models were fit using the Procedure MIXED from Statistical Analysis System (SAS Inc V9.1).

RESULTS AND DISCUSSION

The trend followed by key variables throughout years is presented in Table 1. As was stated in the introduction dairy farms are yearly exposed to economical scenarios that differ severely. The method described in the previous section is exemplified by the variable gross income after feeding. The complete model included: fiscal year, farm size (has), stocking rate (SR, cow ha), production per cow (L, liter per cow year), milk price (cents U$S/L), pasture, conserved forage and concentrate intake (kg DM), pasture, conserved forage and concentrate cost (U$S/Ton DM), the interaction L*SR, and the second order terms SR*SR and L*L. Since, the terms farm size, L*SR and SR*SR were not significant; we removed them to produce a reduced model (Model Reduced I, Table 2). The LRT test for comparing the complete vs. reduced model was not significant ($p>0.55$; Table 2) and the AIC, AICC and BIC information criteria decreased which is desirable (Verbeke, 1997). After this evaluation, we concluded that the removed variables did not affect the goodness of fit of the Model Reduced I when compared with the complete model. As a second step we evaluate to remove the second order term L*L (Model: Reduced II) which was significant in the complete model. The LRT test was significant ($p<0.02$; Table 2) and the AIC, AICC and BIC remained similar to the complete model values. We conclude that the second order term L*L can not be removed without significant reduction in the goodness of fit. Finally, regression analysis was conducted between predicted and observed values for gross income after feeding with an independent set of dairy farms (n=53). Outputs exhibited an R-Square of 0.90 and 0.91 with a coefficient of variation of 9.9 and 9.7 % for the complete and reduced I models, respectively. We concluded that mixed models with repeated measurement in time constitute a suitable tool to develop predictive functions for dairy farms exposed to different economical scenarios. Best models can be selected based on LRT test and AIC, AICC and BIC parameters.

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Table 1. Evolution throughout years of mean (mean ± SD) values of different variables.

Variable	2002/03	2003/04	2004/05	2005/06	2006/07
Milk price (cents U$S/L)	9.9±0.26	13.6±0.39	16.2±0.41	18.0±0.54	18.5±0.68
Net Income (U$S/ha)	43.9±34.1	135.5±65.0	198.0±79.7	231.2±91.2	183.1±82.0
Farm size (ha)	216±148	220±165	219±163	228±178	229±176
Stocking rate (cow/ha)	0.89±0.22	0.92±0.29	0.95±0.29	0.95±0.26	0.94±0.25
Milk Production (L/VM)	4237±770	4738±753	5308±785	5357±899	5225±775
NIAF (U$S/VM)	244 ± 54.8	410 ± 49.8	575 ± 84.8	632 ± 120.0	588 ± 120.1

cents U$S= cents of USA dollars; L= liter; ha=hectare; VM= dry + lactating cows; NIAF= gross margin after feeding; 2002/03= Fiscal year from July 1st 2002 till June 30th 2003 (the same abbreviations apply for the following fiscal years).

Table 2. Outcome of the model selection procedure applied to the variable gross margin after feeding

	Complete model	Reduced I	Reduced II
-2 Log Likelihood	958.2	960.3	969.6
Variables removed		3	4
LRT-Chi square		2.1	11.4
Significance		0.55	0.02
AIC	998.2	994.3	1001.6
AICC	1008.8	1001.7	1008.2
BIC	1018.1	1011.2	1017.5
r	0.983	0.983	0.980

Akaike (AIC), and Bayesian (BIC) information criteria; r= correlation between the observed and predicted values.

CO_2 EMISSIONS IN DIFFERENT OILSEED RAPE CROPPING SYSTEMS

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INTRODUCTION

Carbon dioxide emissions and energy balances are important criteria to assess cropping systems especially if energy production and carbon saving are in the focus. The motivation for this project was to quantify both parameters in various cropping situations of oilseed rape in order to evaluate the range in practical farming as well as in field experiments. Oil seed rape was choosen as an experimental crop, because of its great importance for the production of bio-diesel in Europe. Our results, however, are also relevant for other renewable crops as long as mineral nitrogen fertilization is a major factor for determination of seed yield, however, the absolute level for energy balances and carbon savings will vary between crops and cropping systems.

MATERIALS AND METHODS

For the calculations of the CO_2 and energy balances we have used the model REPRO, which has been described in details by Deike et al. (2008a and 2008b). The calculations were based on results from various long-term field trials as well as from practical farms in different regions of Germany, which represent all major oilseed rape growing areas.

For the energy calculations the input side is dominated by the energy requirement for soil tillage and nitrogen fertilization, whereas the calculation for the energy output is mainly affected by the seed yield. Differences in the oil content only contribute very little to the differences in energy balances in our results since variation between the field trials and also between the farms were negligible. The model REPRO includes changes in the soil organic carbon content (SOC) induced by the different cropping systems in the calculations. The results of the CO_2-calculations are dominated by the amount of fertilizer nitrogen applied, however, the major contribution here arises from the nitrous oxide emission caused by the nitrogen application. In the calculations we have used the IPCC approach to account for emissions of N_2O.

RESULTS AND DISCUSSION

The most important result is the fact that in all rotations winter oilseed rape had a positive energy balance. This occurred for the results from field trials as well as for practical farming situations, however, the differences where quite considerable. Since the level of applied mineral fertilizations had the greatest effect on energy balances, we have included a figure on the effect of nitrogen on energy balances. In the figure the energy balances range from 23 to 51 GJ/ha. Differences due to tillage intensity, however, were much smaller, since in the experimental field trials only standard tillage practices were applied (mouldboard ploughing). In practical farming situations (data not shown) the range of the energy balances was even greater, which underlines the importance of optimization of cropping systems for energy production. The reason for the greater range in practical faming was mainly due to a different tillage intensities, which include either conservation tillage or mouldbourd ploughing. Zero-tillage was not used on the practical farms. Additionally the differences in seed yield in the practical farms exceeded the variation measured in the field trials.

The second major criteria for an assessment of cropping systems are the carbon dioxide emissions per energy unit (GJ). Again, in the field trials, the nitrogen fertilization was identified as a major factor, however, in this case the calculated nitrous oxide emission had the greatest influence. All results on CO_2 balances show a CO_2 saving if oilseed rape is grown for biodiesel, however, the differences between the various cropping systems were again quite considerably ranging between 22 to almost 55 kg $CO_{2\,eq}$ /GJ. The comparison with the results from practical farms showed a similar range, since unlike with the results of the energy balances, the differences in tillage practices did only slightly increase the range. On a rotational level, crop rotations including legumes (i.e. peas or faba beans) show very favorable balances (data not shown) however the problem arise how to relate those effects to single products within a rotation. A second problem with legumes on the rotations arises from the calculation of nitrogen fixed via rhizobium bacteria and if this nitrogen has to be included in the calculations of N_2O emissions. In this short paper, we cannot discuss the applicability of the IPCC approach to calculate nitrous oxide emission from nitrogen fertilizers of via nitrogen fixation from legumes on a field level, however, what again becomes clear from our calculations is the great influence of N_2O emissions on the level of calculated carbon dioxide savings. If a higher proportion of N_2O emissions are attributed to mineral nitrogen fertilization application, the whole concept of carbon saving via biodiesel – and other renewable fuels - is debatable.

In general or results underline the potential for optimization of energy balances and CO_2 savings on the field and the farm level. Calculations of the optimum level of nitrogen fertilization have shown, that nitrogen fertilization in oilseed rape should be reduced of CO_2 emissions are taken as a major criteria. If energy production is the major target, much higher mineral nitrogen applications are necessary.

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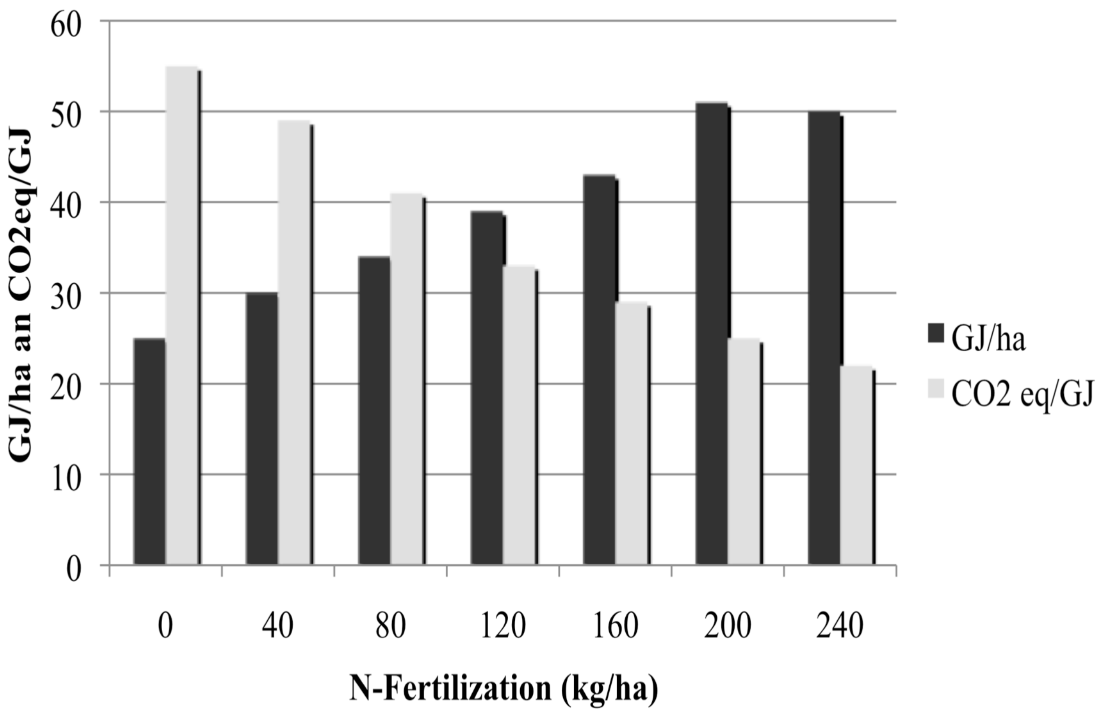

Fig.: Effect of nitrogen fertilization (kg/ha) in winter oilseed rape on energy balance (GJ/ha) and carbondioxid emissions (CO2eq/GJ).

SILASOL: A MODEL-BASED ASSESSMENT OF PEA (*PISUM SATIVUM* L.) CULTIVARS ACCOUNTING FOR CROP MANAGEMENT PRACTICES AND FARMERS' RESOURCES

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INTRODUCTION

Integrating pea into cropping systems has agronomical and environmental advantages which are linked to the capacity of the pea plant to fix atmospheric nitrogen, in turn available to the following crop (Munier-Jolain and Carrouée 2003). It also allows a diversification of the crops in systems containing frequently cereals and oilseed rape, thus a decrease of diseases and weed pressure. Moreover, *Pisum sativum* L. species offers a wide range of winter and spring cultivars that should enhance integration of pea in various types of farming systems. However, spring cultivars, which represent the major part of cultivars in French fields, suffer from high temperatures, water shortage at the end of their life cycle and compacted soil structures when they are sown too early. Winter cultivars escape to thermal and water stress at the end of the crop cycle, but remain sensitive to frost during winter. Seed breeders thus endeavour to create cultivars that have phenotypic characteristics allowing to cope with climatic stresses and to escape to compacted soil structure. Further more, the assessment process for registration of new cultivars in France relies on optimum field experiments, which differ significantly from those encountered in real production situations. Due to shortage of working resources (labour and machinery) for instance, farmers often have to perform cultivation operations at unsuitable climatic periods, leading to the compaction of the soil structure which affects yields (Vocanson 2006). The performances of the cultivars depend on the climatic conditions during the crop cycle, but also on the crop management applied to the cultivar (sowing date for example), itself depending on the global organisation of the farm. In order to help breeders identifying the characteristics allowing the best performances, an ex ante evaluation, based on modelling, can be useful. The paper outlines the simulation model SILASOL developed to support the design of pea cultivars. The originality of the model lies in its capability to take into consideration the interactions between biophysical processes (crop growth, soil compaction) and practical crop management concerns.

MATERIALS AND METHODS

The biophysical part of the SILASOL model is based on two existing dynamic models. The first one, AFISOL (Vocanson 2006), is a climate-responsive pea growth model simulating the plant development, biomass production and storage within the vegetative parts of the plant and the seeds (yield) and the frost resistance mechanism. The second one, SISOL (Roger-Estrade et al. 2000), estimates the dynamic evolution of the soil structure (compaction or fragmentation) as a consequence of mechanical operations, thanks to equations linking equipments features, hydraulic dynamics and properties of soil layers. In addition, simple models simulating the water balance and mineralization are designed for barley, wheat and oilseed rape, which are the other crops potentially interacting with pea production for resource demand in this case study. The re-engineering and integration of these models have been done using an object-oriented simulation package called DIESE that includes a discrete event simulation engine and an ontology-based modelling framework (Martin-Clouaire and Rellier 2009). This tool has specifically been designed to support the modelling of the interactions between a biophysical system (crop and/or livestock systems) and its management by a farmer in relation with climatic conditions. DIESE provides basic constructs to represent management activities, their temporal organization in plans and their requirements for resources such as labour and equipments. The farm management and crop practices included in the model come from interviews carried out with a farmer from the North of France and an analysis of his technical notebooks over the last fifteen years.

RESULTS AND DISCUSSION

Presently, the main result of the project concerns the SILASOL model, essentially the biophysical models and management plans for the different crop sequences on the farmer's fields. The first step in building crop management plans is to make a particularization of the generic concept of operation involved in the crop production process: *ploughing*, *secondary ploughing*, *sowing*, *weed killer spraying* and *harvesting*. Each of these operations has properties such as speed, feasibility conditions, required machinery resources and effect on the biophysical system. For instance *secondary ploughing* requires specific resources - a tractor and a plough - that determine its speed. Its feasibility conditions refer to the soil humidity properties and thresholds above which mud prevents proper use of the equipments. Its effect is to suppress compactness of the soil caused by previous operations. In the second step we specify primitive activities that are composite objects consisting each of an operation (e.g. *ploughing*) applied to a biophysical entity (e.g. a field) by one or several workers. Among its essential properties, a primitive activity possesses two conditions defined by calendar dates or state-based conditions. These conditions allow the execution of the activity when it is relevant according to the farmer's objectives and practices. For instance, the activity *pea-harvest* involving the *harvesting* operation on a pea crop is declared relevant as soon as pea seeds reach their maturity and irrelevant after a given date. Then, the way the farmer grows each crop on each field of his farm during a year is described by a sequence of primitive activities. Finally, human resources (workers) are specified by the constraints pertaining to their time availability and the possibility for them to be engaged simultaneously in several operations or on several fields. Since several crops are grown at the same time on different fields of the farm, the demand for resources may be larger than the supply.

SILASOL simulates (i) the dynamic examination of the activities that are ready for execution, (ii) the allocation of the farm's resources, and finally (iii) the execution of these activities. We simulate the crop sequence over the duration of the rotation in order to assess the pea performance (e.g. yield variability) as well as the management practices with respect to a range of climate scenarios. Like in any experimental approach, this type of virtual exploration requires the construction of a kind of design experiments. The results obtained with the SILASOL model as a framework of virtual experimentation are too preliminary to be reported in this communication. SILASOL will be used by farming systems researchers in partnership with seed breeders to design pea cultivars that have suitable features (e.g. flowering precocity, speed of growth, seed weight) regarding real production situations.

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FARMING SYSTEMS' DIAGNOSIS AND EXPLORATION OF ALTERNATIVES FOR FRUIT-TREE PRODUCTION GROWERS OF SOUTH PATAGONIA, ARGENTINA

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INTRODUCTION

Because fruit-tree crops are perennial, the choice of production system, made at planting in the context of resource constraints and unknown future prices, has overriding implications for yield and fruit quality, and profit.

Sweet cherries have been exported for some time from South Patagonian to Europe, but prices received by growers have been decreasing in the last few years. With the aim of identifying and developing alternative fruit production systems and agricultural policy options to allow improving income generation and sustainable use of natural resources, an EU-funded project, EULACIAS (EUropean Latin American Co-Innovation for Agricultural Systems), started in 2007. The project was based on a system approach and dynamic monitoring developed under a setting of social learning, incorporating the concept of co-innovation as a core for farming systems action-research.

PROJECT APPROACH AND METHODOLOGY

The project focuses on pilot farms, which were selected based on a typology study. This typology was performed through multivariate analysis, using eight classificatory variables: Cherry growing area (ha), Plantation density (plants/ha), Irrigation system (percentage of the area with drip irrigation), Frost control system (percentage of the area with sprinkling irrigation system), Permanent labor (number of employees), Temporary labor (Days-work/year), Advising (0= no; 1 = occasional; 2 = permanent) and Organization for packing (0 = no; 1 = associated; 2 = own packing facility).

Basic farm-level data were systematized in a database (INFOCHACRA), from which relevant socio-economic farm-level indicators (used to evaluate sustainability) were calculated. INFOCHACRA has been specifically developed in the framework of EULACIAS. It was based on bookkeeping registers with which most of the growers were familiar, improving the chances of adoption not only by technicians, but also as a farmer-level tool. The database allowed loading and systematizing farm-level information of cherry (oriented) farms.

Following multi-attribute diagnosis, the re-design phase explored fully new farming systems. Since in fruit production systems crops are perennial and the evaluation of impact of strategic decisions requires long periods, models were used to evaluate them. A dynamic farm-scale optimization model called OPTIFROP (Cittadini, 2007; Cittadini et al., 2008) was developed to generate alternative farm development plans, by allocating, in the course of the time horizon of the run, production activities to different land units, while optimizing different objective functions, subject to several constraints (Fig. 1). Variation in interests and aims of different stakeholders were considered (through a participatory workshop that identified objectives, main problems and acceptable solutions) and a scenario approach was used to analyze the consequences of eventual changes in external conditions. The model included two objective functions at farm level: (1) maximization of the present value of cumulative financial result (FINANCIAL RESULT), which is the main objective for growers, and (2) maximization of cumulative farm labor (FARM LABOR), which is an objective often mentioned by policy makers. The maximum acceptable inter-months deviation for labor demand (i.e. LABOR DEVIATION) during the period of high labor demands (November to April) was incorporated as an upper-bound restriction. Input and output coefficients for the land use options considered in OPTIFROP were quantified using the Technical Coefficient Generator FRUPAT (Cittadini et al., 2006).

PRELIMINARY RESULTS AND DISCUSSION

Based on the farm typology study, specific farm-groups were characterized. Besides, the farm-level indicators allowed identification of critical aspects affecting farm sustainability of each farm-group. Critical aspects such as environmental (e.g. wind erosion processes due to un-proper protection), productive (e.g. low yield due to low LAI), commercial (e.g. low prices due to low quality and/or poor organization) and social (e.g. highly seasonal labor demand due to monoculture) dimensions are included.

OPTIFROP allowed identification of objectives that were conflicting (e.g. FINANCIAL RESULT and LABOR DEVIATION) and those that were so to a very limited extent (e.g. FINANCIAL RESULT and FARM LABOR). Results of the model indicated that, based on the objectives of the stakeholders, sustainable farm-development plans are plausible. They should include more production activities in order to reduce the high seasonality and risks involved in sweet cherry monoculture.

ACKNOWLEDGEMENTS

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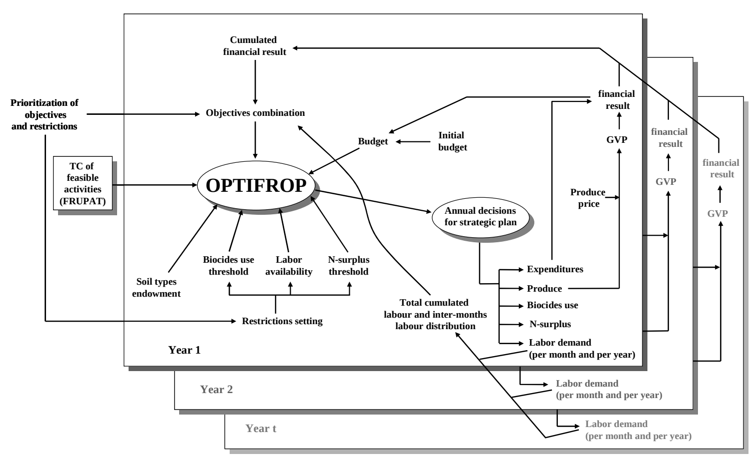

Fig. 1. Structure of OPTIFROP, showing the main components, its inputs and outputs. The time dimension is represented by the different connected planes. After: Cittadini (2007).

NEW CROPPING SYSTEMS UNDER A FOSSIL ENERGY CONSTRAINT

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INTRODUCTION

Due to the ever-evolving economic and agronomic context, new cropping and farming systems are being proposed (Debaeke *et al.*, 1996; Vereijken, 1997; Meinke *et al.*, 2001; Reau & Doré, 2008). However, according to the decrease of the available fossil energy in the world, new constraints such as less fossil fuel use are in the pipeline and need investigation. The objective of our project involved three major steps: (i) designing new cropping systems from scientific and expert knowledge according to a fossil energy constraint in addition to other environmental objectives, (ii) assessing them using models, and (iii) implementing the most promising one in a long-term field trial. The far-reaching objective is to improve cropping systems for arable crops in northern Europe.

MATERIALS AND METHODS

Two type of cropping systems were designed:
(1) to reach environmental objectives (biodiversity preservation, prevention of groundwater pollution by nitrate and pesticides, conservation of the quality of soil, and reduction of energy uses) as well as either maximal production,
(2) to reach same environmental objectives and in addition to have a specific energy constraint, i.e. to reduce by half direct and indirect fossil fuel consumption compared to the productive cropping system.
These cropping systems have been based on the use of decision rules.

For each of these two cropping systems, different scenarios were defined and assessed using the INDIGO tool (Bockstaller *et al.*, 2008). The most relevant scenarios are currently being tested in a field experiment in Grignon (78, France), started in 2008. The agronomical, environmental, and economical performances of the cropping systems will be recorded over a 10-year period. The monitoring of soil physical, chemical, and biological characteristics is being carried out.

RESULTS AND DISCUSSION

Design of new cropping systems

A. The Productive with High Environmental Performances cropping system (PHEP). In order to reach strict environmental goals, the current PHEP system has been designed following three principles:(1) to include a long rotation to increase biodiversity (a 5 year-one instead of the 3 year rotation currently practised in the Ile-de-France region), (2) to include legumes, at least once in the rotation, to reduce the amount of N used, (3) to use highly resistant varieties or species mixtures associated with optimal sowing dates and densities to decrease pesticides use as well as reduce sensitivity to insects and diseases. Finally, the crop rotation of the selected PHEP system is faba bean, winter wheat, winter oilseed rape, winter wheat, mustard as catch crop, and spring barley.

B. The cropping system with a fossil energy constraint (Less-Energy: L-EN). The L-EN cropping system follows three principles: (1) to include as many legumes as possible (faba bean as main crop, *Trifolium* as catch crop, and a legume-cereal mixture) and to use low N requirement species (e.g., oat and flax) in order to decrease indirect fuel consumption due to mineral N fertilization, (2) to reduce tillage to decrease fuel consumption (i.e., no mouldboard ploughing allowed), (3) to decrease the target yield by 25% in order to reduce mineral fertilization (N, P, K). The crop rotation of the L-EN system is faba bean, winter wheat, winter flax, winter wheat-*Trifolium* mixture, *Trifolium* as catch crop, and spring oat.

Ex ante assessments by model

Performance assessment of the most relevant L-EN cropping system and PHEP system are presented in table 1. Due to the decrease of N fertilization (-75%), the yield in the L-EN system is 25% lower than in the PHEP cropping system. The direct and indirect fossil fuel consumption (including machinery, N P K fertilizations and pesticides) has been decreased by 48%, 23% and 36% expressed in MJ/ha, MJ/q and MJ/protein units respectively compared to the PHEP cropping system. For these two cropping systems, all the environmental indicators, calculated over a 10-year period using the INDIGO tool, are higher than 7, which is the minimum value to be labeled an environmentally-friendly system. The high number of species (more than 3) and theirs place in the rotation, the low quantity of pesticides in the soil and in the atmosphere (less than 3 pesticides have been used for each crop), the maintain of a high soil organic matter level (higher than 1.6% in the region Ile-de-France), the specific management of the P and N fertilizations (either in quantity and in time of spreading) allow us to have fine values for biodiversity, pesticides, soil organic matter, phosphorus and nitrogen indicators respectively (Bockstaller *et al.*, 2008).

No results from the field experiment are available yet. The first and the second steps of the program can nevertheless be discussed from a methodological point of view. (1) Scientific and expert knowledge show that designing a L-EN system means a decrease in targeted crop yields. In the selected prototype, we can cut in half energy consumption by accepting a 25% drop in targeted yield. This trade-off is nevertheless still only virtual, and it will be particularly interesting to observe the real performance in the field. (2) As the energy constraint is expressed in reference to the PHEP system, the performance of this system plays an important role. We have chosen a PHEP system whose fossil fuel consumption is already low compared to current farming systems. (3) Only the main principles used for designing the cropping systems have been reported here. As the experiment unfolds, the decision rules governing crop management will require fine-tuning which is a key element of the research.

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Table 1: Direct and indirect fossil fuel energy consumption assessed for L-EN and PHEP cropping systems through the INDIGO tool, calculated over a 10-year period

	Mean yield q/ha/year	N-fertilisation UN/ha/year	Direct and indirect fossil fuel energy consumption		
			MJ/ha	MJ/q	MJ/protein unit
PHEP	61	89	8 826	145	8.74
L-EN	46	22	4 570	111	5.60
Ratio	-25%	-75%	- 48%	- 23%	- 36%

NEW CROPPING SYSTEMS UNDER A GREENHOUSE GAS EMISSION CONSTRAINT

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INTRODUCTION

Due to the ever-evolving economic and agronomic context, new cropping and farming systems are being proposed (Debaeke *et al.*, 1996; Vereijken, 1997; Meinke *et al.*, 2001; Reau & Doré, 2008). However, new constraints such as less greenhouse gas emissions are in the pipeline and need investigation. We have set up a 3-step project that entails: (i) designing new cropping systems based on scientific and expert knowledge according to a greenhouse gas constraint in addition to other environmental objectives, (ii) assessing them using models, and (iii) implementing the most promising one in a long-term field trial. The far-reaching objective is to improve cropping systems involving arable crops in northern Europe.

MATERIALS AND METHODS

New cropping systems were designed to reach environmental objectives (biodiversity preservation, prevention of groundwater pollution by nitrate and pesticides, conservation of the quality of soil, and reduction of energy uses) as well as either maximal production, or a specific greenhouse gas constraint as follows: to reduce by half the greenhouse gas emission, compared to the 'productive' cropping system, both by increasing C sequestration in the soil and decreasing N_2O emissions.

Environmental performances of the candidate scenarios were assessed using the INDIGO tool (Bockstaller *et al.*, 2008). C sequestration was estimated using the AMG model (Andriulo *et al.* 1999) and N_2O emissions were calculated with different references (Gregorich *et al.*, 2005). The performances were calculated on a per ha basis.

The most relevant candidate for each cropping system is currently being tested in a field experiment in Grignon (78, France), started in 2008. The agronomical, environmental, and economical performances of the cropping systems will be recorded over a 10-year period. The monitoring of soil physical, chemical, and biological characteristics is being carried out.

RESULTS AND DISCUSSION

Design of new cropping systems

A. The Productive with High Environmental Performances cropping system (PHEP). In order to reach strict environmental goals, the current PHEP system has been designed following three principles: (1) to include a long rotation to increase biodiversity (a 5 year- rotation instead of the 3-year one currently practised in the Ile-de-France region), (2) to include legumes, at least once in the rotation, to reduce the amount of N-fertiliser used, and (3) to use highly resistant varieties or species mixtures associated with optimal sowing dates and densities to decrease pesticides use as well as reduce sensitivity to insects and diseases. Finally, the crop rotation of the PHEP system is faba bean, winter wheat, winter oilseed rape, winter wheat, mustard as a catch crop, and spring barley.

B. The cropping system with a greenhouse gas constraint (Less-GreenHouse Gas: L-GHG). In order to reach the objectives previously described, the principles of the L-GHG system are: (1) to include as many cereals as possible (i.e., maize, winter wheat, winter barley or triticale) in order to produce high amounts of residual straw; to forbid mouldboard ploughing; to keep continuous soil coverage; and to target high yields; and (2) to include legumes and take into account climate conditions when spreading N fertilisation. The crop rotation of the given L-GHG system is maize, triticale, mustard as a catch crop, spring faba bean, winter oilseed rape, winter wheat, legumes-cereal mixture as a catch crop, winter barley, and a legumes-oat mixture as a catch crop.

***Ex ante* assessments by models**

Performance assessment of the most relevant L-GHG and PHEP cropping systems under the Ile-de-France pedoclimatic conditions (i.e., soil organic matter = 1.6%) are presented in table 1. Due to the specific species in the rotation and the level of yields, the C sequestration in the L-GHG system is 24% higher than in the PHEP cropping system. Yet, the N_2O emission in the L-GHG system is 8% higher than the PHEP cropping system because of the high N fertilisation required on the crops to reach high yields. For both cropping systems, all the environmental indicators, calculated over a 7-year period using the INDIGO tool, are higher than 7, which is the minimum value to be labelled an environmentally-friendly system (Bockstaller *et al*., 2008).

No results from the field experiment are available yet. The 1st and the 2nd steps of the program can be discussed from a methodological point of view. (1) The N_2O emission assessment is very uncertain due to the lack of N_2O emission references from faba bean residues and the use of IPCC coefficients to calculate N_2O release from N applied. (2) The level of C sequestration highly depends on cereal yields, difficult to estimate without any mouldboard ploughing: it will be necessary to measure them in the field to confirm the interest of this cropping system for increasing C sequestration. (3) The models and tool only partially take into account the fact that the fields are constantly covered with crops: the impact on C sequestration in the soil is being measured. (4) Soil organic matter highly influences cropping system capacity to reduce GHG emissions by C sequestration: the extrapolation of such cropping systems to other fields should take into account. (5) In a further step, the uses of machinery and agro-chemical have to be taken into account to allow a full assessment of the GHG.

With all these uncertainties, an *ex post* assessment appears necessary to confirm the *ex ante* results.

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Table 1: C sequestration and N_2O emission (both in kg CO_2 equiv) assessed for L-GHG and PHEP cropping systems, calculed over a 100-year period

	Mean yield q/ha/year	N fertilisation UN/ha/year	C sequestration kg CO_2 equiv	N_2O emission kg CO_2 equiv
PHEP	60	92	46 567	34 151
L-GHG	70	100	57 567	36 815

TARGETING FARM SCALE LAND USE CHANGE TO REDUCE CATCHMENT SALT LOAD

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INTRODUCTION

In southern Australia, replacement of deep-rooted perennial vegetation with shallow-rooted annual crops and pastures has caused increased deep drainage, rising groundwater, and subsequent land and river salinisation. Successful management of salinity, including getting adequate return on investment into salinity mitigation is measured at the catchment scale. However, catchment scale responses are the result of action by individuals at the paddock or farm scale. Much salinity research in Australia has not adequately linked farm and catchment considerations. This study, in south eastern Australia, sought to assist farmers and catchment managers target land use change so catchment salt and water targets could be met at least cost.

MATERIALS AND METHODS

Simmons Creek is located at the eastern edge of the Riverine Plain, north east of the township of Walbundrie in southern New South Wales, Australia. Approximately 98% of the 178 km^2 catchment is used for agriculture, mainly mixed cropping. Local farmers helped identify 8 broad classes of land use. Typical gross margins were calculated for each component (e.g. wheat or lucerne) of each land use which were averaged over ten years to produce an annual gross margin ($/ha/year). The Agricultural Production Systems Simulator (APSIM) (Keating et al., 2003) was configured to simulate the crop/plant growth and water balance of each of the land use scenarios on each of five soil types (i.e. a matrix of 8 land uses x 5 soil types). Simulations used historical climate data from 1891 to 2006 (116 years). The APSIM model supplies estimates of run-off, drainage and gross margin from each land use and soil to a linear programming (LP) model.

The LP model calculates minimum-cost changes in land use to attain specified targets of future salt-loads and water-yields from the catchment. The model incorporates 13 sub-catchments with various levels of connectivity reflecting the conceptualisation of the catchment's hydrology (English et al., 2002). Within sub-catchments, the model accounts for lateral fluxes of surface water down-slope thereby changing the productivity and water balance of the land receiving run-on. In the lower (southern) Simmons Creek, deep drainage beneath a sub-catchment results in discharge at a specified fraction of the salinity of the associated groundwater.

The LP modelling analysed: 1) Return from current land use extent and distribution, 2) Changes to current land use extent and distribution that would maximise farm income (i.e. maximise catchment gross margin) while maintaining current salt export, and 3) The progressive changes to current land use extent and distribution that would be required for least-cost reduction from current estimated salt export to zero (in 1000 t salt/year steps).

RESULTS AND DISCUSSION

The model selects an arrangement of land use that preserves as much highly productive and profitable agriculture as possible whilst addressing salt load and water yield targets. Seeking greater reduction in salt load shifts land used for pasture into tree growing, and then as a last resort, land used to grow highly profitable rotational crops is shifted into growing trees. Shifts in land use to reduce salt export from the catchment progressively reduce farm income from the maximum catchment gross margin (~$3M) - although the reductions in gross margin are modest (< 5%) at least until salt load has been reduced by ~50%. The marginal cost (cost per each extra tonne of salt load reduction) of reducing salt load gets progressively more expensive as greater reductions in salt load are sought.

Most of the land use change (both in area and degree) suggested by the modelling is in a few sub-catchments in the south of Simmons Creek catchment. These are the sub-catchments with saline groundwater and where deep drainage reduction will have the most direct impact in reducing salt load. The changes are to replace cropping rotations with tree plantations in saline catchments and to maintain water yield by adopting higher water yielding land uses in non-saline catchments. In both cases the changes result in significant loss of income. The majority of the cost of salinity management within the whole catchment would be on only a few farms; the rest of the catchment remains unaffected until high levels of salinity mitigation are sought. However, since our analysis estimates the cost of these land use changes, it could form the basis to negotiate cost share between the relevant parties.

There is considerable uncertainty in the ‘current’ baseline salt load contribution from Simmons Creek catchment. This translates to uncertainty in the unit cost ($/t) of salt mitigation. The sequence of land use change for least-cost meeting of salt targets remains the same, no matter what value is assumed for baseline salt load.

The careful targeting of changes in land use is essential for cost-effective salinity mitigation in this landscape - there are many locations in Simmons Creek catchment where land use change would not be effective. In fact, land use change to achieve reductions in salt load could easily cost more than the apparent value of benefit derived. This situation can be avoided by undertaking appropriate economic analysis as part of salinity management planning. The bio-economic modelling developed here enabled: quantification of where land use change is needed, the nature of the change in land use, and the extent of change needed to meet given salinity and water yield targets at least economic cost. The modelling identifies inequities in cost share within the catchment and informs choice of land use options but should not be seen as providing any sort of prescription for land use change.

An essential prerequisite for this type of analysis is prior investment in understanding the catchment basics - including the hydrogeology, the surface and groundwater hydrology, the pathways by which salt is being mobilised, the current land use, the distribution of soils, and landholder capacity to change.

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EVALUATION AS A TOOL FOR RESOLVING AGRICULTURAL CONFLICTS

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INTRODUCTION

Evaluation is an established discipline that was professionalized in the late 1960's, emerging in response to governmental demands for program accountability. The profession has since evolved into an academic discipline with professional associations across the globe, many peer-review journals, and doctoral programs often situated in schools of education, psychology, public policy, and public health.

Evaluators ethically and systematically collect information about a project, program, system, organization, etc. That information is used during the evaluation process and afterwards to make decisions about what is working well, what needs adjustment, and to identify possible alternatives. Evaluation designs may combine experimental, quasi-experimental, ethnographic or other qualitative approaches. Evaluators may conduct one-off studies to assess program impact or they may help organizations build evaluation into management systems. Evaluative techniques are also useful for ensuring program plans are well-designed with measurable results, for securing funding, and for resolving conflicts. In the case discussed below, an evaluation was conducted to foster collaboration between competing groups. It served as a unifying force in defining future research and organizational priorities.

On 15 Aug. 2006, an infected spinach crop was harvested along the Central Coast of California. By the following January, this harvest had been linked to three deaths and 205 illnesses as a result of *E. coli* O157:H7 contamination. In the interim, product recalls and public concerns resulted in substantial financial losses to growers, processers, and marketers of leafy greens. Wildlife, in particular feral pigs, were suspected of vectoring the *E. coli* from neighboring ranches. To protect their investments and public health, many larger buyers pressured growers into removing vegetation and standing water near their fields since it was thought that those areas might attract infected wildlife. Because agriculture is a significant source of pollutants in Central Coast surface water, and because much of the vegetation and the standing water to be removed had been installed to prevent sediment losses into open water, their removal created a conflict with agencies charged with protecting water quality. Little information was available on co-management of water quality and food safety however, and the conflict quickly intensified as growers complied with the wishes of

In the wake of the spinach scare of 2006, an April 2007 conference in San Louis Obispo brought together people representing a variety of public, private and governmental organizations to increase understanding and cooperation among those with a vested interest in water quality or food safety. The first half of the conference focused on sharing current research and policies from each side. On the second afternoon small groups of participants representing both food safety and water quality concerns performed audits of local farms according to the other side's criteria which proved instructive and challenging for both sides (Crohn and Bianchi, 2008). On the third and final day of the conference participants discussed common research priorities and ways to collaborate. These discussions served as the first round of the Delphi process, discussed below, helping participants hone research priorities.

MATERIALS AND METHODS

A third-party evaluator with conflict resolution experience was sought to facilitate discussions and document progress. A request for proposals was posted to the American Evaluation Association's listserve and interested respondents were interviewed and asked to submit a brief description of suggested evaluation approaches. The evaluator was selected based on his academic credentials, demonstrated creativity, and experience. He helped refine the conference goals and suggested a Delphi process, an evaluation method often used to generate consensus in contentious situations. The Delphi began on the third day of the conference with the intention of eliciting consensus across the two groups on the top three research priorities, the organization of future research, and the various agencies that should be collaborating on research and projects.

The underlying question driving the evaluation was “What is the science that is available to help us decide on best co-management practices and where are the holes in the research that need to be addressed most urgently?” Results were documented through the evaluation. The Delphi method elicited some agreement on key research priorities and ways to continue collaborative work among key agencies and organizations. The second and third rounds of the Delphi were conducted after the conference via Web surveys. In response to the first survey, 43 out of 69 conference participants answered questions regarding research priorities identified at the conference. The evaluator culled out those research ideas with little consensus and those of least priority. He categorized the remaining research ideas into lists of short- and long-term priorities and by three research categories: pathogen vectors and pathways, mitigation and management practices, and risk management. Through the second Web survey, 35 of the 69 conference participants ranked the research priorities and also identified organizations and individuals that should lead research and project activities. The evaluator sorted the responses into categories and identified the top two results in each. Another organizer, noting that some items received both very high and very low support, then used a method borrowed from the decision sciences to rank all of the significant responses. Results were shared in an online report by the conference planners.

RESULTS AND DISCUSSION

The conference planners had little to no previous experience working with a professional. In designing an evaluation, one conference planner noted that she typically focuses on the product of a program, answering questions like: Does it work? What information was gained? Did we see a behavior or policy change as a result of a particular program theme? They had not previously considered evaluation as a tool for conflict resolution and, as such, some time at the beginning of the process was dedicated to clarifying what evaluation is and how its techniques can be applied.

Evaluation results showed that food safety and water quality constituencies have differing priorities and but did not disagree on the types of research that are needed to resolve the conflict. One conference planner is confident that a particularly important conversation led to some changes: The field portion of the conference was a defining moment for many conference attendees, helping them truly understand the others’ perspectives. On the bus on the way home from the field visit two national program leaders for Cooperative States Research Education and Extension Service, one focused on food safety and the other on water quality, talked for the first time about co-management. The next year, their office called for research proposals with an emphasis on co-management. With additional funds, a follow-up evaluation could systematically assess how the conference is influencing participant’s thinking and plans. This kind of information would be valuable to organizing committees, funding agencies and researchers in understanding the extent to which: (1) co-management research and projects stemmed from conference, (2) what kinds of research and projects are currently underway, (3) which topics have yet to be undertaken, why, and what barriers must be addressed, (4) when another conference would be productive, and (5) how participants could exchange ideas in the mean time

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A SYSTEM FOR WEIGHTED ENVIRONMENTAL IMPACT ASSESSMENT OF RURAL ACTIVITIES: APOIA-NOVORURAL

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INTRODUCTION

Farmers world around are increasingly committed to the application and demonstration of environmental management practices applied to their farming systems. Whether or not implicated with a variety of best practices arrangements or eco-certification schemes, the impact assessment of rural activities has become a priority for guiding sustainability. Numerous environmental impact assessment (EIA) methods have been developed to meet this demand, both as auditing procedures for third party conformity evaluations and as environmental management systems to aid farmers' decision making.

In the ample majority of cases, EIA methods rely on performance indicators and, according to the scale and required complexity level, the ensuing agricultural performance statements address particular aspects such as pesticide contamination risks and input-output balances, up to the integrated environmental and socio-economic performance of farming systems. Beyond agricultural performance evaluations, the integrated farm sustainability approach offers procedural advantages for environmental management – for it is at the rural establishment scale that production practices and technology adoption decision-making takes place.

Methodological alternatives for integrated farm sustainability assessments have been made available, most often involving specific cropping systems and special market affiliations such as organic farming and integrated production programs. The present paper details the 'system for weighted impact assessment of rural activities' (APOIA-NovoRural; Rodrigues and Campanhola, 2003), devised to promote the environmental management of rural establishments, applicable to a variety of socio-environmental contexts and spatial scales.

Eight case studies carried out with the methodology are briefly reviewed, attesting to the malleability of the approach and its applicability as an integrated environmental management tool for rural establishments and its extension to promoting local agricultural productive arrangements and territorial sustainable development.

DESCRIPTION OF THE APPROACH

The presently proposed method considers the general framework of EIA science, as to observe and integrate the (1) **pressure** premise: be adaptable to imposed impacts, according to local socio-economic contexts, environmental conditions and production scales; (2) the **state** premise: express the effects of changes on the quality of the environment and natural resources, including social, economic and ecological concerns; and (3) the **response** premise: offer the basis for issuing recommendations for decision making on alternative management practices and agricultural technology adoption.

The APOIA-NovoRural system has been developed observing the following objectives: (i) allow practical assessment of the most diverse rural activities with objective, quantitative indicators, applicable in varied environmental settings at the specific scale of the rural establishment; (ii) integrate ecological, sociocultural, economic and management aspects pertaining to local sustainable development; (iii) express results in a simple and direct manner to farmers, rural entrepreneurs, decision-makers, and the general public; (iv) facilitate the detection of critical control points for management correction; (v) provide a user-friendly interface and integrated sustainability index. The system consists of 62 indicators integrated in five sustainability dimensions: i) landscape ecology, ii) environmental quality, iii) sociocultural values, iv) economic values, and v) management and administration. The indicator level assessment results offer a diagnostic tool for farmers and managers, pointing out specific attributes of the rural activity that may be failing to comply with defined benchmarks. The output integrating indicators by each of the five considered dimensions shows decision-makers the major contributions of the rural activity toward local sustainable development, facilitating the definition of control actions and promotion measures. Finally, the aggregated 'sustainability index' is a yardstick of environmental performance, offering a straightforward eco-certification tool for rural activities.

RESULTS AND DISCUSSION

To date, a total of 139 rural establishments have been studied in formal, fully documented research projects, in addition to numerous evaluations carried out in training programs, graduate courses, and project preparatory trials. These assessments have included from very small (2-5 ha), subsistence family landholdings, to medium size (~100 ha) family farms; and from commercial farms of different scales, to large (600 – 3000 ha), productively diversified and technologically advanced agribusinesses.

Varied rural sectors have been included in these projects, both typically agricultural such as horticulture, grain production and dairy farming; and non-agricultural such as agro-tourism, fee-fishing, carcinoculture, and artisanal mussel / crab fishing. Also, different social arrangements have been adaptively approached, including traditional communities (and indigenous groups), agrarian reform farmers, cooperative groups and farmers involved in special local productive arrangements in governmental programs. Subject to minor adaptations and calibrations, the system has been applied in the most varied socio-economic and physicochemical environmental settings, from the equatorial Amazonian region to the temperate pampas.

Comprising ecological, sociocultural, and economic (including management and administration) dimensions, integrated into an objective measure of rural activities' contributions toward local sustainable development, the APOIA-NovoRural system is straightforwardly applicable by trained researchers and technicians, allows the active participation of farmers / administrators, and facilitates the storage and communication of information concerning environmental impacts. The computational platform is readily available and allows issuance of easy-to-interpret printable graphic outputs. A template is available for the formulation of 'Environmental Management Reports', facilitating recommendation of practices and technologies for correction of faulty indicators and promotion of positive ones.

The results regarding the performance of the studied activities according to particular environmental indicators offer a diagnostic tool for farmers / administrators, pointing out how the activities may comply with defined environmental standards and socioeconomic benchmarks. Additionally, the indicators show a measurement of the relative variation and temporal tendency of impacts imposed by agricultural practices, indicating corrective courses of action for management.

The results combined according to the integrated dimensions provide decision-makers with an overview of the effects, both positive and negative, of rural activities on local sustainable development, facilitating the selection and recommendation of incentive policies or control measures at the local community level. Finally, the 'sustainability index' can function as a measure of the contributions of rural activities to local development, meeting the demands of farmers, administrators, decision-makers and rural organizations, pursuant to defined objectives of integrating ecological integrity, economic vitality and sociocultural equity measures for local sustainable development.

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ENVIRONMENTAL ACCOUNTING OF AGRICULTURAL COMMODITIES PRODUCTION: A USA/BRAZIL CONTRAST

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INTRODUCTION

It has been a common practice to evaluate the performance of agricultural development and technology adoption according to economic, technical, and political criteria. However, the recognition of wide-ranging environmental impacts of agriculture makes mandatory the incorporation of sustainability criteria in performance evaluation. The environmental accounting techniques proposed by H.T. Odum offer a systemic approach to decide on agricultural practices intensification / diversification and technology selection / adoption, allowing consideration of questions concerning the sustainable use of natural resources, the tradeoffs between improvement and growth of economic activities, environmental conservation, and the fair sharing of wealth among the social groups involved.

The 'Sustainability Assessment Methodology Framework' (SAMeFrame – Rodrigues et al., 2002) presented in this study is a tool for carrying out the environmental accounting of energy and material flows in agricultural and livestock production, integrating the individual farm scale, the regional insertion of the farm at the county scale, the systemic evaluation at the country level and the insertion and impact of agricultural production in the national economy. Based on such a 'systems agriculture' approach, a series of performance indices is obtained for all scales and expressed in numeric and graphic formats, facilitating circumstantiated assessment of, e.g., renewable/non-renewable resources use ratio, environmental loading ratio, and general systems sustainability.

DESCRIPTION OF THE APPROACH

SAMeFrame comprises a set of integrated spreadsheets for accounting the emergy balances from the agricultural and livestock production activities at the farm level, the regional insertion of the farm at the county or State level, and the systemic evaluation of the country and national agriculture. Data needed to fulfill the requirements of SAMeFrame at the macro scales (country through county) are obtained from the national, regional, and agricultural censuses, while micro-scale data are obtained directly from individual farm records. Results of the assessment for each scale considered are expressed in emergy flow diagrams (as solar emergy Joules – seJ), summarizing resource use ratios and sustainability indices.

The emergy evaluation of the country establishes the large-scale resource base and economic setting for all productive activities developed in the smaller scales, and must be the first step in the sustainability assessment. The overall energy use and emergy evaluation of the country are combined with the market values of imports, exports, and money flows to define the emergy/money ratio for the national economy. This emergy/money ratio influences all production activities within the country, as well as the exchanges of goods and services between countries.

The general emergy analysis of the country offers the basis for assessing the National Agriculture and Livestock Production System, which sets the economic and the resources environment for the insertion of the local agriculture and individual farms. This stepwise scaling of rural productive activities determines how the local production of individual farms can match the emergy investments characteristic of the whole country, and better rely on special local conditions to improve sustainability.

In the present study the national economies and the agricultural emergy flows in Brazil and the USA have been analyzed (year 2000 basis), as examples of the sustainability assessment approach offered by emergy analysis and the broad-scale environmental accounting provided by SAMeFrame.

RESULTS AND DISCUSSION

Environmental performances, as expressed by resources dependency, are shown to be strongly influenced by agricultural product diversification and by the environmental and economic resources bases of the two economies, with the USA being more dependent on man-made and non-renewable resources.

With total national emergy used equal to 1.18E+25 seJ year^{-1}, being 1.72E+24 seJ from renewable resources, 6.80E+24 seJ from non-renewable resources and 3.26E+24 seJ from imported sources, for a throughput of 2,39E+24 seJ, the USA economy showed 72% of emergy use from home sources, 15% of which are locally renewable, a ratio of concentrated (human-economy) resources to rural equal to 2.13, 'empower density' (emergy use ha^{-1}) of 1.25E+16 seJ and an emergy use per capita of 4.18E+16 seJ.

For Brazil the total national emergy used equaled 5.17E+24 seJ year^{-1}, being 2.77E+24 seJ from renewable resources, 1.72E+24 seJ from non-renewable resources and 6.83E+23 seJ from imported sources, for a throughput of 7.19E+23 seJ, being 87% of emergy use from home sources, 54% of which locally renewable, with a ratio of concentrated (human-economy) resources to rural equal to 0.37, 'empower density' (emergy use ha^{-1}) of 6.07E+15 seJ and an emergy use per capita of 3.05E+16 seJ.

The USA national crop production amounted to 3.05E+19 J, the livestock production amounted to 7.86E+17 J, with transformities equal to 1,42E+05 seJ J^{-1} and 1.88E+06 seJ J^{-1}, respectively, corresponding to empower densities of 3.50E+16 seJ ha^{-1} for crop and 7.52E+15 ha^{-1} for livestock production, with 44% and 38% based on renewable resources, respectively.

The national crop production for Brazil amounted to 6.55E+18 J, the livestock production amounted to 1.91E+17 J, with transformities equal to 6.52E+05 seJ J^{-1} and 1.24E+06 seJ J^{-1}, respectively, corresponding to empower densities of 6.55E+16 seJ ha^{-1} for crop and 1.21E+15 ha^{-1} for livestock production, with 70% and 29% based on renewable resources, respectively.

These data indicate that urban and quite intense agricultural activities (high empower densities) are diluted in the very large natural and range areas occurring in both countries (explaining the smaller empower densities for the whole economies as compared with agricultural empower densities), while livestock production is much less intense, especially in Brazil (just 16% as intense). Also, the analysis shows that the Brazilian agricultural sector relies more heavily on natural and renewable resources, reaching net emergy ratios (return on emergy investment) of 13.4 and 1.41 (for crop and livestock), as compared to 6.27 and 1.26 for the USA. These attest to a comparatively more efficient agricultural sector in terms of resources uses in the Brazilian economy.

Contrasting with economic benefit-cost analyses normally carried out to assess the performance of agricultural activities and technology contributions toward sustainability of farm systems, which are highly influenced by transitory aspects of the market and do not account for environmental issues in general, the integrated emergy assessment made possible by SAMeFrame explicitly considers the cross-scale matching of environmental and purchased input uses. Accordingly, the results obtained with SAMeFrame point out that soil and water conservation practices (to warrant needed natural resources) are crucial for sustainability, and that these practices should be greatly stimulated.

However, resources for such are difficult to come by because, even with contrasting contexts regarding resources uses, in the two countries studied the energy flows (emergy) characteristic of rural areas impose that both the farms and the national agriculture function as net providers of large amounts of wealth to the urban markets.

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TAPIS: AN INTEGRATED INDICATORS SYSTEM FOR PERFORMANCE ASSESSMENT OF TRADITIONAL AGRO-FORESTRY IN SOUTH WEST CAMEROON

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INTRODUCTION

Farming Systems developed in Humid Tropical Zones are frequently characterized by a combination of perennial and annual plants, intermixed in complex tree-crop associations. The productive functioning, the agronomic and economic performances, and the sustainability of these Agroforestry Systems (AFS) remain poorly understood, although they continue to ensure the livelihood of large portions of rural populations in the tropics. To improve the management capacity of these complex AFS, adequate indicators must be developed and integrated in assessment systems that harness a very diverse set of biophysical, economic and social data, and organize them into synthetic, understandable recommendations. These may then be used to account for and elucidate the relationships and tradeoffs among concurrent indicators in order to aid farmers, assisted by their extension agents, in making decisions regarding management practices (Rodrigues et al. 2009).

The present study focused on the performance assessment of AFS in the South West Region of Cameroon, aiming at (1) proposing an integrated indicator system directed at aiding farmers in their decision making on management practices and (2) contributing toward sustainability evaluations of traditional agroforestry systems.

MATERIALS AND METHODS

The present study focused on the agroforestry systems developed by 38 farmers in the South West Region of Cameroon (Kumba and Bombe-Malende zones), which were surveyed for a large set of variables, aiming at formulating a 'Traditional Agroforestry Performance Indicators System' (TAPIS). This region falls within the rainforest area, has a marked rainy season, and high mean annual temperatures. Soils are ferrallitic with patches of fertile volcanic areas, and altitudes varying from 25 to 400 m toward the North. The exploitations existing in the area are permanently occupied (no fallow) small areas integrating main perennials (cocoa, oil palm and rubber trees), food crops (plantain, manioc, yams, maize, banana, etc.), native trees, ornamentals and medicinal plants (not considered in the surveys).

Two sustainability dimensions, agro-economic and agro-ecological were defined for parcel performance ranking, each comprised by a set of eight meaningful indicators, as follows:

Agro-economic dimension indicators: (1) Income; (2) Input expenses; (3) Pesticide independence; (4) Hired workforce independence; (5) Family workforce engagement; (6) Total workforce independence; (7) Internal gross added value, and (8) Total gross added value.

Agro-ecological dimension indicators: (1) Harvest; (2) Area equivalence index; (3) Soil resource use index; (4) Productive diversity; (5) Diversity of associated arboreal species; (6) Adventitious plants controllability; (7) Beneficial adventitious plants and (8) Adventitious plants infestation control.

The composition of these locally meaningful indicators ensued from (i) a regression significance analysis of the broad set of field variables surveyed, (ii) the experience attained by contact with the farmers and the local reality, and (iii) a review of integrated indicators systems for environmental farm (and AFS) management (for details see Rodrigues et al., 2009). Accordingly, agro-economic indicators were devised to appraise attributes of cash flow, work dedication, expenses and profitability. Agro-ecological indicators were, on their part, devised to cover the essential biophysical efficiency attributes of productivity, land use, productive diversity and weed competition.

RESULTS AND DISCUSSION

With sizes ranging from just 1,000 m^2 up to 4.0 ha, all studied plots were densely packed with a diversity of annuals and seedlings of perennial crops in the implantation phases, progressing to still dense plant stands even when main crops reached production; with the exception of rubber tree-dominated plots, which tended to almost exclude annuals after onset of latex extraction.

The aggregated results for the mean performance indices in TAPIS across all plots showed that no farmer obtained combined agro-economic and agro-ecological indices to be ranked within the upper performance quartile for the two dimensions considered in the indicator system. This result implies, on the one hand, performance unevenness among farmers within each of the indicators; and on the other, important tradeoffs among indicators for all plots.

Observation of the distribution of main crops and their development stages showed that there were no evident clusters determining performance trends. This means that the variety of crop combinations, associated production stages, and practices adopted in the different plots were more important in determining performance, as indicated by TAPIS indicators, than the main crop alone, while a significant relationship still existed between the sets of agroeconomic and agroecological indicators.

One-fifth of the plots gave agro-economic mean performance indices above the 0.5 level, with the best performance indices being related to Pesticide independence (measured according to expenses, hence an agro-economic indicator), Total workforce independence, and Hired workforce independence, indicating that low expenditures were directed toward pesticide inputs and hired worker recruitment. These indicators were inversely and significantly correlated with the level of Income and Added value, which in turn were directly correlated among themselves, meaning that those who obtained better incomes tended to rely on higher investments.

Regarding the agro-ecological indicators, and with only one exception, all plots ranked in the lower performance quartile. Only the Adventitious plants infestation control indicator reached a mean value above 0.5, which is interpreted as a tendency for an adequate management situation, as suggested by a significant positive correlation between this indicator and the Adventitious plants controllability. This latter indicator, itself related to a low diversity of weeds, was significantly but inversely correlated with the presence of Beneficial adventitious plants. This strategy seems logical as weeding is a major time consuming practice and usually a constraint for farmers. The Area equivalence index was the second highest agro-ecological performance indicator, being related to a high level of crop association.

Confirming the performance results and the tradeoffs observed for the agro-economic indicators for the whole group of plots, with mean Income and Added value indicators being low, the total Harvest indicator showed the lowest mean agro-ecological performance index, implying that the majority of the plots had dense plant stands (high AEI) consisting mostly of still immature crops, resulting in a low mean Soil resource use index (0.31). In fact, only 15 of the 38 plots already had the main perennial crop in production stage. A modest Diversity of associated arboreal species (0.33) indicated a relatively low importance of non-crop, spontaneous tree species conserved in the plots.

With this kind of interactive indicator analysis and interpretation, TAPIS offers farmers, extension agents and researchers a tool for interpreting and deciding on management options and resource allocation strategies, as well as an approach for better understanding tradeoffs in traditional agroforestry systems.

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EMERGY[†] EVALUATION AND ECONOMIC PERFORMANCE OF BANANA CROPPING SYSTEMS IN GUADELOUPE (FRENCH WEST INDIES)

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INTRODUCTION

Banana is the second most important agricultural commodity in Guadeloupe (French West Indies—FWI). It represents 24% of local agricultural production, 12% of the total cultivated area, and generates about 5000 direct jobs. For several years this sector has been facing severe environmental and economic crises, mostly due to market liberalization that has prevailed during the last 15 years, causing the price of bananas to decline by an average rate of 1.4% per year, often compelling farmers to intensify their production systems in order to maintain their income. Looking for higher productivity, farmers have increased the use of technological inputs such as intensive use of machinery, fertilizers, pesticides, and irrigation, that push energy flows through the agro-ecosystem to unsustainable levels.

The intensive use of technological inputs in banana production in the FWI has been associated with severe impacts on the environment, because the systematic use of ploughing and pesticides has led to chronic contamination of soils and waters by organochlorine compounds like Chlordecone. The reported contamination problem has in turn contributed to a decrease in soil biological diversity and consequent reduction in fertility, while contaminating drinking water sources. These environmental costs or the externalities of such detrimental environmental impacts of agricultural practices are typically unmeasured and often do not influence farmers' or societal choices regarding agricultural production practices.

The goals of the present study are: (1) to compare the different banana cropping systems in Guadeloupe with regard to: resource use, productivity, environmental impact, and overall sustainability; (2) to evaluate the eMergy signature of the banana production as a whole in the region; (3) to contrast an ecocentric analysis (eMergy) with an anthropocentric analysis (economic) of the banana cropping systems and determine their respective tradeoffs; and (4) to highlight points where innovations might result in greater improvements toward overall sustainability of banana cropping systems in Guadeloupe.

MATERIALS AND METHODS

In Guadeloupe, six different cropping system types for banana production have been identified: (1) Lowland intensive small farms; (2) Lowland intensive medium farms; (3) Lowland intensive large farms; (4) Flat uplands intensive medium farms; (5) Highlands moderately intensive small farms and (6) Highlands extensive small farms. Each type described above has been translated into a hypothetical farm that represents the average flows of resources and outputs for all farms in the type class.

After quantifying annual flows for each component and cropping system in physical units (i.e., joules, grams, US$), these values were normalized for area (1 ha) and translated into eMergy units (solar eMergy Joule - seJ) through previously calculated transformities for each item. For some components and products, different transformities had been derived in different contexts, so the transformity calculated under the most similar conditions to those observed in the studied situation has been selected. Furthermore, each component or production item was classified whether it is a renewable resource (R), a

[†] eMergy (spelled with a "M") is defined as the total energy of one kind (usually solar equivalent) directly and indirectly in the work of making a product or service (Odum, 1996; Odum et al., 2000).

local non-renewable source (N), a resource purchased from outside (P) or an exported product (Y). Several performance and sustainability indices have been calculated for the different cropping systems. These indices (Transformity, Mass-eMergy, Fraction renewable, Environmental loading ratio, eMergy investment ratio, eMergy yield ratio, eMergy exchange ratio and eMergy sustainability index) summarize the systems' resource use intensity, process efficiency, economic–environment interactions and quantify sustainability (Rodrigues et al., 2002). Additionally, aiming at improving managerial capacity and investment decision making, the environmental performance results obtained were contrasted with economic analysis for the six cropping systems.

RESULTS AND DISCUSSION

As a general outcome, the analyses showed that the better the environmental performance of the cropping system, the worse its economic performance. This result was corroborated by an increased contrast among cropping systems as related to their dependence on purchased inputs, although all cropping systems followed the same intensive and arguably wasteful agricultural model. Therefore, the analyses point out that sustainable banana production in Guadeloupe depends on a shift from the high fossil input model to a natural resources intensive one.

In this sense, eMergy flow analysis showed that innovation toward environmentally sound practices that would enhance nutrient cycling; integrate weeds, pests and diseases control; and improve the banana packing process might result in most positive impacts on overall sustainability.

Economic analysis showed that the high labor and input costs, as well as post-harvest processing contribute largely to the dependency of banana production on agricultural subsidies. These issues stem from European Commission's regulations on quality standards for commercial bananas that, by imposing strict aesthetic benchmarks, have had a negative effect on the sustainability of banana production; because substantial nonrenewable and purchased eMergy inflows into banana production systems aim to impose improved aesthetic standards over sound ecological management.

Therefore we may conclude that reorienting the current European agricultural income policy to an environmental performance-based subvention might be a policy opportunity to achieve the present socio-economic goals while promoting sustainability in banana production.

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OPTIMIZING LOW INPUT PRODUCTION SYSTEMS USING IMPROVED AND STABLE WHEAT INBRED LINES ARISING FROM A NEW BREEDING SCHEME

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INTRODUCTION

The most challenging key questions for the development of new varieties for low input farming systems, relate to both the genetic resources to be used for selecting new genotypes, and the selection criteria suitable to predict the future performance and stability of those genotypes.

The likely outcome from breeding major cereal crops such as wheat, using intraspecific genetic variation and quantitative traits as selection criteria, is one of small increase in genetic progress despite considerable research investment. Transfer of genes between wheat species, will be more promising, and may occur by: (i) crossing the tetraploid durum wheat *Triticum turgidum* ssp. *durum* (*Td*) with the hexaploid wheat *T. aestivum* ssp. *aestivum* (*Ta*) (Lanning et al., 2008), or (ii) crossing synthetic hexaploid wheat lines (developed from *Td* x *Aegilops tauschii* D genome donor) to elite hexaploid wheat cultivars. The first procedure provide favorable genetic recombination and segregants for ploidy levels without the need for extensive backcrossing to elite cultivars (cv) for deriving commercial varieties, while the second require repeated backcrossing to the elite cv and several generations of prebreeding before new cv can be released. We have developed a new breeding scheme which merges the methodological simplicity of approach (i) with the pedigree complexity of approach (ii). It is based on the use of *Td* x *Dasypyrum villosum (Dv)* amphiplod in a bridge crossing to *Ta*, for transferring, through recombination, *Td* and *Dv* genes to hexaploid wheat inbred breeding lines (IBLs) that display trait enhancement for grain yield, yield stability and grain quality under low-input field trials.

MATERIALS AND METHODS

An F_2-like breeding population with broad genetic diversity, was obtained from selfing the F_1 plants obtained after crossing an hexaploid amphiploid (*Td* cv 'Modoc' x *Dasypyrum villosum,Dv*; 2n=6x=42, genomes AABBVV) to the hexaploid bread wheat (*Ta* cv 'Chinese Spring', CS; 2n = 6x = 42; genome AABBDD). Eighty percent of the pollinated florets of *Ta* used as female parent, produced F_1 caryopses. Homologous pairing and recombination between the A and between the B-genomes of *Td* and *Ta* and the random assortment of the chromosomes of the D and V genomes, occurred at meiosis of the F_1 plants. This favoured the arrangement of aneuploid and euploid AB, ABV or ABD gamete configurations and various assortments of genetic-blocks from the A and B parental genomes. The selfed F_1 plants were partially fertile and the surviving F_2 embryos tended to be euploid due to lack of viability of aneuploid gametes. About 42% of the F_2 seeds produced complete fertile plants. Root-tip chromosome counting of the resulting F_3 seeds showed a prevalence of 14A, 14B and 14 D chromosome configurations. Chromosome painting technique (GISH) recognized F_3-seedlings with one to seven V-chromosomes (Minelli et al., 2005). Selfing, occurring from F_3 to F_4 generations, coupled to: (a) chromosome counting for selecting 2n=42 plants, (b) field-plot trials managed using low-input criteria, and (c) selection for spike fertility and plant yield components, allowed the identification of several euploid IBLs with interesting plant and grain quality features. In the 2007/2008 growing season, three of those IBLs, named "41-3", "Mut 3-04", and "8-1", were tested in the field at two sites (S. Angelo Lodigiano, SAL, near Lodi in northern Italy, 45° 14' N, 9° 24' E, 74 m asl, and Tolentino, TOL, near Macerata in central Italy, 43° 12', 13° 17' E, 238 m asl) in a randomized block design with three replications at each site. The blocks were managed using low-input criteria. The hexaploid wheat cultivars "Bologna" and "PR22R58" were used as checks. HT, heading time (days from April 1st) and yield components were evaluated at both sites. Small- (PC, protein content as % of dry matter; SSV, SDS-sedimentation volume, mL; GI, Gluten index as % of strong gluten over the total gluten), as well as large-scale (DS, Farinograph degree of softness in BU; W, Alveograph W value x10^{-4}J; BV, bread volume, mL) bread making quality tests, were performed only at SAL.

RESULTS AND DISCUSSION

The 41-3", "Mut 3-04", and "8-1", IBLs selected using the new breeding scheme based on bridge crossing of the *Td* x *Dasypyrum villosum (Dv)* amphiplod to *Ta* , were significantly better than the testers for heading time and 1000 kernel weight, while maintaining good grain yield performance. The bread-making quality traits were significantly enhanced compared to the *Ta*-CS parent (Table 1). Major advantage of the breeding scheme rely on the induction and rapid fixation of new and stable assortments of the parental gene-blocks for grain yield and grain quality, offering ample opportunity to release cv for the diversity of agro-climatic conditions were low-input farming systems are practiced.

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Table 1-Grain yield, yield components, and bread making quality traits in inbred breeding lines selected from selfed progenies of fertile F_2 plants from *T. aestivum* x (*T. turgidum* x *D. villosum*) hybridization.

IBL and testers	Site	Plant height (cm)	HT	1000 kernel weight (g)	Grain yield (t ha^{-1})	Test weight (Kg hL^{-1})	PC	SSV	GI	DS	W	BV
41-3	SAL	90	33	37.8	7.4	76.4	12.3	89	98	25	334	685
	TOL	87	30	50.8	6.1	80.7						
Mut 3-04	SAL	88	33	39.4	7.3	77.0	12.6	91	99	33	375	720
	TOL	85	29	48.9	6.1	79.7						
8-1	SAL	89	33	37.2	7.1	74.9	12.6	91	99	23	400	710
	TOL	91	29	49.1	6.3	79.9						
Bologna (Tester)	SAL	86	36	29.2	6.8	77.0						
	TOL	79	39	34.8	6.8	81.8						
PR22R58 (Tester)	SAL	82	36	35.1	7.7	74.6						
	TOL	75	39	43.7	8.0	77.9						
CS (Tester)	SAL	105	35	29.5	na	64.7	12.2	48	32	93	90	560
SE	SAL	2.9	0.4	2.10	0.32	1.68	0.10	0.7	0.3	3.1	19.2	10.4
	TOL	3.1	0.8	1.54	0.20	0.70						

na: data not available due to lodging. SE: Standard error for comparing IBL mean values to the testers in each location

DESIGN AND EVALUATION OF RULE-BASED CROPPING SYSTEMS

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INTRODUCTION

Considering the increasing number of issues that are impacted by agricultural activities, designing innovative cropping systems (CS) to fulfil economic, environmental and social requirements should be a routine process for agronomists. Usually CS experiments compare the performances of cropping systems defined according to current standards (e.g. conventional vs organic) without any clear reference to the design process. As a matter of fact, design and field evaluation are not frequently combined in practice. One reason might be that, at the crop rotation level, more than at the crop level, the design process cannot be based on multi-factorial trials, because of the huge number of combinations to test over a crop sequence. To cope with this methodological bottleneck, a novel design and evaluation approach was proposed.

DESCRIPTION OF THE DESIGN AND EVALUATION APPROACH

This prototyping approach is based on 5 steps : (1) definition of goals and constraints for each cropping system ; (2) suggestion of suitable agronomic strategies (such as escape, avoidance, tolerance or correction of limiting factors) at crop and crop rotation level ; (3) formulation of relevant sets of technical rules, to put the strategies in action ; (4) implementation of the action rules in large field experiments or pilot farms ; (5) evaluation, refinement and eventually re-design of the CSs if not valuable (improvement loop).

A main feature of this method is to put the systems in action by means of action rules as: "if [indicator] then [action 1], else [action 2]". As a consequence, the techniques are not fixed but result conditionally from weather conditions, crop and pest development or soil status. To trigger most rules in practice, indicators of soil/plant/pest status are observed or simulated and then compared to a reference or a threshold value. The rules cover all the decisions of a crop management system but also the crop choice, the fallow management and the decisions at crop rotation level (as weed control). Consequently, the details of the crop/pest management techniques may change with locations and seasons while the agronomic strategy remains unchanged.

The experimental design is composed of a limited number of relevant combinations of crops and techniques, built to fulfil the objectives of the farmers while complying with the environmental concerns. Expert knowledge or models are used to select *ex ante* the most promising CS candidate(s) before a complete field experiment process. The evaluation process includes 3 levels: (1) global, multi-criteria and comprehensive, to test if the CS globally fits with the assigned objectives, using data collected at harvest or agri-environmental indicators; (2) agronomic, based on dynamic simulation or field measurements, to test the validity of the assumptions underlying the CS design; (3) analytical, to thoroughly evaluate some decision rules. In all events, data collected for the CS evaluation should be clearly separated from data used for rule triggering.

RESULTS

Several rule-based experiments have been set up in France from the 90s (Debaeke *et al*., 2009). To illustrate the previous approach, 3 case studies, differing by the context of crop production and resource use, are briefly exposed below: adaptation to limited irrigation water (Toulouse), introduction of innovative CSs (Versailles), substitution of herbicides by non-chemical methods (Dijon). The Toulouse experiment focused on methodological developments, *ex post* agronomical diagnosis and the development of decision tools to adapt the strategies to the environmental and economical context. The mean feature of the experiment in Versailles was to test very innovative strategies requiring frequent tunings of the sets of decision rules and an improvement loop with a short time-step. In contrast, the Dijon experiment tested CSs on a criterion (weed flora) subjected to cumulative effects, therefore requiring stable sets of decision rules during a long period.

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Table 1. Main features of three pluri-annual (8-12 yrs) experiments in France (Toulouse, Versailles, Dijon) designed and conducted according to the previous approach

	Toulouse	Versailles	Dijon
Objectives			
Agronomic	Adaptation to variable irrigation availabilities	Feasibility, sustainability of innovative CSs	Long-term weed control in IWM systems
Environmental	Optimizing water use, minimizing N leaching	Minimizing N leaching and the use of pesticides	Minimizing the use of herbicides
Economic	Maximizing GM, minimizing labour time	GM equal to conventional	No GM objective : evaluating the cost of IWM
Constraints			
General	Summer + winter crops	Wheat every 2 years	
Specific to a system	Irrigation availability	Direct seeding in mulches Organic, Low input	Minimum tillage, mechanical weeding (+/-) herbicides (+/-)
Agronomic strategy	Diversified rotation, stress escape, canopy rationing,	Pests and diseases escape	Diversified rotation, soil tillage, competitive crops
Rule building	Simulation + regional expertise + factorial trials	Expert knowledge Experimental references	Simulation + expertise + exp. references + DSS
Degree of rule explanation	+++ for N, water, cultivar + other inputs	Complete	+++ for weed management + other decisions
Lay-out	Plot size = 1.5 ha 4 replicates	Plot size = 0.5 ha 2 replicates	Plot size = 2 ha 2 replicates
Evaluation			
Global	Agronomical, GM, environmental (water use, nitrate, pesticide use), labour	Agronomical, GM, environmental (nitrate, pesticides, energy, earthworms), labour	Weed control, GM, environmental (pesticides, energy, GGE, nitrate), labour bottlenecks
Strategies	Disease reduction, weeds, water saving	Numerous	Canopy competitiveness
Rules	agronomic diagnosis + models + factorial trials : varieties, fungicides, plant density	agronomic diagnosis + check plots	check plots
Major revisions of systems and rules	Rule thresholds (N, water) crop changes in low-input system (less durum wh. and fababean under low-input)	Crop changes in the organic system (less oilseed rape, more alfalfa)	Increasing the part of legumes in the rotation

GM : Gross margin ; IWM : Integrated Weed Management ; DSS: Decision Support System ; GGE: Greenhouse gas emissions

APPLICATION OF A MODEL TO SUPPORT VARIETY EVALUATION AND CHOICE IN SUNFLOWER

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INTRODUCTION

The variety evaluation process is commonly based on the analysis of multi-environment trials (METs). In France, the official registration of a new cultivar is pronounced after two years of field testing using METs conducted by GEVES (Fig.1). Then the new sunflower cultivars are evaluated by CETIOM during one year (post-registration testing) over a wider area to determine their local adaptation and provide variety x management advices to the farmers. Although this 3-yr evaluation process is time-consuming and expensive, it results in a poor sampling of the soil-weather-crop management conditions over the sunflower growing area (~600 000 ha). We suggest that dynamic simulation models of variety response could improve the efficacy of this experimental evaluation. Several examples of model application are indicated in the literature: environmental diagnosis, detection of G x E interactions, selection of best variety x management combinations (Messina *et al*., 2006). This paper reports the attempt to include a sunflower model (SUNFLO) into the official evaluation scheme using a participative approach with CETIOM and GEVES.

MATERIALS AND METHODS

The SUNFLO model was developed to simulate the dynamic response of sunflower genotypes to various soil-weather environments and crop management options (sowing date, plant density, N-fertilization, irrigation) (Casabebaig, 2008). Its 12 genotypic parameters are easily measured on microplots devoted to variety testing (crop phenology, plant architecture, oil content and yield components) or in greenhouse (response of transpiration and leaf expansion to soil water deficit on isolated plants). Two main dynamic outputs are leaf area index and soil water content. Indicators of plant water status (number of stress.days) and nitrogen status (N Nutrition Index) are simulated at the end of each growing period. Achene yield and oil content are simulated at harvest.

In 2008, two field experiments were carried out by CETIOM in South-West and Center-West of France to determine the genotypic parameters in dense stands and non-limiting conditions for 18 oleic and linoleic cultivars. A greenhouse experiment was set up in INRA Toulouse to parameterize the response of these cultivars to varying water constraint levels.

In 2006 and 2007, the pre-registration field network (GEVES) was composed of 25 locations in France and the post-registration network (CETIOM) in 2008 of 47 locations. The output variables collected were: date of anthesis, plant height, achene yield and oil content.

The model was run over the 3 years after collecting 3 kinds of data: daily weather recordings (Tmin, Tmax, Radiation, Potential ET, Precipitations), soil (available soil water content) and crop management information.

RESULTS AND DISCUSSION

When using all the variety x environment combinations (320 data), achene yield was simulated with a relative error of 12.3 % (RMSE yield = 0.36 $t.ha^{-1}$) (Fig.2) and oil content with a RRMSE value of 6.8 % (RMSE oil = 3.1 %). The date of anthesis was detected with a mean error of 2.7 days. The mean environment (E) and mean genotype (G) effects were simulated with a RRMSE of 7.7 % on yield. These values are within the performance range of crop simulation models. Consequently, SUNFLO could be used reasonably to predict E and G rankings over the range of sunflower growing conditions in France. For each variety, the model provides additional information on water and nitrogen phasic stresses. Applied to probe genotypes, for instance, this information could be used for the *ex post* diagnosis of limiting factors. Actual achene yield (YLD) was expressed as a combination of the 3 simulated water stress indices (number of stress.days, WSD: 1. emergence-anthesis, 2. flowering, 3. grain filling) : $YLD = 0.23\ WSD_1 - 1.25\ WSD_2 + 0.22\ WSD_3 + 39.1$ (r^2= 0.95). Water stress during flowering was the most detrimental to yield.

In spite of the good agreement between observations and simulations, the yield prediction of a given variety is not enough accurate to imagine the complete replacement of METs by simulation. Firstly, the residual error is explained by the importance of pathogens (sclerotinia, phomopsis, phoma) which are not controlled on these trials and may reduce yield in some situations depending on the genotypic tolerance. Obviously, this is a limitation to a sound representation of G by E interactions by the model (Casadebaig, 2008). Secondly, the uncertainties on soil water content and initial soil nitrogen content (which may range from 30 to 180 $kg.ha^{-1}$) probably contribute to most of the gaps between simulation and observation. In addition, as weather data were collected from stations sometimes located at 20 km from the trials, additional errors might come from a bad representation of summer storms for instance. For using routinely this kind of model in official registration and extension activities: a) a minimum soil dataset should be provided by GEVES; b) additional genotypic parameters should be measured in some potential situations (field) and in stressed conditions (greenhouse) by CETIOM; c) virtual experiments should be carried out by CETIOM according to simulation protocols in order to determine the optimal G x E x M combinations for new cultivars in a given region.

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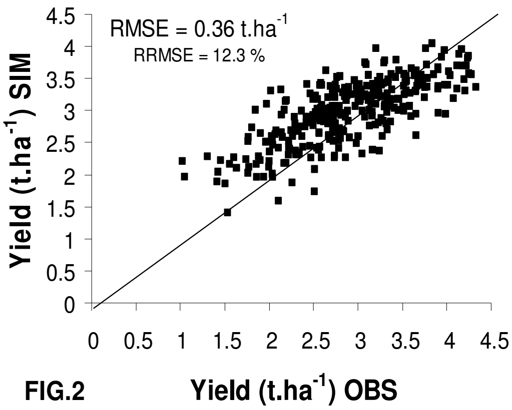

FIG.2

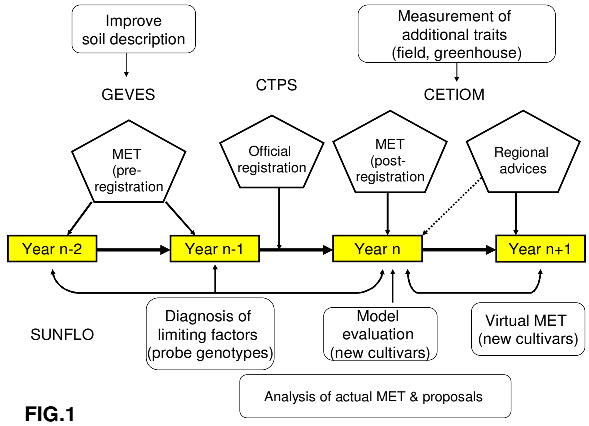

FIG.1

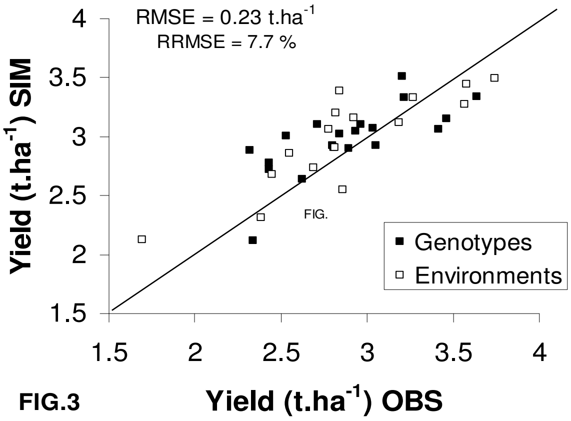

FIG.3

Fig.1 - A schematic representation of the actual variety registration process in France, of the possible contribution of a simulation model (SUNFLO) and of the actor's involvement

Fig.2 - Simulated vs observed yields for 320 'genotype – environment' combinations (2 years)

Fig.3 - Simulated vs observed yields for 16 environments (location-year) and 20 genotypes

A SUSTAINABLE FARMING SYSTEM TO MAXIMIZE PHOTOSYNTHESIS

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INTRODUCTION

Current dense planting practices limit the sunlight reaching the lower leaves of plants. We hypothesized that if we could enable the mature chloroplasts of specific cultivars to access more incident sunlight, we would increase the potential to produce photosynthates. Through proper selection of specific cultivars and variety specific population thresholds, we could convert this increase into increased crop yield. This paper will present the results of Phase I studies to test this hypothesis.

DESCRIPTION OF THE MODEL

This model develops canopy architectural properties that enable sunlight to reach each leaf in widely spaced twin-rows of the primary crop. Since each leaf is a potential source of photosynthesis and since current canopies shade the lower leaves that contain mature chloroplasts, this model should increase photosynthesis and potential crop yield (since crop yield is largely sourced from carbon based photosynthetic compounds). The current studies utilize an example (Fig. 1) of the model suitable where corn and winter wheat can be grown, using 30 and 10 inch row equipment. In this example we have:

- Solar corridors of sunlight between 60 inch twin-rows of corn that enable incident sunlight, the catalyst for photosynthesis, to reach each leaf for the entire reproductive stage of growth, and
- Solar corridors of sunlight between 30 inch wide swaths of winter wheat/clover 60 inches apart that enable sunlight to reach more of the photosynthetically active organs of the wheat plants for critical reproductive growth and extra light to clover seedlings until the corn leaves intercept the sunlight.

After corn harvest, the clover and young wheat receive incident sunlight until cessation of fall growth.

This example, as shown in Figure 1, is constructed by planting a 7.5 inch twin-row of corn every 60 inches, exactly in the center of 30 inch fallow swaths of winter wheat spaced every 60 inches, and by frost seeding clover into the 30 inch wheat swath in February. After corn harvest, the process is repeated with the center row of no-till wheat centered between the 7.5 inch twin rows of corn stalks.

This model provides a production environment that allows maximum interaction between the incident sunlight and the plant organs most capable of intercepting photosynthetically active radiation (PAR). The resulting higher rates and increased duration of photosynthesis for each of the mature chloroplasts (instead of relying on juvenile chloroplasts for most of the photosynthate production) should lead to an enriched production environment that maximizes PAR and total crop yield.

MATERIALS AND METHODS

Our hypothesis was tested (for the primary crop, corn, only) as detailed in Table 1. Hybrids B, C, and D were selected on the basis of their favorable performance in screening trials utilizing widely spaced single rows of corn. Hybrid A, a widely used high yielding variety, was included for comparison. Each of the four commercial hybrids studied demonstrated clearly different phenotypic expressions, indicating with some confidence that each were different genotypes.

Soils ranged from Bryce to Brenton silty clay loams to a Gilford sandy loam in the U. S. Corn Belt at latitudes from 40 to 41 degrees. Our study protocol used best supporting practices appropriate for the control, as independently determined by each study site and host producer. Interdisciplinary supporting practices to maximize the solar corridor treatment haven't been determined yet.

RESULTS AND DISCUSSION

Overall, on a corn yield per crop acre basis (vs. per corn acre basis), our data analysis showed that hybrid B, C and D solar corridor treatment yields exceeded those from conventional row spacing by an average of 9.4%, while hybrid A yields were reduced 2.8% (Fig. 2). Our results give corn yield per crop acre only, without recognition of any value for the secondary crop, or corn yield loss, due to the presence of the secondary crop. Figure 3 shows the results for the highest yielding population, with treatment yields exceeding 200 bushel/acre for each of the selected hybrids. As indicated by our results, if we select, on a site specific basis, the phenotypes that place the greatest reproductive sink demand on the now more productive photosynthetic source, we can deliver improved corn yields with the proposed model compared to the conventional row spaced controls. We expect that if we subsequently determine, on a hybrid specific basis, their specific population thresholds and appropriate interdisciplinary supporting practices, further yield increases can be achieved.

Phase II of this study considers our objective of producing maximum corn yield while producing an additional yield from the secondary crop (winter wheat and clover in this model), as well as identifying obstacles to be overcome before Phase II commercialization can be accomplished. Future work will address the interdisciplinary implications and subsequent research needs to further develop and complete the interdisciplinary and multidimensional model.

Figure 1: Crop System Cross Section

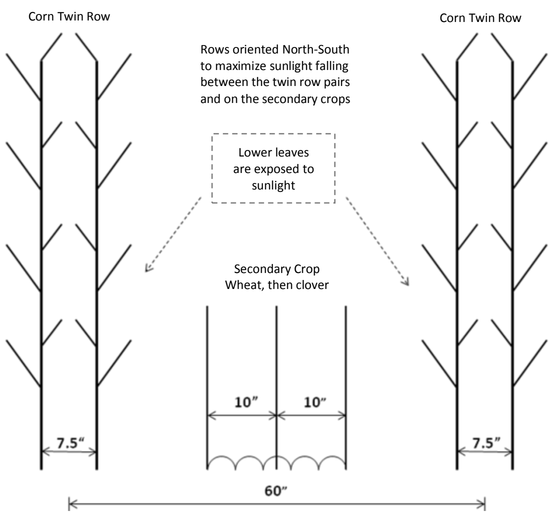


Table 1: Treatments

- 12 Production Environments
- 4 Hybrids (Designated A, B, C, and D)
- 4 Plant Populations
- 3 Replications
- Randomized Block Split/Split Plot design
  - 1st Split by hybrid, 2nd by plant population
- 2 Row width entries
  - Control: Single rows on 30 or 36 inch centers
  - Treatment: Twin rows on 60 or 72 inch centers
- All treatments were in north/south rows between 40 and 41 degrees North latitude

Figure 2: RESPONSE OF HYBRIDS TO ROW SPACING
Average Over 12 Environments and 4 Plant Populations

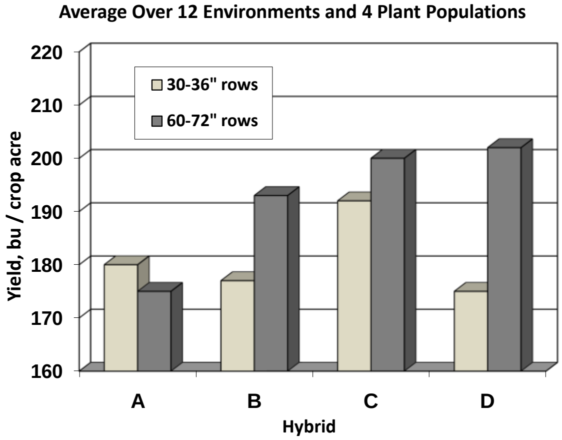
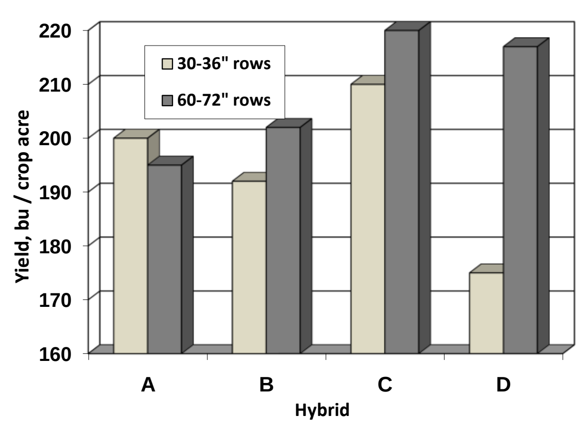


Figure 3: RESPONSE OF HYBRIDS TO ROW SPACING
Average at Highest Yielding Plant Population (30,000)



SCENARIOS ASSESSMENT FOR ALTERNATIVE FARMING SYSTEMS AT DIFFERENT SCALES: ADVANTAGES AND DRAWBACKS OF EXISTING APPROACHES AND PROPOSITIONS FOR THE CAMARGUE REGION

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INTRODUCTION

The design and implementation of alternative farming systems requires a combination of coordinated actions at different scales because, as the history of agronomic research shows, single technological innovations are seldom adopted by farmers. This shortcoming is often due to the fact that innovations do not fit in with the functioning of the farm as a whole and/or are incompatible with the policy and social environment in which the farmers function.

For *ex-ante* evaluation of alternative farming systems, scenarios must enable light to be shed on the plausible consequences of their adoption at different scales and to identify the main opportunities and bottlenecks in their implementation. The views and evaluation criteria of different stakeholders operating at different scales (from farm to region) must be taken into account to enhance the chances of success in the implementation of alternative farming systems.

The objective of this study was to make a comparative analysis of different approaches for scenarios assessment of agricultural systems at regional scales. Identifying their main advantages and drawbacks and pinpointing possible complementarities and incompatibilities is the first step toward the development and application of a multi-scale, multi-criteria and participatory method for scenario analysis of organic farming systems extension in the Camargue region, South of France.

METHODOLOGY

We identified three approaches commonly used for scenario analysis in relation to agriculture and land use. They are based on modeling which is necessary for quantitative and explorative studies. (i) Bio-Economic models (BEM) identify the optimum combination of agricultural activities that maximize or minimize an objective function under a set of constraints. Optimization is done by a multiple goal linear programming model (van Ittersum et al., 1998). (ii) Multi-agent models (MAS) are used to simulate the behavior of different agents (such as farmers and other stakeholders) and their interactions concerning the management of their activities and one or more natural resources (Bousquet and Le Page, 2004). (iii) Land use/cover change models (LUCC) identify and analyze relationships between biophysical and economic drivers for land use. The drivers of land use are statistically analyzed and hot-spots of land use change can be identified (using empirical functions of land use) in the case of a modification of an external factor (such as policies, finance, markets, new regulations) (Verburg et al., 2004).

The application of each approach was analyzed in relation to (i) the suitability of the approach for the analysis of scenarios and prospective evaluation (ii) the application of the approach for multicriteria analysis and the integration of the different domains of sustainability (i.e. environmental, social and economic), (iii) the scale(s) of application and the methods for up and down-scaling to and from regional scale, (iv) the degree of interaction with stakeholders.

RESULTS AND DISCUSSION

The three approaches enable the use of multiple indicators, therefore allowing an integrated and multicriteria analysis of farming and land use systems (Table 1). BEM appears to be a good tool for ex-ante assessment, as it is commonly based on mechanistic models allowing the inclusion of activities not yet practiced in a given region and the calculation of hardly measurable externalities. MAS is also a good approach for prospective studies as they can be formalized using decision rules and represent the stakeholders' view of their future. LUCC approaches are based on top-down perspectives built on projections and empirical functions of land use. LUCC is difficult to use for participatory assessment as it usually ignores the farm scale and the method used for down-scaling does not facilitate the use of participatory methods with farmers. In MAS and BEM, it is possible to explicitly formulate farmers' objectives, and as farmers should be considered as the ultimate decision makers with respect to land use, these approaches could enable strong links between farmers and stakeholders.

CONCLUSION

The analysis of the case studies showed that BEM and MAS are more suitable for prospective, multi-scale (up to regional), multi-criteria and participatory evaluation of scenarios for the development of alternative farming systems. On the basis of the results of this analysis, we are currently analyzing the complementary use of MAS and BEM to explore different scenarios related to the extension of organic farming in the Camargue in the south of France.

A six-step framework has been developed and it is now being implemented, which includes: 1. characterization of the systems at different scales in relation to stakeholders' perceptions, 2. definition of relevant indicators to be calculated, 3. identification of the options to be evaluated, 4. quantitative description of the agricultural activities at field scale, 5. aggregation of information for the quantification of indicators at multiple scales using BEM and MAS and finally, 6. iterative evaluation of scenarios on the basis of indicators and role playing games. Currently, our efforts are devoted to the selection of stakeholders and the description of land use activities using crop models.

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Table 1: Comparison of BEM, MAS and LUCC through their suitability for prospective, multiscale, multucriteria and participatory evaluation of alternative farming systems

Requirements	**Bio-Economic Modeling**	**Multi-Agent Systems**	**Land Use / Cover Change**
Prospective	Target oriented approach Mechanistic model, validation through sensitivity analysis	Individual based decision rules, empirical and mechanistic modeling, validation through behavior exploration	Model based on projections and statistical analysis of drivers of Land-Use.
Multiscale	Bottom-up and top down approach, Simple aggregation to up-scale from field to farm and region, could be spatialized if coupled with a GIS system	Bottom-up approach, no aggregation procedure, scaling is done through indicators calculation and observation of emerging properties, spatialized	Top-down approach, disaggregation through statistical analysis, minimum scale close to the square kilometer, no explicit consideration of field and farm scale, spatialized
Multicriteria	Multiple indicators (social, economical and environmental) through the objective function and constraints.	Multiple indicators (social, economical and environmental) through decision rules of the different stakeholders	Indicators mainly on environmental and economic aspects, recent developments allow calculation of social indicators
Participative	No explicit representation of stakeholders apart from farmers through objectives. Criticized for non realistic results, failure to be applied for concertation	Explicit representation of stakeholders (agents) and their decision rules. Commonly used in roles playing games as a tool for negotiation. Allow to incorporate perceptions and empirical knowledge in the model	No explicit representation of the stakeholders and their objectives. Suitable for high scale stakeholders concertation (country, region) but not for small scale stakeholders (e.g. no explicit representation of the farm)

MAXIMISING PRODUCTIVITY OF CROPPING SEQUENCES FOR DAIRY SUPPLEMENTS IN NEW ZEALAND

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INTRODUCTION

Intensive pasture-based dairy production in New Zealand's South Island relies on supplementary forage crops to enhance seasonal milk production and winter dry cow feeding (Clark et al., 2007). Intensification of dairy farming with more on-farm feed production and off-farm feed imports has implications for farm profitability and risks of nutrient leaching (de Klein and Ledgard 2001). Crops are increasingly being used for grazing on runoff land comprising short term rotations between pasture phases. Alternative systems such as 'cut and carry' or 'silage' crops grown during summer create opportunities for maximising productivity and reducing the nutrient loading on land. We evaluated experimental cropping sequences for their productivity and nitrogen (N) losses.

MATERIALS AND METHODS

Trials were conducted at Lincoln, New Zealand (43.83°S, 171.72°E) on a free draining alluvial soil. Soil water balances were determined using rainfall/irrigation, soil water content by neutron probe, and Penman PET calculations. Soil N was monitored to 1.5m depth. Biomass yield, soil N and drainage processes were compared with simulations for using the LUCI model, (Zyskowski et al., 2007).

Expt 1. (2005–2007): Crop sequences (45 x 4 m plots) were sown in a RCBD with split N sub plots. Crop main plots were cv Gruner kale (KL), multi-purpose cv Doubletake triticale (DT), cv Feast II Italian ryegrass (IT) and cv Crackerjack triticale (CJ) taken to silage maturity. Sequences (S1–S4) were DT–KL, KL–IT–DT, KL–CJ–IT and KL–CJ–KL with S1 sown on 24 Feb 2006 and S1–S3 on 3 Nov 2005. N rates were typical of grower applications 'Norm N' or double rate ('High N').

Expt 2. (2006–2008): Productivity of 12 crop sequences (T1–T12) in a spit plot (50 x 20 m) design were compared under optimum nutrient and irrigation over a 2-year period beginning in Oct. 2007 and with minimised breaks between crops. Treatments T1–T8 had maize (P39G12) or kale (cv Gruner) as the main plot first-summer crop. These were followed by factorial splits of winter wheat (cv Morph) or 'triticale (cv Crackerjack) +tick beans (var. NZ)' followed by maize or kale. T9–T12 (cv Salute barley as first summer crop) included 'grazable winter crops' (cv Titan rape then cv Milton oats, 'oats + Italian (cv Feast II)' followed by either whole crop barley (cv Salute) or kale (cv Kestrel).

RESULTS AND DISCUSSION

Expt. 1: Accumulated yield in the respective sequences ('High N') were 32.2, 56.8, 61.6 and 50.8 t/ha. Cumulative potential yield differences were influenced by variable season length. Simulated yields for 'Norm. N' were, on average, 5 t/ha less than 'High N'. Accumulated biomass was close to the simulated values (Fig 1A). Measured yield responses to N were small in most treatments indicating non limiting conditions for growth. In the 'Norm.N' treatment only small amounts of N were recovered from soil in the winter period. Excess N applied in the 'High N' treatments caused N leaching in wet conditions. Soil mineral N accumulation was higher under winter triticale than kale with N leaching events only occurring in the first winter. The second winter was dry with no N leaching loss.
Expt. 2: Optimum crop management practices were used to maximise productivity in all sequence treatments, while aiming for target annual DM yield of 45 t/ha (Brown et al. 2007). Highest annual

yield of 32.5 t/ha was achieved with a ‘maize–triticale+tick bean’ sequence. There was a significant yield penalty for not taking the winter cereal through to silage maturity (as in Expt. 1). A ‘kale – triticale + tick bean’ rotation produced yields that matched simulations closely (Fig 1B). Most of the N applied or derived from soil mineral N pools was removed by ‘cut and carry’ kale, maize silage or barley silage. Measured residual soil N (0–150 cm) following a summer maize was high (144 kg N/ha), but there was little loss by leaching (<10 kg N/ha). After maize, the net N loss in winter drainage under winter cereal was >113 kg N/ha compared to 40.1 and 9.9 kg N/ha following summer kale and summer barley. N loss was low following barley (<6 and <30 kg N/ha for rape and oats).

CONCLUSIONS

Crops with high N uptake such as kale were best options for ‘cut and carry’ systems. Yields of crop sequences were close to the theoretical limits in the South Island (NZ) environment. These were achieved with reduced transition time between crops and with no nutrient or water limitations. ‘Cut and carry’ with high N inputs did result in excessive residual soil mineral N primarily under maize cropping. Summer crops used N efficiently and N leaching was low in spite of regular irrigation. Potential for winter N leaching was high but actual leaching was variable depending on the soil water balance. Losses from a system grazed with high animal N excretion were not tested.

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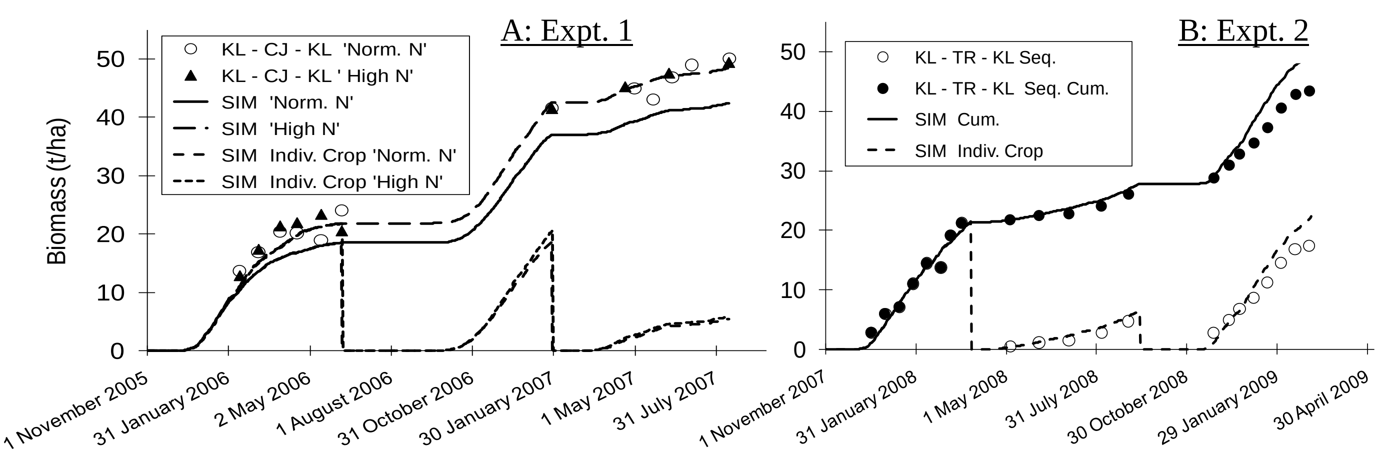

Fig. 1. Accumulated yield in equivalent cropping sequences in the respective experiments.

Long Term Effects of Cropping System Practices on Soil Organic Matter: Applications of the DSSAT Model

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INTRODUCTION

In the last 60 years soil organic carbon (SOC) depletion were related to same agricultural practices applied within intensive cropping systems (Doran, 2002). The adoption of deep soil tillage in continuous cereal rotations removing crop residues from the fields has been recognised as one of the most important reasons of the SOC decrease (Morari et al., 2006). Part of SOC which has been lost can be re-sequestered through adoption of recommended soil and crop management practices. While an increase of SOC in the top 10 cm could be substantial in order to contain soil erosion (Franzluebbers, 2002), the deeper layers could be considerable in the total carbon sink amount (Baker et al. 2007). These issues are often addressed through low N and tillage inputs.

The DSSAT v. 4.5 (Decision Support System for Agrotechnology Transfer) cropping system model (Hoogenboom et al., 2004), which includes the CENTURY soil organic carbon (SOC) module (Porter et al. 2009) and the CERES-Till module for tillage effects on soil processes were tested to simulate the long term dynamics of SOC.

The objective of this study was to analyze the long term impact of tillage and fertility management on soil organic matter in a low-input durum wheat-corn rotation in a hilly rainfed area in a northern Mediterranean context, using long term field experiments and model simulations.

MATERIALS AND METHODS

This study is based on a long term field experiment established on 1994 at the “Pasquale Rosati” farm of the Polytechnic University of Marche, in Agugliano (100 m a.s.l., 700 mm mean annual rainfall), in a hilly area (slope: 10-15%) with silt-clay soil. The experiment was designed to compare the effects of two different soil tillage practices on SOC: no till (S) vs 40 cm deep plowing (T) and two levels of nitrogen fertilization (0 and 90 kg ha^{-1} N) using a split-plot RCBD with two replicates for each crop (sub-plot size 500 m^2). Durum wheat and maize were alternatively sown every year on two adjacent groups of 8 sub-plots (2Tx2Nx2 reps), keeping same tillage and N input on each subplot. Glyphosate was spayed prior to sowing in no tilled plots, in addition to conventional chemical weed control. The SOC dynamic was simulated by DSSAT in relation to N fertilization and tillage practices. Daily meteorological data (Tmax, Tmin, precipitation) from 1998 through 2007 and daily radiation estimated by Radest 3.00 (Donatelli et al., 2003) were used as meteorological inputs. Soil texture, bulk density and SOC, among other soil variables, were measured from sixteen different soil profiles within the experimental field. Soil hydraulic properties were estimated according to Saxton and Rawls (2006). Crop grain yield was measured in the field (2004-07). Local farm surveys suggested to initialize SOC fractions starting from default model values (De Sanctis et al., 2008) for fifty years before 1994, using a durum wheat-maize rotation with conventional tillage and 140 kg ha^{-1} of N. The fifty years SOC dynamics was simulated in relation to the field experiment treatments.

RESULTS

Simulation outputs (crop grain yields and SOC after 12 years since the experiment started) were consistent with field data collected. Observed grain yield (2004-07) of fertilised wheat was significantly higher (3.66 vs. 1.80 t ha^{-1}) but not influenced by tillage techniques; grain yield of tilled maize was significantly higher (2.00 vs 0.90 t ha^{-1}), as a consequence of a poorer plant density, but summer drought stress flattened the effect of fertilisers. The total SOC dynamics in the 50 years was significantly influenced by the different tillage and fertiliser practices (table 1). The SOC simulation showed a steady SOC dynamic of the top 10 cm layer in the T90 treatment. SOC decrease (on average -0.003% SOC $year^{-1}$) was simulated for T0, due to the lower amount of crop residues incorporated in the soil. No till significantly increased top layer SOC: +0.009%, and 0.023% $year^{-1}$ respectively on S0 and S90. In the 10-30 cm soil layer, SOC was slightly increased by T90 (+0.003% $year^{-1}$) as a consequence of an higher amount of crop residues left in the soil and a more efficient incorporation of the crop residues in the deeper layers, while all other treatments did not significantly affect initial SOC. Overall, in the 0-30 cm layer, S90 lead to a significant gain in the carbon stock of the top soil 30 cm layer (+0.30 tons ha^{-1} $year^{-1}$). S0 and T90 treatments increased SOC was as low as +0.10 tons ha^{-1} $year^{-1}$, while T0 resulted in a not significant decrease of the carbon stock (-0.04 tons ha^{-1} $year^{-1}$).

CONCLUSIONS

Soil tillage and fertilisation practices can substantially affect the long term SOC dynamic in the rainfed hill cropping systems of central Italy, characterised by sub.-humid Mediterranean climate and silt-clay soils. Among the different options under comparison, no till and moderate N fertilisation (S90) proved to be the most effective option. However, limitations are related to low maize yield and incompatibility of no till with organic systems because herbicides are essential.

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Table 1. SOC dynamic (% weight) in top soil layer of durum wheat - maize rotation as influenced by N and tillage, vs. baseline measured in 1994. *=P<0.05; **=P<0.01; ns=not significant.

Soil layer (cm)	1994 (observed)	2044 (simulated)			
		T0	T90	S0	S90
0-10	0.87±0.11	0.71 *	0.87 ns	1.30 *	2.00 **
10-30	0.74±0.05	0.71 ns	0.87 *	0.66 ns	0.73 ns
0-30	**0.78±0.06**	**0.71 ns**	**0.87 ***	**0.87 ***	**1.15 ****

RE-DESIGNING OF VEGETABLE FARMING SYSTEMS IN SOUTH URUGUAY; LINKING THEORY AND PRACTICE

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INTRODUCTION

Most vegetable farms in Uruguay are family farms producing for the internal market, which had to deal with 20 years of continued decreasing of products prices and increasing of inputs and energy costs. The strategy followed by most farmers to maintain their income was to intensify and specialize their production systems, putting more pressure on already deteriorated soils and on limited farm resources. To explore options for sustainable development a study was conducted based on a bio-economic whole farm model which allowed taking into account different farm development paths. This study showed that for most vegetable farms it is possible to significantly increase family income, reduce soil erosion by a factor 2-4 and reverse soil organic matter decline by reducing the area of vegetable crops, implementing crop rotations including green manure, pastures, and forage crops, and integrating animal production, which is the opposite of the strategy followed by most farmers (Dogliotti et al. 2005).

To explore these hypotheses, a project was started at the end of 2004 and expanded in 2007 with participation of the Farmers' Unions. A basic assumption of this project is that the sustainability problems described above cannot be solved by isolated adjustments in some system components such as pest management or soil tillage but require whole farm re-design. Such a re-design of farm systems at the strategic level could be achieved by a participatory, interdisciplinary, systems approach. Involvement of the main stakeholders is particularly important since any intentional change in production systems is always a result of changes in human conduct and therefore requires an individual and collective learning process (Leeuwis 1999). Moreover, solutions to problems of this complexity do not come as 'take it or leave it' validated packages; they need to be designed within the context of application with direct involvement of farmers in all stages of the process, from diagnosis to dissemination (Leeuwis 1999; Masera et al. 2000). The EULACIAS project aims to improve sustainability of vegetable farming systems by linking quantitative systems approaches to participatory learning processes and on-farm diagnosis and design with main stakeholders as participants. This paper reports on the approach followed in the project and presents evidence of increasing sustainability of vegetable farming systems in Uruguay.

MATERIALS AND METHODS

The project is based on 16 pilot farms. Selection criteria included variability among pilot farms in resource endowment, soil quality and distance to the market, attitude of the farmers towards change, willingness to discuss their strategic choices, and involvement in local farmers' groups.

The systems approach involved diagnosis of farm system sustainability, re-design, implementation and evaluation, and dissemination. The pilot farms were characterized during a diagnosis phase. Sustainability was assessed following the MESMIS approach (Masera et al. 2000). With the farmers we identified the critical points for sustainability and drew up a problem tree of each farm.

The re-design procedure comprised improvements in erosion control support practices and spatial layout of fields; designing a feasible cropping plan according to resource availability and agronomic rules; designing and ex-ante evaluating crop rotations and inter-crop activities using ROTAT, RUSLE and ROTSOM. The plans were discussed with the farmers and modified until an agreement was reached.

Implementation and evaluation started in 2005 for a first group of six pilot farms.

RESULTS AND DISCUSSION

Average family income for the pilot farms increased from 2005 to 2008 by a factor 2.6 in average (constant prices). Estimated soil erosion rates for selected fields of these farms were reduced by a factor 2-3, although some of them still are above the tolerance level for these soil types (Fig. 1). The estimated rate of change of soil organic matter for some selected fields reversed from negative to positive values, the magnitude depending on the initial soil organic matter content of the topsoil. These results were achieved by increased crop yields, increased organic matter input to the soil and improved soil cover. Better market prices for some vegetable products during 2007-2008 also contributed to family income increase.

Yields increased mainly due to the effect of green and animal manures during the intercrop periods, improved crop management by matching labor demand and availability throughout the year, and lower frequencies of the same species and botanical family in the rotation. Including green manure crops and matching labor demand and availability required in many cases reducing the area of vegetable crops. Including green manure crops and 3-4 year pastures in the rotation contributed to improve soil quality by increasing organic matter input to the soil and keeping the soil covered.

This experience demonstrated that significant improvements in sustainability of vegetable farms in South Uruguay are feasible. However farmers will need technical assistance to re-design their production systems. For many farms their area and water availability are limiting their long term possibilities to increase income to acceptable levels without deteriorating the soil quality.

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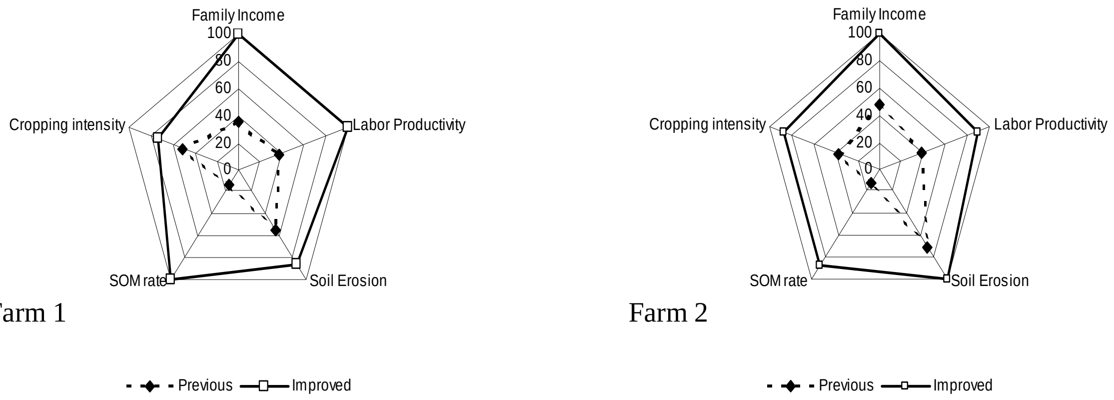

Figure 1. Results of the previous against the improved production systems implemented on two of the pilot farms relative to target values and best performance in the farm population. Targets: Family Income 12300 USD yr^{-1}; Labor productivity 3.1 USD hr^{-1}; Soil Erosion 7 Mg ha^{-1} yr^{-1}, SOM rate 700 Kg ha^{-1} yr^{-1}; Cropping intensity (vegetables cropped area/available area) 0.75.

A MODEL FRAMEWORK TO SIMULATE AGRO-MANAGEMENT AT FIELD AND FARM LEVEL

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INTRODUCTION

Farm management is the result of planned management for each production enterprise, and, during the growing season, of physical states at field level and resource competition at farm level. As an example, the irrigation scheme for each field at a given time leads to potential irrigations if the thresholds for irrigation set in the relevant rules are met. At farm level, such potential irrigations become quantities of water and labour required for each field, and they compete for the resources available. Rules for actions at farm level are a layer above the one at field level. In the case of a well adapted agro-management scheme, rules at farm level can possibly either delay of impede specific management actions either once resources become unexpectedly limited, or when environmental conditions change, such as under climate change scenarios. Modelling agro-management at field level provides estimates of technical feasibility and performance for a production enterprise, whereas the simulation of agro-management at farm level allows estimating agro-management feasibility either in concrete farms or in farm abstractions such as farm typologies.
Whether the logic above is known, its formalization in a flexible scheme suitable for different cropping system modelling approaches and its implementation in a concrete and reusable software component are not trivial. The rule-impact approach of the AgroManagement component (Donatelli et al., 2006) at field level and used in APES (2008) is now extended as tentative design at farm level. The objective of this paper is to present the main guidelines of the farm level model extension.

DESCRIPTION OF MODEL

The rule-impact approach at field level. When the decision making process is based on biophysical drivers, each management action is implemented both given to a pre-made management plan defining time windows and in response to the state of the system. For instance, plant a crop may be implemented if at a given date the soil water content of the first 0.6 m is at least 2/3 of plant available water is stored in the soil; if not, a fallow year may be acted on. The set of conditions to be tested to apply a specific management action are “rules”. Hence, rules are a formal way to model farmers’ decision making process in response to states of the physical system. A rule based model is characterized by 3 main sections:

- Inputs: state of the system, and time (e.g. soil plant available water and current day)
- Parameters (e.g. soil plant available water threshold to trigger irrigation)
- Model which returns a true/false output

Impacts stands for: "sets of parameters to implement the impact of a management event in a model component" (e.g., irrigation type = sprinkler, amount = 40 mm). Such sets are different changing management event, and can be different within management event if the modelling approach to implement the impact is based on alternate approaches. When making the planned agro-management scheme for a production enterprise (which in the real farm corresponds to a field), impacts are coupled to rules.
The rule approach at farm level. In the modelling of a farm, each production enterprise is simulated separately via instances of states, rates, and auxiliary variables, and using specific sets of parameters and an agro-management configuration (a collection of rule-impact objects, see above). At run time, each field simulation may make available one or more impacts if rules are triggered (Fig. 1). The impacts are not made available to agro-management models; instead the use of resources is quantified based on field information and

a set of coefficients if needed (e.g. an irrigation action, expressed in mm of water, becomes a flux, a number of working hours and the number of days required). Impacts are then ranked by priority; priority is chosen in the planning phase, but it increases every time an action is delayed by a priority factor also chosen in the planning phase. Actions are then applied using a set of rules which validate with respect to the availability on one or more resources (e.g., if water flux/amount is not limiting, it will validate against labour only). This workflow is summarized in Fig. 2. Initial resources available are an input at a time resolution equal to the time step of the simulation model, but if an accepted action implies the use of resources over more than a day, the availability of the following days is modified accordingly.

RESULTS AND DISCUSSION

The extension of agro-management simulation at farm level is expected to provide means to explore the technical feasibility either of new farms settings or of known agro-management schemes in farms under changed climate scenarios. It is also expected to be a useful tool to validate via bio-physical simulation the output of management optimization in farms via bio-economic models.

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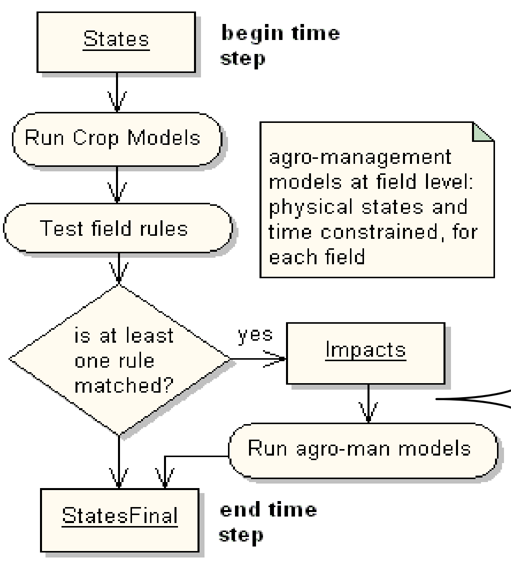

Fig. 1. Single field simulation: agro-management models are run if at least a rule is matched, using the impacts published; no limitation due to resources availability is imposed.

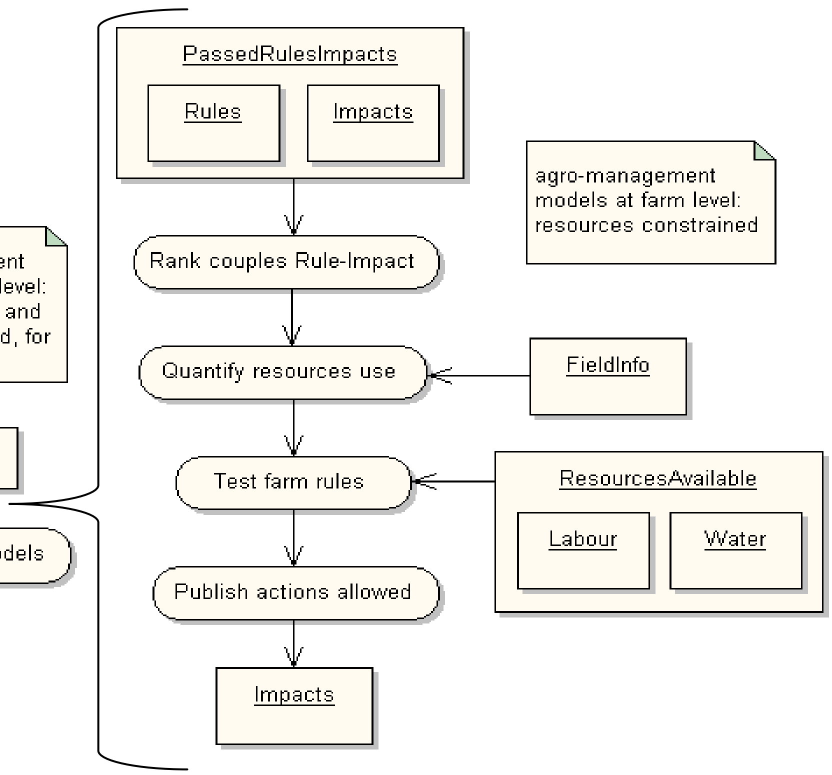

Fig. 2. Farm simulation: agro-management models are run, for each field, if an impact relevant to the field is published after allocating resources. Resources other than labour and water (e.g. implements) can be used as constraining factors.

COEXISTENCE BETWEEN GM AND NON GM MAIZE: EXPLAINING THE REPARTITION OF CROPS AND COEXISTENCE MEANS USED IN 2007

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INTRODUCTION

Setting up coexistence between GM (Genetically Modified) and non GM (NGM) crops means insuring that there is no cross pollination during production in order to respect a 0.9% threshold of GM in non GM material. We focused our work on improving a model of farmer's varietal choice (Coléno, 2008), which combined with a spatially-explicit population gene flow model (Angevin et al., 2008) evaluates the consequences of different scenarios of segregation strategies on maize mixing from the plot to the silo.

Our objective in this study was to know whether the adoption of GM maize in a farm had an effect on resources allocations or not. We also wanted to identify under what conditions was the GM maize cropped and in which farms and what was the allocation of GM and NGM maize in the farm in order to improve the model.

MATERIALS AND METHODS

We chose to study 6 counties in the South-west of France where 25% to 63% of the maize cropped in 2007 was GM in order to survey farms that, as GM and/or NGM maize producer, had had to manage the coexistence between GM and NGM crops.

As we wanted to identify the determining factors of GM adoption and of cropping system choice, we tried to survey the most varied sample of farms. We used the phone directory to build our sample of 23 farms, which we surveyed using semi-structured interviews (Miles and Hubermen, 1994).

A lot of data about the farm and its management was gathered, such as production resources (area, soils, distances, equipment, labour), productions on the farm (crops, livestocks, income repartition), technical choices in maize (cropping techniques, plots' localisation, varietal choice, crop succession, pest and disease management, coexistence means in 2007…), commercial and advising relations but also farmers opinions about the advantages and constraints of GM maize from their point of view.

We then synthesised and analysed these 23 interviews to identify the relations between these data and the presence of GM maize or not on the farm, the coexistence means used and the localisation of maize on the field pattern.

RESULTS AND DISCUSSION

The 23 farms we surveyed constitute a very diverse sample: 15 types of production combinations can be found from the all-cereal producer (5 farms) to the cereal/duck/seed/orchard producer (1 farm). In 7 cases, farmers had another activity either in relation with agriculture or not. Farm size varied from 33ha to 280ha with one to four workers on the farm. Maize was cropped on 7.6% to 80% of the UAA (Usable Agricultural Area) and maize was the first contributor to the farm income in 13 farms.

In 2007, only NGM maize was cropped on 9 farms (but in one farm GM maize was cropped in 2006). In the 14 farms where GM maize was cropped in 2007, GM maize accounted for 5-80% of the maize area. In 7 cases, GM maize represented 80% of the maize cropped.

As for the coexistence means, buffer zones were used in 14 farms cropping GM maize. Five farms isolated their maize (GM, organic or seeds) from other maize. In 6 cases, neighbouring farmers coordinated themselves to put in place a minimum distance between the GM and NGM plots. In two cases only, the farmer cropping GM maize did nothing (distance from the nearest maize or pop-corn as neighbour). Thus, a majority of farmers put in place a buffer zone, generally of 24 rows of NGM maize around their GM maize. Both the buffer zone and the 20% refuge area of NGM maize had been recommended by the Ministry of Agriculture (MAP, 2007) and the French maize trade union (AGPM, 2006).

As for the cropping system in place for maize in the farms surveyed, we found maize monoculture in 14 farms but the delay between two maize crop we found in farms was up to 7 years. Corn-borer or sesamia was perceived as a problem in 12 farms but only 8 of those treated their maize with an insecticide.

Using these data, we connected GM adoption to crop use, crop rotation, yield and pest presence. No GM maize was found in farms with a specialised output for their maize (organic, seeds, duck force-feeding). On the other hand, some factors increased GM adoption like high yield (no GM maize was found for a yield of less than 100q/ha), corn-borer presence (GM maize was found in 9 cases out of 12 when corn-borer was present, whereas it was found only in 5 cases out of 11 without a corn-borer perceived risk) and a high return of maize on the same plot (GM maize was found in 9 cases of monoculture out of 10 and only in 1 case of long rotation out of 5).

This can be explained by the fact that farmers with a specialised output had contracts specifying the use of NGM maize. As for farmers, with a high return of maize on the same plot or with a strong presence of corn-borer, they had more risk of yield loss and used GM maize as a safety measure. Farmers with a high yield had already optimised their cropping techniques in maize and their only leeway left to improve their yield was to use a new variety, the GM maize, to eliminate the small yield losses due to sanitary reasons. The same behaviour was observed on GM cotton (Hofs et al., 2006).

Farmers' opinion of the GM maize cropped in 2007 and 2006 differed: in 8 cases, farmers observed a yield increase (less than 15% in 6 cases and more than 15% in 2 cases), no effect in 6 cases and a 12% yield loss in one case as compared to the NGM maize the same year. In 6 cases, farmers observed an improvement of the sanitary state of the GM maize as compared to the NGM maize.

We thus found 3 kinds of reason for cropping GM maize: yield increase, sanitary state increase and work organisation (2 cases). Three kinds of reason for not (re)cropping GM maize were also found: technical reasons (no gain observed, other technical leeway to improve the yield), strategic reasons (specialised productions) and ideological reasons.

As for maize location, the only determining factors were the irrigation equipment and in some case the soil. No differences were found between GM and NGM maize crop management except for the coexistence means and the cancellation of insecticide treatment of GM maize in the case of corn-borer presence.

We are now beginning a comparison of our results with those found in another French region where the constraints are different, Alsace, in order to integrate these results in a multi-criteria model of maize allocation in space for France.

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Intercropping of Chinese cabbage and maize – traditional system with future potential for the North China Plain

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INTRODUCTION

Due to highly intensive agricultural production land and water resources are continuously degrading in the North China Plain endangering future food security. The rapid increase of vegetable production aggravates this trend, as vegetables demand significantly higher inputs in terms of water, fertilizer and plant protection. There is an urgent need to develop and disseminate more sustainable vegetable production systems in the region. Intercropping, the cultivation of two or more crops in the same field is a traditional system in the North China Plain. Farmers intercrop various vegetables with grain crops, trees and other vegetables. Several studies showed that intercropping can use environmental resources more efficiently and reduce leaching and erosion (Altieri, 1994; Liebmann, 2000; Zhang, 2003).

MATERIALS AND METHODS

In a seven to seven meter strip intercropping field trial with maize and Chinese cabbage, we tested the influence of the neighboring crop on growth and development. Two irrigation strategies "farmers' practice" and "farmers' practice minus 20%" were additionally tested. A randomized block design with four replications was used. The rows were oriented in north-south direction. The measurements were conducted in certain distances from the boarder of the two crops. The rows next to the neighboring crop were exposed to a real intercropping situation, whereas the rows in the middle of each strip were exposed to a monocropping situation. Various growth parameters, like plant height, leaf area index, dry matter of all above ground plant parts and growth stages were measured continuously over the growing season. Additionally solar radiation and soil temperature were measured to determine the effects on microclimate in the system. Two sets of Chinese cabbage, one in spring and one in autumn were grown next to spring maize. The experiment was run at Quzhou experimental station, China in 2008 and continued in 2009. Data were analyzed with the GLM procedure of the Statistical Analysis System.

RESULTS AND DISCUSSION

Reducing the irrigation amount by 20% had no significant effect on yield of spring maize and autumn Chinese cabbage. However, it had a significantly negative effect on the yield of spring Chinese cabbage. As precipitation during the winter months is hardly occurring in the region, sufficient irrigation previous to planting vegetables in early spring has to be recommended. Even though maize reduced solar radiation in the first rows of autumn Chinese cabbage by 30%, these rows produced a higher yield. The intercropped maize was significantly smaller and had less leaf and stem dry matter. However, due to a significantly higher harvest index, the plants in the first four rows over yielded the monocropped maize (Fig.1). We assume that the reduced intra-specifies competition for light in the first rows of maize allows the plants to generate a higher yield even though their leaf area is smaller. The intercropped rows of both crops did not generate a better yield under lower irrigation compared to the monocropped rows, and thus a higher water-use-efficiency could not be observed. Looking at the whole system of two sets of Chinese cabbage next to spring maize, the first two rows of maize and Chinese cabbage produced a land equivalent ratio of 1.07, rows three and four even of 1.09 (Tab. 1). It could be shown that this system generates significantly higher yields compared to monocropping. Higher yields make the only convincing argument for farmers to practice intercropping and moreover enhance a further dissemination of the system.

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Table 1: Land equivalent ratios of spring maize (SM), spring Chinese cabbage (SCC), autumn Chinese cabbage (ACC) and the whole intercropping system (LER).

Row	SM	SCC	ACC	LER
1 & 2	1.24	0.91	1.05	**1.07**
3 & 4	1.14	1.01	1.1	**1.09**
5 & 8	1.08	1.02	0.95	**1.02**
6 & 7 (monocr)	1	1	1	**1**

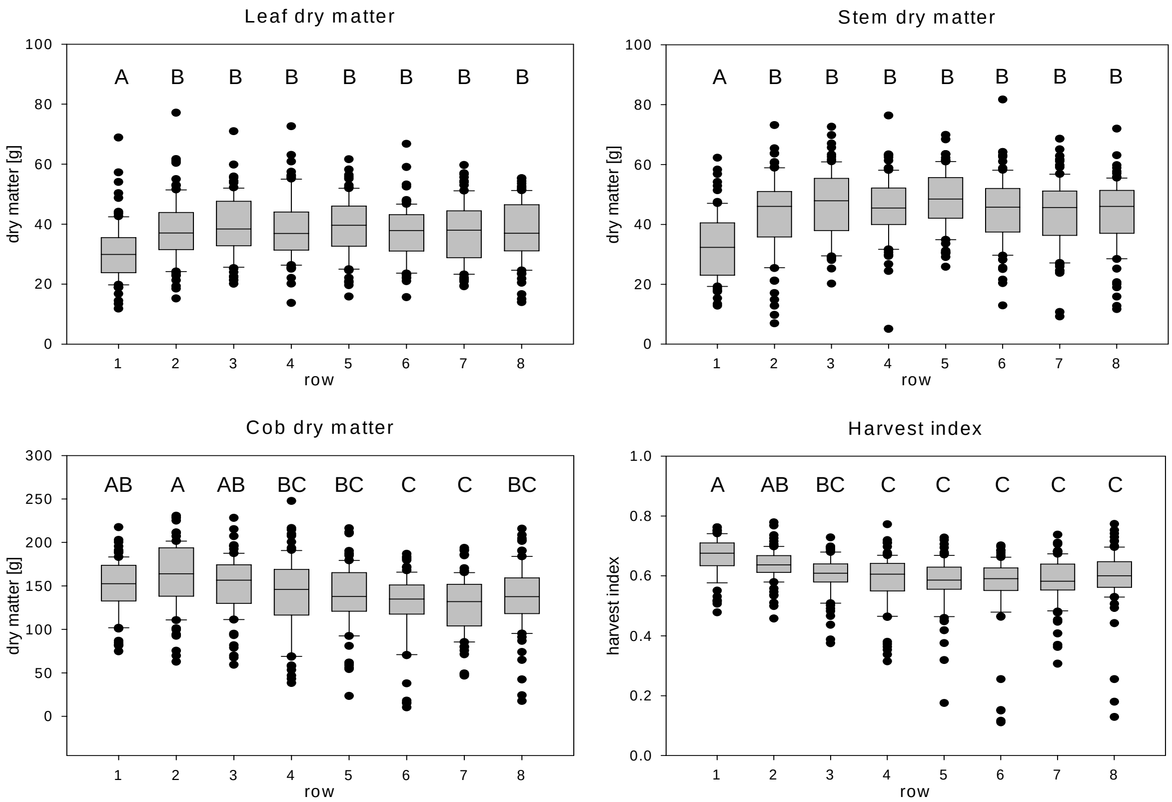

Figure 1: Leaf, stem and cob dry matter per plant and harvest index of spring maize at final harvest. Row one standing next to Chinese cabbage (intercropping); row six and seven are in the center of each plot (monocropping). Capital letters indicate significant differences (p<0.05).

Designing a forage crop production system to maximize annual radiation capture and utilization

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INTRODUCTION

In the past 20 years crop scientists have identified that factors that maximize radiation capture also maximize individual crop yield (Hay and Porter, 2006). However, in a farm system each crop is part of a continuous sequence and it may be necessary to trade-off yield of individual crops in the sequence in order to maximize the overall system yield. Isolated field experiments of rotation sequences would have limited relevance due to strong location and season effects on yield. However, simulation models could be used to design optimized sequences. Simulation models focus on individual crop growth and yield, but recently modeling platforms that link these models into sequences have been developed.

In this paper we present an example of a silage crop rotation used in New Zealand. This system uses a maize crop sown in late spring-early summer followed by an autumn sown cereal crop. Early sown maize crops have greater yields but force the premature harvest of a rapidly growing cereal crop in spring. Similarly, longer season maize hybrids out-yield short season hybrids but delay the sowing of the cereal crop. The influence of these trade-offs on the sequence yield is poorly understood. To determine their impact we linked a maize simulation model (Li et al., 2006; Wilson et al., 1995) with an established cereal model (Jamieson et al., 1998).

MATERIALS AND METHODS

The maize model was first validated against an experimental data set that included short, mid and long season hybrids and 10 sowing dates. This validation had a RMSD of 4.4 t/ha (data not shown) but slightly underestimated the yield of the long season hybrid from early sowings. However, it simulated the trend of decreasing maize yields with delayed sowing date and was therefore judged to be suitable for this analysis. The maize and cereal models were linked using the LUCI framework model (Zyskowski et al., 2007).

Sequences were simulated continuously for 28 years at four sites (Canterbury, Taranaki, Waikato and Northland) with differing spring and autumn transition dates between crops. The simulated maize crop was harvested at silage maturity and different transition times were achieved by altering the maize sowing date and the hybrid duration (short, mid and long season). The cereal crop was sown one day after maize harvest and cereal harvest occurred one day before the next maize sowing.

RESULTS AND DISCUSSION

Results were similar for all four sites so data are only presented for Waikato (Figure 1). Maize yields progressively declined as the maize sowing was delayed. At sowing dates before 1 Dec this reduction was offset by an increased cereal yield. However, at sowing dates later than 1 Dec the increase in cereal yield was less than the reduction in maize yield. As a result, the total sequence yield (averaged across the three hybrids) increased from 38.3 t/ha for a 20 Sep sowing to a maximum of 41.1 t/ha for a 1 Dec sowing, and then decreased to a minimum of 38.1 t/ha for a 6 Jan sowing. The long hybrid gave the greatest maize yield but meant that autumn sowing of the cereal crop was delayed; however, this had only a negligible effect on cereal yield. Thus, the long season maize hybrid gave the greatest sequence yield. The advantage of the long season hybrid decreased with delayed sowings.

The yield differences between the sequences could be explained by the capture and utilization of solar radiation. The maximum solar radiation was intercepted by the long season hybrid sown on 1 December (Figure 2). This minimized the transition, from a closed canopy of one crop to a closed canopy of the next crop, in order to maximize solar radiation interception. A 20 Sep maize sowing took longer to reach canopy closure due to cool spring temperatures. Thus, each delay in sowing up until 1 Dec increased the total radiation intercepted. Delaying maize sowing past 1 Dec decreased seasonal crop DM yield because it decreased total solar radiation interception and the proportion of solar radiation intercepted by maize (Figure 2). During summer maize has a greater radiation use efficiency (Sinclair and Muchow, 1999) than cereals.

This simulation study showed that the yield trade-offs between subsequent crops can be managed to maximize sequence yield. The largest sequence yields were achieved by choosing appropriate transition times between crops so that solar radiation capture was maximized; and ensuring that the most efficient crops were capturing this solar radiation at the appropriate time. In the present case sowing a long season maize hybrid around the 1 Dec achieved these goals.

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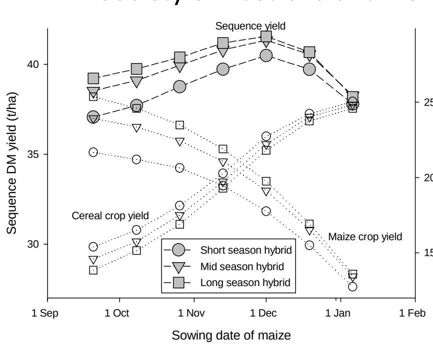

Figure 1 Average simulated maize, cereal and total dry matter yields for Waikato.

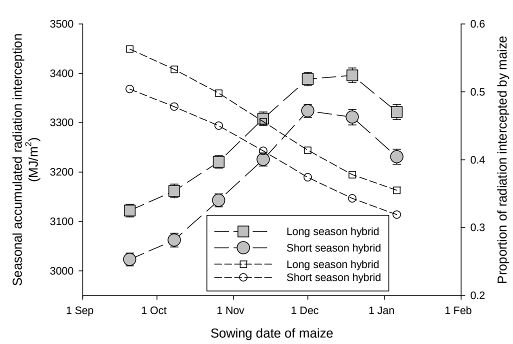

Figure 2 Average accumulated solar radiation interception each sequence (full symbols), and proportion of solar radiation intercepted by maize against maize sowing date for a long and short season maize hybrid.

Principles and models for circular agriculture development in China

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From the mid-20th century, the circular economy was developed in many countries under the influence of sustainable development. Agriculture, as the basic industries for human, which has the ten thousands of years of history, experienced different developing stages from primitive agriculture, traditional agriculture, conventional modern agriculture and to sustainable agriculture. World agriculture is also facing many serous challenges, such as the resources shortage, ecology degradation, environment pollution and energy crisis.

In China, Artificial energy input, such as fertilizers, pesticides, agricultural film, irrigation and agricultural machinery promoted the rapid development of agriculture, but it increased the consumption of fossil energy and production cost as well. About 20% of the agricultural labors, 30% of the fertilizers, 25% of the pesticides and 25% of the irrigation water of the world have been occupied in China agricultural production. From 1990 to 2005, fertilizers application has been increased from 25.9×10^6 t to 47.7×10^6 t (pure discount), pesticides input has been increased from 7.61×10^5 t to 1.46×10^6 t, agricultural film input has been increased from 6.42×10^5 t to 1.35×10^6 t, and the total power of agricultural machinery input has been increased from 5.9×10^7 kw to 1.26×10^8 kw. Cultivated land decreasing and water resource shortage were the two main factors limiting Chinese agricultural further development. At present, excessive fertilizer application and low use efficiency were common problems in china Fertilizer application was 357 kg hm^{-2} in 2003 in china, which 4 times of American, and fertilizer use efficiency of N, P, K were only 30%, 10-20%, and 35-50%, respectively. This problem also occurred in pesticides . The annual output of agricultural film reached 1.0×10^6 t, and increase by 10% annually. Morever, greenhouse gas and serious waste during agricultural production were widespread.

So it is imperative to explore the "circular way" to promote agriculture sustainable development. In this article, the concept and bisic principles were identified and the supporting technologies were discussed for China circular agriculture (CA)development.

1 The concept and basic principles for circular agriculture

The concept of the CA is still under discussion at present. What is CA?In our opinion, according to circular economy, CA will achieve the multi-level recycling use of matter and resources, and reach the maximum of resource use efficiency, minimum of external energy input, high efficiency recylinization of renewable resource and controlling the hazardous being and pollutant. So *CA is a mode that suited for sustainable agriculture, with the characteristic of "high economy efficiency, available technology, ecological safety, environment friendly and social approval".* And the "4R" rules should be obeyed to develop CA: "Recycle" for the waste resource, "Reuse" for the renewable resource, "Reduce" for the merchandise reosurce and "Regulating" for the pollution emission materials.

The main difference between circular agriculture and traditional agriculture as follows: More attention was paid to the application of the concept of circular economy to agricultural production. The "life cycle control" was promoted in the whole process of agricultural production and process of agricultural products. High investment, high-yield, high consumption, high emission is not encouraged in circular agriculture. On the contrary, more attention was paid to the establishment of production targets of resources efficient use, minimizing external input and minimizing pollutant emissions.

2 **Basic model of circular agriculture in china**

2.1 Recycling production model, including kinds of multi-cropping pattern and comprehensive utilization of straw. The typical multi-cropping model in China were maize/soybean, wheat/phoenix tree, rape/early rice/late rice, tree/fungus, and so on. The straw comprehensive utilization pattern including: the wheat root stubble and maize stalks crushed are returned to the field, total maize straws crushed is incorporated into the field, total wheat and maize straws crushed are incorporated into the field, maize straws uncrushed is incorporated into soil, and no-tillage with straw mulching on soil surface.

2.2 Combination cultivation and raising industry, Which including:the circular patterns of crop-livestock represented by grain and pig, the circular patterns of grass –livestock, the circular patterns of rice-fish ecosystem, the dimensional patterns of rice- ducks in paddy fields, and the circular patterns of fish pond-dike system.

2.3 Agricultural wastes processing and using. Various patterns were developed in the past more than 20 years in china, including:pattern of transforming agricultural wastes into biomass energy, pattern of using agricultural residues cultivating fungus (mushroom), circulation pattern of waste substrate of mushroom, comprehensive utilization pattern of excrements and sewage in breeding farm, comprehensive utilization pattern of corncob, circulating pattern of straw stalk transformed into the paper pulp and the fertilizer, and mixed pattern of straw raising Lotus or Lotus-fish.

3 conclusion

Along with the rapid economy development in China, it is necessary to set up a new production and consumption pattern following the theory of circular economy based on utilizing resources and energy in the most effective way and protecting environment. The technology innovation of the CA can not only solve the contradiction among the fast development of economy, the correspondingly deficient resources and the environment pollution in China, but also is the strategic demand of the sustainable development of science and technology in China.

RECORD: a new software platform to model and simulate cropping systems

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INTRODUCTION

In order to extend the use of simulation models for the design of innovative cropping systems, the French Research Institute INRA has launched the RECORD project for the development of a modelling and simulation software platform for crop scientists. The platform is now available and is currently evaluated on several cropping system modelling projects before its larger diffusion in INRA research laboratories.

RECORD is a platform designed for developing models of cropping systems, including crops, soils, pests, pathogens and farm managers, at different spatial and temporal scales. Scientists will use the RECORD platform to develop new models as modular components, to re-use and combine them in order to represent cropping systems and to share them with the community. In accordance with these specifications, the generic VLE (Virtual Laboratory Environment) simulation platform, an object-oriented programming software based on the DEVS formalism, has been chosen as the simulation kernel.

The second objective of the RECORD platform is to allow scientists to work with this simulation models: designing simulation experiments for parameters estimation, sensitivity analysis, optimization. The solution proposed by RECORD consists in using generic or specific methods developed with scientific softwares like R, which are directly linked with VLE.

DEVS MODELS AND VLE

The Modeling and Simulation (M&S) theory (Zeigler et al., 2000) addresses major issues of computer sciences, from artificial intelligence to model design and distributed simulations. The DEVS discrete event formalism of the M&S theory is a common framework (formal and operational) for the specification of dynamical systems. DEVS defines an atomic model as a set of input and output ports and a set of state transition functions. Every atomic model can be coupled with one or several other atomic models to build a coupled model. This operation can be repeated to form a hierarchy of coupled models. The set of atomic and coupled models and their connections forms the structure of the model.

The VLE Virtual Laboratory Environment (Quesnel et al., 2009) is an original framework that can be used to model, simulate, analysis or visualize dynamics of complex systems. It is a free and open source software and its API (Application Programming Interface) that provides C++ libraries which support multi-modeling and simulation by implementing the DEVS abstract simulator. VLE is oriented toward the integration of heterogeneous formalisms like ordinary differential equations, difference equations, finite state automata, cellular automata, etc. Furthermore, VLE is able to integrate specific models developed in most popular programming languages into one single multi-model.

BUILDING MODELS WITHIN RECORD

The model construction of a specific cropping system is conducted through a three-steps approach. First, the systemic analysis of the cropping system allows to define the different atomic or coupled models to implement, their hierarchical organization and their granularity. Then, atomic models are implemented as VLE components. Finally, these components are linked in order to define the whole cropping system model.

Atomic components can be built in different ways. Models based on various formalisms, e.g. differential equations, difference equations, state automata, cellular automata, decision rules, can be either described directly at the modelling language level or using the C++ API of VLE. Models originally developed outside the platform can be easily adapted and included within RECORD. The crop model STICS (Brisson et al., 1998) was thus recently included within RECORD after several adaptations: the time and the spatial dynamics was delegated to the VLE simulation engine, the procedure of model initialization was modified, and the program was encapsulated.

The linkage of components can be done through *gvle*, the graphical interface of VLE. With this interface, modellers can visualize the whole model at its different hierarchical levels. Atomic or coupled submodels can be included for building the whole model. The persistence of the linkage work is provided by an xml file (extension vpz) which is automatically generated by saving the work within *gvle*.

WORKING WITH MODELS

People working with RECORD are modellers, model linkers, and model users. RECORD provides functionalities adapted to their specific requirements. For modellers, a wide range of API classes and numerical libraries cover the needs for cropping systems modelling. A repository of validated and well documented models allows model linkers to “pick up” existing components. The *gvle* interface of the platform can be used to plan model simulations and to specify the type of needed outputs. Users can also work directly from the R statistical software, or run simulations on a distant server through a web-interface.

PERSPECTIVES

For some months, several models, e.g. crop rotations (Dury et al. 2009), TNT2 (Beaujouan et al., 2002), STICS (Brisson et al. 1998), and statistical methods (Quesnel et al. 2009) have been developed or reimplemented within RECORD/ VLE. The platform is planned to be launched in spring 2010 (see *http://record.toulouse.inra.fr*).

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CROPSYST MODEL APPLICATION TO IDENTIFY MORE SUITABLE CROPPING SYSTEMS IN WATER LIMITED CONDITIONS

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INTRODUCTION

Continuous wheat is one of the most common cropping systems in Mediterranean countries, especially in rainfed conditions. This cropping system is characterised by low input (tillage, fertilisers and pesticides), but it can produce detrimental effects on soil fertility (Blair and Crocker, 2000). Consequently, it may be necessary to increase the level of technical input to obtain a satisfactory grain yield or, alternatively, could be useful to use crop rotations. Aim of this work is to simulate durum wheat (*Triticum durum* Desf.) in continuous cropping and in 2-year and in 3-year rotation with chickpea (*Cicer arietinum* L.) and sunflower (*Helianthus annuus* L.) to evaluate the cropping systems response on a long-term basis, by different points of view.

MATERIALS AND METHODS

The CropSyst simulation model (Stockle *et al*., 2003) was previously calibrated and validated for sunflower (Donatelli *et al*., 1997), durum wheat and legume crop (Garofalo *et al*., 2008) and recalibrated for chickpea. It was used in a seasonal analysis (54 years of daily weather data) to compare wheat (DW) cropped as “continuous crop” (CC) and in sequence with sunflower (SF) and chickpea (CP) in 2-year (DW_1-CP and DW_1-SF) and 3-year (DW_1-DW_2-CP, DW_1-DW_2-SF), where the pedix indicate the wheat after chickpea or sunflower (DW_1) and after wheat (DW_2). For the 2-y and 3-y rotations the simulation runs were performed starting with the different crops. DW was fertilised with 100 kg of nitrogen ha^{-1}, whereas SF with 120 kg ha^{-1} split in two applications. No nitrogen application was simulated for CP. Only for SF one irrigation (80 mm) at flowering was managed. Crop residues were removed in the case of DW and SF and soil incorporated for CP. Weather data, soil characteristics and typical crop management for all the crops in Southern Italy were used in simulation input files. The main crop productivity components, ETc, soil nitrogen and organic matter content and net income (gross margin minus expenses) were examined.

RESULTS

CropSyst model simulated a positive effects (Tab. 1 and 2) for biomass and grain yield of DW, if CC is grown with other crops in a rotation, either CP or SF, with an increase of dry biomass over 7% and 4.6% on average for grain yield, considering 2-y and 3-y rotations. This improvement can be explained by a greater soil water content at sowing for DW in sequence with the other crops, which produced an higher nitrogen uptake (Tab. 1 and 2). For DW in sequence with CP, the higher soil moisture was due to the legume root depth (over 1.2 meter) and greater WUE (Garofalo *et al*., 2009), whereas for SF the irrigation at flowering ensured discrete residual moisture for the following crop. Improvement of soil organic matter was also observed for DW in sequence with both crops, with an increase of 3% on average.

Considering SF and CP crops, no significant variation of examined variables was noticed between the 2-y and 3-y rotations, except the soil organic matter content in SF (higher in 3-y) and net income for CP (higher in 2-y rotation). Tables 1 and 2 show as the net income of DW increased of 18% if rotated with CP (208 vs. 177 € ha^{-1}) and 8% if rotated with SF (190 vs. 177 € ha^{-1}).

Finally, if we consider the net income of whole cropping system, the introduction of chickpea significantly increased the profitability (354, 125 and 177 € ha^{-1}, respectively for cropping systems with CP, SF and for CC).

CONCLUSIONS

The simulation results indicated that growing wheat in a rotation with chickpea or sunflower may lead to higher and more stable yields than growing wheat as a monocrop. This is particularly true when growing it with chickpea, thanks to a lower water consumption by the legume crop; this crops ensures also advantages from an environmental point of view, considering the N-fixation capability of CP and the organic matter enrichment. Moreover, crop legumes do not require nitrogen fertilization and irrigation (Rinaldi *et al*., 2008), and consequently reduce the management cost, with the benefit related to farmer's income.

ACKNOWLEDGEMENTS

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Table 1 – Long-term (averages and standard deviations) of CropSyst simulated output for the three crops in the different cropping systems.

	TDM *($t\ ha^{-1}$)*	***Yield*** *($t\ ha^{-1}$)*	***ETc*** *mm*	***N uptake*** *($kg\ ha^{-1}$)*	***Soil o.m.*** *%*	***Net income*** *(€/ha)*
Wheat						
CC	7.81 (± 1.77)	2.27 (± 0.58)	335 (± 48)	147 (± 31)	1.15 (± 0.02)	177 (± 151)
DW_1-*CP*	8.76 (± 1.35)	2.57 (± 0.42)	350 (± 43)	177 (± 15)	1.21 (± 0.03)	226 (± 123)
DW_1-*SF*	8.34 (± 1.57)	2.43 (± 0.50)	342 (± 46)	183 (± 33)	1.17 (± 0.01)	187 (± 134)
DW_1-DW_2- *CP*	8.64 (± 1.25)	2.53 (± 0.39)	349 (± 43)	166 (± 17)	1.21 (± 0.03)	218 (± 92)
DW_2- *CP*-DW_1	8.26 (± 1.65)	2.41 (± 0.53)	340 (± 47)	167 (± 22)	1.20 (± 0.03)	181 (± 143)
DW_1- DW_2- *SF*	8.20 (± 1.46)	2.39 (± 0.47)	342 (± 46)	160 (± 34)	1.17 (± 0.02)	180 (± 116)
DW_2-*SF*- DW_1	8.15 (± 1.69)	2.37 (± 0.54)	338 (± 48)	167 (± 34)	1.17 (± 0.02)	204 (± 142)
Sunflower						
DW_1-*SF*	6.39 (± 1.95)	1.96 (± 0.60)	337 (± 45)	176 (± 30)	1.15 (± 0.01)	12 (± 179)
DW_2-*SF*-DW_1	6.38 (± 1.87)	1.96 (± 0.56)	338 (± 45)	168 (± 26)	1.22 (± 0.11)	10 (± 169)
Chickpea						
DW_1-*CP*	8.74 (± 3.07)	2.00 (± 0.76)	291 (± 38)	202 (± 77)	1.20 (± 0.03)	672 (± 403)
DW_2-*CP*-DW_1	8.58 (± 3.17)	1.97 (± 0.78)	289 (± 39)	201 (± 80)	1.19 (± 0.03)	474 (± 420)

Table 2 – Statistical significance of orthogonal contrasts of analysed variables for durum wheat, sunflower and chickpea (ns. = not significant; * = P < 0.05; ** = P < 0.01; *** = P < 0.001).

Contrasts	***TDM*** *($t\ ha^{-1}$)*	***Yield*** *($t\ ha^{-1}$)*	***ETc*** *mm*	***N uptake*** *($kg\ ha^{-1}$)*	***Soil o.m.*** *%*	***Net income*** *(€/ha)*
Wheat						
CC vs ALL	*	*	ns.	***	***	**
2-y vs 3-y	ns.	ns.	ns.	***	ns.	ns.
DW_1 *vs* DW_2	ns.	ns.	ns.	**	**	**
CP vs SF	ns.	ns.	ns.	ns.	ns.	***
Sunflower						
2-y vs 3-y	ns.	ns.	ns.	ns.	***	ns.
Chickpea						
2-y vs 3-y	ns.	ns.	ns.	ns.	ns.	**

DOES DISEASE RESISTANCE HAVE A COST IN POTENTIAL YIELD OF WINTER BREAD WHEAT VARIETIES?

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INTRODUCTION

The growing concern about the environmental impacts of farming practices is driving an increasing number of farmers to adopt crop management systems combining low input levels and varieties resistant to several diseases. In turn, over the last 20 years, French breeders have been working on improving resistance of winter wheat varieties to the main diseases (Lonnet, 1997). Meanwhile, the world population has been constantly increasing, requiring an increase in wheat production and thus an increase in varietal productivity.

These varietal characteristics are thought to be antagonist. In fact, several studies have shown a yield penalty of disease resistance in winter wheat (Brown, 2002). This penalty must be clearly quantified in order to be able to forecast the global loss of potential wheat production if those systems combining low input levels and resistant varieties were adopted at a larger scale.

MATERIALS AND METHODS

To quantify the impact of the main disease resistances on the potential yield (the yield achieved without any disease in the crop), we used data from GEVES, the French organization in charge of the registration of new varieties. These data involve 192 winter bread wheat varieties assessed in the northern part of France between 1991 and 2007. During the registration process, each variety has been assessed in trials carried out on 7 to 20 sites over 2 successive years. In each trial, the varieties were grown under two cropping systems, one totally protected against diseases providing the potential varietal yields (PY) and another one with no disease control used to assess varietal resistance to the main diseases according to a 1 to 9 discrete scale.

In order to take into account the complexity of the trial network design into our statistical treatment, we used a mixed model considering genotype effects of interest as fixed and environment effects or residual genotype effect (GEN') as random. The environment of the trial was described by two nested grouping levels: (i) the year (YEAR) and (ii) the location into the year (LOC). In our study, the genotype fixed effects are the following genotype characteristics known to have an impact on yield: (i) wheat quality (WQ: factor presenting two levels, common quality [CQ], and superior quality [SQ]), (ii) first year assessment (FYA: this variable will allow to assess the genetic improvement between 1991 and 2006) and (iii) disease resistance. As the list of disease resistance assessed during the registration has slightly changed in the last 16 years (because of the evolution of main disease pressures in France), we first used in our model an overall resistance (OR) for each variety estimated by averaging all the disease resistances characterized at the time of its registration. In a second step, we considered individually the resistances of brown rust, yellow rust, powdery mildew, *septoria tritici* blotch, *septoria nodorum* blotch, eyespot and *fusarium*.

Since each variety has been assessed on a 2 successive year period, there is an important risk of confusion between the effect of the trial year (YEAR) and the effect of the first year assessment (FYA). To best estimate the trial year effect and thus reduce this risk of confusion, we considered in our study 16 winter bread wheat varieties grown as reference varieties in each trial on several years (from 2 to 16 years). To make the difference between those reference varieties and the assessed varieties, we introduced a factor STATUS presenting two levels (REF for the reference varieties and ASS for the assessed ones). The statistical analysis was then realised with the following model:

$$PYtijk \sim \mu + STATUSt + STATUSt{:}WQi + STATUSt{:}FYAi + STATUSt{:}ORi \quad \text{(fixed effect)}$$
$$+ \mathit{STATUSt{:}GEN'i + YEARj + LOCjk + \varepsilon tijk} \quad \textit{(random effect)}$$

RESULTS

Enhancing the quality of bread wheat has a small negative impact on yield. In fact, the yield of SQ varieties is on the average 43 kg/ha smaller than the one of CQ varieties (Table 1).

The potential yield increased by 54 kg/ha each year over the last 16 years (Table 1). This increase due to genetic improvement, confirms the annual yield improvement assessed by Brancourt-Humel *et al.* (2003) over a period of 50 years between 1946 and 1992. However, this improvement is lower than the 90 kg/ha/an assessed on winter wheat in trials between 1991 and 1999 (Luciani, 2004). By selecting in our database, we showed that the yield has increased by 85 kg/ha/an (sd=16 kg/ha/an) before 2000 and only by 11 kg/ha/an (sd=13 kg/ha/an) between 2000 and 2006. Thus the yield progress seems to have sharply decreased over those last six years!

Finally, the overall resistance has a significant impact on potential yield. Indeed, a one point increase of this resistance decreases the potential yield by 112 kg/ha (sd=25 kg/ha) (Table 1). Thus, in a disease free context, the yield achieved by a resistant variety (GR=7) will be 0.5 t/ha lower than the one achieved by a sensitive variety (GR=3). Furthermore, this resistance impact ranges from 2 to 65 kg/ha/U according to the disease considered (Table 2). However, the cost of resistance is all the smaller that the disease pressure increases in the field. For instance, Zhang *et al.* (2005) have shown that for a potential yield of 9 t/ha and a medium intensity (4 on a 0 to 8 discrete scale) of brown rust, yellow rust, *septoria tritici* blotch and powdery mildew in the environment, increasing the varietal resistance of one point can decrease the yield loss of respectively 68 kg/ha, 76 kg/ha, 112 kg/ha and 50 kg/ha, which compensate the cost of the resistance to each of those diseases.

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Table 1: Estimation of mixed model fixed effects for the assessed varieties (STATUS="ASS")

	Fitted value	Standard deviation
μ	9.528 tons/ha	0.189 tons/ha
WQ = "SQ"	-43 kg/ha	40 kg/ha
FYA	54 kg/ha/year	5 kg/ha/year
OR	-112 kg/ha/U	32 kg/ha/U

kg: kilogramme
ha: hectare
U: unit of disease resistance on a 1 to 9 discrete scale

Table 2: Estimation of varietal resistance cost by disease

	Fitting period	Fitted value	Standard deviation
fusarium	1991-2002,2005,2006	-2 kg/ha/U	21 kg/ha/U
yellow rust	1991-2006	-9 kg/ha/U	12 kg/ha/U
eyespot	1991-2006	-21 kg/ha/U	12 kg/ha/U
brown rust	1991-2006	-23 kg/ha/U	13 kg/ha/U
septoria nodorum blotch	1991-2003	-33 kg/ha/U	24 kg/ha/U
powdery mildew	1991-2006	-49 kg/ha/U	18 kg/ha/U
septoria tritici blotch	1999-2006	-65 kg/ha/U	26 kg/ha/U

IS THE BETHA-VAR MODEL ABLE TO IDENTIFY THE CULTIVARS BEST SUITED TO LOW-INPUT CROP MANAGEMENT SYSTEM?

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INTRODUCTION

The growing concern about the environmental impact of farming practices, combined with the sharp increase of input prices, leads even more farmers to adopt crop management systems requiring lower level of inputs. Yet high yielding winter wheat cultivars obtained poor yields when grown with a low level of inputs (Loyce *et al.* 2008). In order to select cultivars able to maintain satisfying yield when grow under low-input crop management systems, breeders must adapt their varietal evaluation system. Up to now, this evaluation system has been composed of trials carried out during several years and locations representative of the target growing area, but in a very low range of crop management systems. Most trials were carried out under intensive conditions in order to select high-yielding cultivars. As it is too costly to test all cultivars under low input systems, agronomic models seem valuable tools to forecast the performance of new cultivars in crop management systems unexplored by the multi-environmental trial network. This presentation aims at assessing the predictive and decisional quality of Betha-var (Loyce *et al.* 2002; Zhang *et al*. 2005), a parsimonious static model simulating the performance of cultivars under a wide range of crop management systems.

MATERIALS AND METHODS

We used in this study experiments carried out in 2003 on four locations in the west and north of France. In each trial, 20 wheat varieties were grown under two different crop management systems, a high-input one (HI) and a low-input one (LI).

In a first step the Betha-var model was assessed on its predictive value for yield. This first assessment was based on the calculation of the relative root mean squared error of prediction (RRMSEP).

In a second step, another type of assessment was realised, aiming at testing the capacity of the model to help the user to take an appropriate decision. To do it, we proposed a methodology for evaluating the decisional quality of an agronomic model. The steps of this methodology are detailed below and illustrated by our breeding study case:

(i) *Identification of the main end-use of the model*: in our case, the breeder is interested in selecting, from experimental results obtained on HI trials, the cultivars best suited to a low input crop management system.

(ii) *Design of relevant indicators to assess the decisional quality of the model*: we proposed two different indicators :
   a. Number of cultivars (among the *n* best cultivars grown under LI) identified by the Betha-var model fed with HI trials results;
   b. Mean yield loss due to the use of Betha-var model on HI trial results instead of LI trials to identify the *n* best cultivars under LI. The mean yield loss is defined as the difference between the mean yield of the n best cultivars under LI and the mean yield of the n cultivars identified by Betha-var model fed with HI trial results.

(iii) *Definition of a reference value above which the model can be considered good enough*: since we want to assess the adding value of Betha-var model, our reference is the value of each indicator obtained thanks to the trial results under HI (without using the model) to make a choice under LI.

RESULTS

With a RRMSEP equal to 29%, the model showed a low predictive value not better than the one of a median model without cultivar effect. This first assessment of the model would lead to conclude that Betha-var model is not useful for a breeder mainly interested in predicting cultivar yield under LI crop management system.

Nevertheless, despite this low predictive value, the Betha-var model used in a breeding context enhanced the decisional quality in a significant way. Indeed, the model fed with HI trial results always allowed identifying more cultivars well suited to LI than the simple use of experimental results under HI (Figure 1). Furthermore, whatever the number of cultivars we want to identify, using the Betha-var model to make a choice leads to yield losses twice as low as those obtained with only HI experimental results (Figure 2).

Thus, more than the adding-value of the Betha-var model in a breeding context, this study shows the importance of assessing a model not only on its predictive value but also on its ability to help the user to make the right decision.

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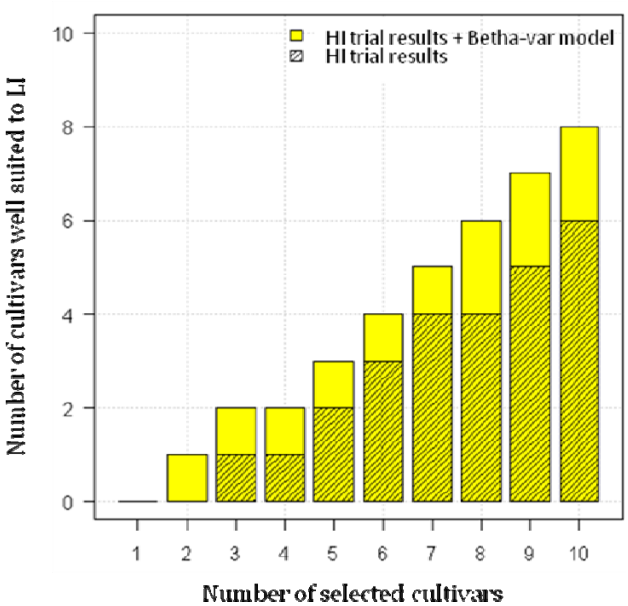

Figure 1: Number of cultivars (among the *n* best cultivars grown under LI) identified by HI trials results with and without using Betha-var model

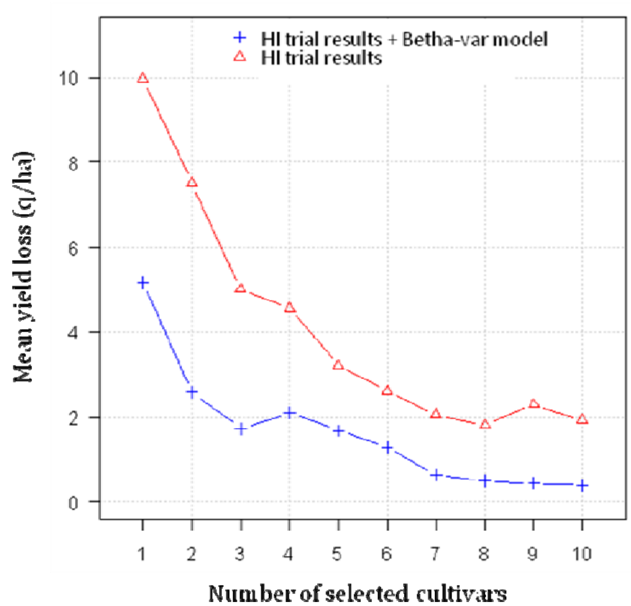

Figure 2: Mean yield loss due to the use of HI trial results with and without Betha-var model instead of LI trial results to identify the *n* best cultivars under LI

Simulating rice within broader farming systems using the APSIM framework

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INTRODUCTION

Worldwide, water for agriculture is becoming increasingly scarce. Suggested pathways to increasing water productivity (WP) in rice-based farming systems include the incorporation of non-flooded crops and pastures into traditional rice rotations, changed agronomic and/or irrigation practices, reduction of non-productive water loses, and genetic improvement. Simulation models are excellent tools to explore the limitations and opportunities for increasing WP. The APSIM farming systems model (Keating et al. 2003) has a proven track record in modelling the performance of diverse farming systems, rotations, fallowing, crop and environmental dynamics. However for rice-based systems the major drawback has been the lack of significant descriptions for soil processes under anaerobic conditions. Other models which are able to capture such anaerobic soil processes are unable to provide the degree of flexibility for assessing changed management practices that APSIM offers. For that reason, work to incorporate the required aerobic-anaerobic soil modelling functionality within APSIM has been undertaken. Up until now, it has been impossible to simulate the complete C&N dynamics in complex farming systems that involve rice in rotation with other crops and pastures. In this paper we report how we incorporated this functionality into APSIM, and on the ultimate aims for the modelling framework.

DESCRIPTION OF MODEL

A key challenge was simulation of transitions between flooded and non-flooded soil environments. It was a design criteria that this transition be contingent on continuous hydraulically-modelled variables, rather than an arbitrary ‘switch’ when one phase had finished and the next begun. Both the APSIM modeling framework and the ORYZA2000 rice model have been described in detail previously (Keating *et al.* 2003, Bouman and van Laar 2006.). The following (a-d) is a brief description of the new system elements which were introduced into APSIM. **a)** *Pond C and N loss and gain mechanisms*. Ponded water introduces a range of C and N loss and gain mechanisms not present in aerobic soil environments. These include significant volatilization of ammonia (NH_3) from the free water surface, and the growth of photosynthetic aquatic biomass (PAB - algae) which plays a significant role in regulation of many processes and may be N-fixing. **b)** *Fertiliser applied into pond*. In rice-based systems, fertiliser is often applied as urea directly into the pond. This fertiliser is then subject to hydrolysis, potential losses via ammonia volatilization, diffusion into the soil via mass flow and adsorption, and ultimately uptake by the rice plant. **c)** *Surface organic matter decomposition in pond*. Surface organic matter decomposition in water take place at slower rates than decomposition in air **d)** *Reduced rates of soil organic matter decomposition and cycling.* In an anaerobic soil profile saturated for extended periods, reduced rates of organic matter decomposition and cycling are likely to be a significant factor in modelling system behaviour (Jing et al 2007).

The chemistry of the ponded layer is modelled by a new module, APSIM-Pond, and the chemistry of the soil layers by APSIM-SoilN. These two modules communicate with each other on a daily basis to transfer nutrients via a central *engine* according to standard APSIM protocols (Keating et al 2003). We assume that N is only available for uptake by the rice crop once it is in the soil layers (ie from the SoilN module), as per other APSIM crops. The presence (or absence) of a ponded surface layer is determined hydraulically by the APSIM Soilwat module and this also provides the ‘trigger’ for smooth transitional changes to rate constants governing organic matter cycling and decomposition within the soil, and of crop residues on the soil surface or in the pond.

RESULTS AND DISCUSSION

Model evaluation is provided against a multi-year crop rotation experiment at Coleambally, NSW, designed to examine the impact of various land-forming and irrigation practices. We simulated a flat-bed layout with conventional irrigation (Beecher et al. 2006). Figure 1 illustrates acceptable model performance in this rice-wheat rotation on heavy clay soil with direct-sown temperate rice in a southern Australian climate, however the new modelling framework has also performed acceptably with tropical transplanted cultivars, porous soils, SE Asian climates, and in rice-legume rotations. A future challenge will be simulation of C & N dynamics in new and emerging rice water management practices such as alternate wet-and-dry. To this point, the demonstrated ability of the framework to capture the nutrient dynamics both within and between anaerobic soil phases is encouraging. The ultimate aim for this modelling framework is to provide a tool for future studies on adaptation in complex farming systems which involve rice in rotation with other crops and pastures. We have yet to test our assumptions on algal turnover and incorporation on long-term system nutrient dynamics, and are actively seeking evidence to test our assumptions. This work is part of a wider initiative on modeling rice within diverse farming systems, and parallel work is being conducted by IRRI and WUR on enhancing the capacity of ORYZA2000 to model the rice crop response to drought stress, extremes of temperature and increased atmospheric CO_2. Within the farming systems modeling framework described in this paper, the ultimate aim is to provide a robust simulation platform for evaluating rice-based farming system adaptation strategies in response to climatic changes and changes in water availability, internationally.

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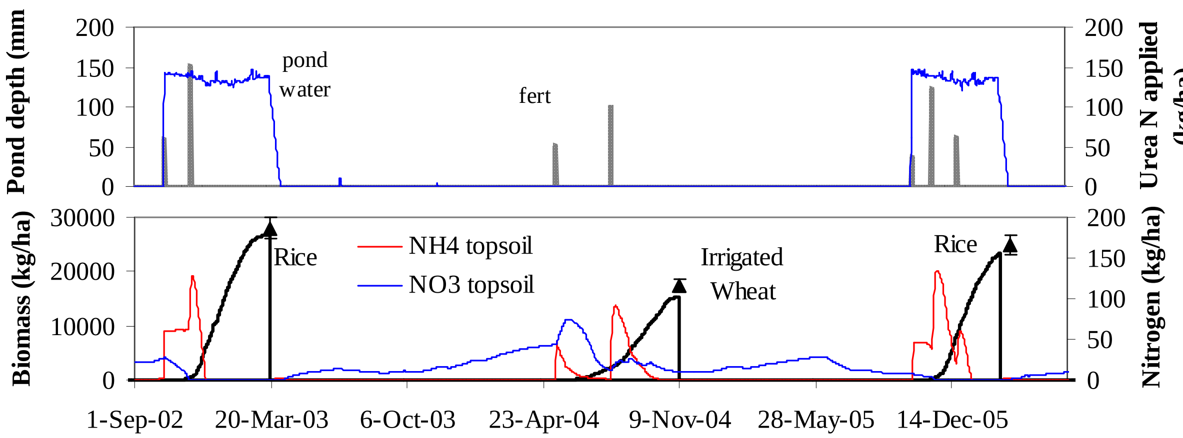

Figure 1. Simulated vs measured biomass data for a rice-wheat-rice experimental rotation on a transitional red brown earth soil at Coleambally, NSW. Simulated pond depth, soil NH_4 & NO_3 in top 40cms is also shown (Beecher et al. 2006)

Effects of Tillage on Paddy Soil Carbon Management Index under Long-term No-tillage

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INTRODUCTION

Compared with conventional tillage, no tillage could provide several benefits including increased fuel and labor efficiency, reduced production costs, and decreased soil erosion (Shipitalo and Edwards 1998; Stockfisch et al. 1999). Such conservation tillage is commonly used in paddy soil in Southern China. However, the long-term conservation tillage has caused some weed control problems, covered with heavy residues and organic C, increased subsoil bulk density, and reduced yield (Blanco-Canqui and Lal 2007; Camara et al. 2003). Therefore, it is necessary to study the tillage ration on the long-term no tillage paddy field.

Soil C management index (CMI) which based on the integration of both soil organic C pool and labile C fractions can provide a useful parameter to assess the capacity of management systems into promote soil quality (Blair et al. 1995; Vieira et al. 2007). When the trends were in the same direction as for both soil C pool and the ratio of labile C to total organic C, the higher CMI increased, the better quality of soil C pool can be indicated, and vice versa. The effects of soil type, fertilization, farmland ecosystem on soil CMI have been well documented elsewhere (Blair et al. 2006; Vieira et al. 2007). However, there has been very little research on the soil CMI that affected by tillage rotation management. The objective of this study was to determine and evaluate the effects of different tillage rotation systems on paddy soil with 7 years no-tillage. The information we obtained will be useful to supply groundwork and knowledge for establishing tillage rotation mode in the double rice cropping region.

MATERIALS AND METHODS

The experiment was conducted in Dongfu town (27°37.8′N, 113°32.5′E) of Liling in a double rice cropping region. Average annual precipitation is approximately 1429 mm and annual mean temperature is about 17.6℃. For the sake of comparison, continuous no-tillage (NT), rotary tillage (RT) and conventional tillage (CT) were conducted at the no-tillage paddy field in April, 2006. In the half field of rotary tillage (RT) and conventional tillage (CT), no-tillage (NT) was proposed in April, 2007. Treatments were NT-NT, CT-CT, CT-NT, RT-RT and RT-NT, respectively. The same tillage methods were used for early rice and late rice. Each had 3 replications. Soil organic C was determined by dichromate oxidation using modified Mebius method (Yeomans and Bremner 1988). Labile C was determined by oxidation with 333 mM $KMnO_4$ according to the method by Blair et al. (1995). The CMI proposed by Blair et al. (1995) was calculated as following:

$$\mathrm{CMI} = \mathrm{CPI} \times \mathrm{LI} \times 100 \quad (1)$$

$$\text{Where, Labile C Index (LI)} = \frac{L_{\text{sample}}}{L_{\text{reference}}} \quad (2)$$

$$\text{Lability of C (L)} = \frac{\text{labile C}}{\text{non-labile C}} \quad (3)$$

$$\text{C Pool Index (CPI)} = \frac{\text{total C in sample}}{\text{total C in reference}} \quad (4)$$

In our study, the long-term no-tillage soil was used as the reference. The content of non-labile C was estimated from the difference between total organic C pool and the labile C. The SPSS 11.5 analytical software package was used for all statistical analyses.

RESULTS AND DISCUSSION

For the surface soil (0-0.05 m), the CMI of NT-NT was significantly ($P < 0.05$) greater than that of CT-CT and RT-RT treatments. In addition, the CMI were significantly ($P < 0.05$) higher for CT-NT and RT-NT than CT-CT and RT-RT, respectively. The greater CMI with continuing NT at the surface soil was largely

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due to accumulation of soil surface organic C (Franzluebbers 2002) that keep higher CPI against tillage rotation treatments. And the CPI and LI were significantly greater for CT-NT and RT-NT than CT-CT and RT-RT at the 5% level, respectively.

However, for the subsoil (0.05–0.20 m), the CMI of NT-NT was significantly ($P < 0.05$) lower than that of CT-CT and RT-RT. The lower CMI with continuing NT were results of CPI and LI which were significantly ($P < 0.05$) lower for NT-NT than CT-CT and RT-RT treatments. In addition, the CMI were significantly lower for CT-NT and RT-NT than CT-CT and RT-RT at the 5% level, respectively. Such results can be explained by that the CPI were significantly ($P < 0.05$) lower for CT-NT and RT-NT than CT-CT and RT-RT, and the LI were lower under CT-NT and RT-NT than CT-CT and RT-RT, but it was not significant at the 5% level, respectively.

Compared with the reference (NT-NT with CMI defined as 100.00), the means of CMI in the arable soil layer (0-0.20m) increased with CT-CT and RT-RT by +10.68% and +27.58%, respectively. Such results can be explained by that the means of labile C index (LI) increased with CT-CT and RT-RT by +5.8% and +20.7%, respectively. In addition, the means of C pool index (CPI) increased with CT-CT and RT-RT by +3.8% and +5.0%, and decreased with CT-NT and RT-NT by -6.6% and -5.7%, respectively. Thus, the means of CMI were greater for CT-CT and RT-RT than CT-NT and RT-NT in the arable soil layer, respectively.

In conclusion, the CMI can increase with continuing NT treatment at the surface soil (0-0.05m) and decrease in the subsoil layer. In addition, the means of CPI, LI and CMI tended to increase with tillage (which were higher in RT than CT treatment.) under long-term NT treatment in the arable soil layer (0-0.20m). Thus, the quality of soil C pool tended to be higher under CT and RT compared to long-term NT treatment.

A similar result was found in Oct, 2008.

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Table 1

Paddy soil C pool index (CPI), Lability of C (L), Labile C index (LI) and C management index (CMI) affected by tillage treatments (NT: no-tillage; CT: conventional tillage; RT: rotary tillage) in Oct, 2007.

Depth /cm	Tillage	CPI	L	LI	CMI (%)
0-5	NT-NT	1.000a	0.307b	1.000c	100.00b
	CT-CT	0.747e	0.296c	0.964d	71.99e
	CT-NT	0.835d	0.315b	1.026bc	85.67d
	RT-RT	0.883c	0.317b	1.032b	91.13c
	RT-NT	0.933b	0.340a	1.108a	103.31a
5-10	NT-NT	1.000d	0.289b	1.000c	100.00c
	CT-CT	1.137a	0.299b	1.036bc	117.84b
	CT-NT	1.028c	0.302b	1.045bc	107.38c
	RT-RT	1.120b	0.328a	1.136a	127.16a
	RT-NT	0.964e	0.314ab	1.085ab	104.58c
10-20	NT-NT	1.000c	0.261c	1.000d	100.00c
	CT-CT	1.133a	0.291b	1.117b	126.45b
	CT-NT	0.937d	0.281bc	1.078bc	101.08c
	RT-RT	1.098b	0.347a	1.330a	146.01a
	RT-NT	0.937d	0.270bc	1.034cd	96.91c
mean	NT-NT	1.000	0.280	1.000	100.00
	CT-CT	1.038	0.294	1.058	110.68
	CT-NT	0.934	0.295	1.057	98.80
	RT-RT	1.050	0.335	1.207	127.58
	RT-NT	0.943	0.299	1.065	100.43

Means in a column followed by the same small letter were not significantly different at $P < 0.05$ within each soil depth.

MODEL-BASED ON-FARM DESIGN OF MIXED FARMING SYSTEMS

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INTRODUCTION

The planning of mixed farming systems with cropping and animals is complicated, since it involves many management decisions. These choices and their resulting outcomes are subject to a large range of constraints and objectives. For instance, bio-physical conditions can restrict the possibilities for allocating crops and rotations, the requirements of animals should be balanced with feed supply and the farmer will aim to optimize operating profit while also improving the sustainability of the system. Recently, various tools have been developed and applied for exploration of strategic improvements in farming systems (e.g. Dogliotti et al. 2005; Groot et al. 2007). However, tools that enable tactical planning, which can provide rapid insight into the consequences of large ranges of options would be very helpful to inform the planning process of farmers and farm advisors. In this paper we present the Farm DESIGN tool, which supports evaluation and design of mixed farming systems.

DESCRIPTION OF MODEL

A static farm balance model was used to calculate flows of nitrogen, phosphorus and potassium to, through and from a farm, the feed balance, the amount and composition of manure, labor distribution and economic results on an annual basis. Input data described rotations and crops (area, yield, and destination), farm animals (species, number, weight, growth, production, and activities), feed rations, additional fertilizers, labor, equipment and buildings. This model was applied to a 100 ha mixed organic farm named 'Ter Linde', located in Oostkapelle, The Netherlands.

The trade-offs between socio-economic and environmental objectives were explored by linking the farm balance model to a multi-objective Pareto-based Differential Evolution (DE; Storn and Price 1997) algorithm within the Model Explorer environment. With this modeling approach, alternative management options are generated and evaluated in terms of Pareto optimality. The objectives were to maximize operating profit to generate sufficient income, to minimize the labor balance to optimize allocation of labor resources, and to maximize the organic matter balance to improve soil structure. The decision variables concerned the areas of cultivated crops (including feed crops), the number of milk cows kept and the destination of crop products, which could be either sold or used on-farm as feed or green manure. Constraints were set on crop areas in the three different rotations on the farm, the energy and protein balances of animals, the self-supply rate of feeds, and acceptable nutrient balances (N, P and K; no excessive losses and no mining). The optimization algorithm was run for 10,000 iterations on a set of 630 solutions, with a total processing time of half an hour on a laptop with an Intel® 2.0 GHz Dual Core processor.

RESULTS AND DISCUSSION

The large result set of feasible farming systems showed that at a particular level of operating profit often many alternative options were possible with strongly contrasting environmental impact in terms of nutrient losses and organic matter balance. The relations between the objectives as reflected in the set of solutions are displayed in Figures 1a-1c. The relations between the value of the objective and the decision variables were determined, and are illustrated here with the relation between labor balance and cropping area of pumpkin and the number of milk cows (Figure 1d). The decrease in required labor (smaller labor balance) and operating profit along the Pareto frontier in Figure 1c was associated with a reduction of the area of pumpkin and the number of milk cows kept on the farm. Pumpkin is a cash crop that requires many hours of hand weeding. The revenues from milk sales are generally high, but the labor input per animal for milking and animal care is high. It is concluded that Farm DESIGN can help to understand interactions among farm components and allows what-if analyses of changes in farm organization and structure.

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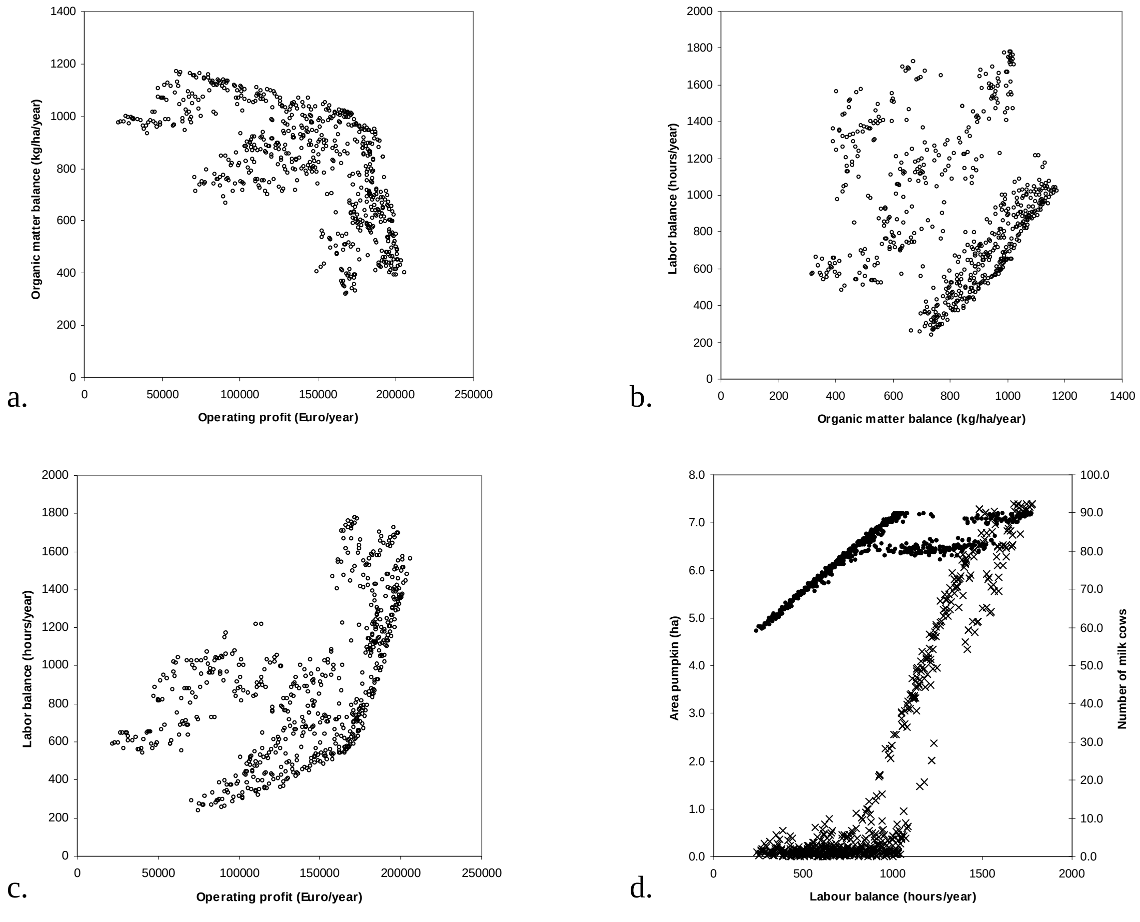

Figure 1. Result set of multi-objective Pareto-based optimization with the Differential Evolution algorithm, representing relations between the farm objectives of operating profit and organic matter balance (a.), organic matter and labor balances (b.), and operating profit and labor balance (c.). In d. the relation between labor balance and area of pumpkin (x) and number of milk cows (•).

USE OF THE FARM DANCES MODEL FOR ACQUIRING SYSTEMS ANALYSIS SKILLS IN INTEGRATED NATURAL RESOURCE MANAGEMENT TRAINING PROGRAMS

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INTRODUCTION

Biological systems are inherently complex. Making dynamic interactions between system components transparent to students is challenging. Innovative teaching tools complementing conventional training approaches thus may be needed to facilitate this process (Williams et al. 2009). Simulation models provide opportunities for researchers, managers and policy makers to gain insight in system dynamics and interactions among soil-crop-animal-environment components. However, most existing models are not user friendly and are poorly suited for training purposes due to their complexity and extensive input requirements (Williams et al. 2009; Van der Burgt et al. 2006). Wageningen University (WU) is uniquely positioned to develop educational modelling tools due to its long-standing expertise in system analysis and simulation models. In this paper we illustrate the use of the Farm DANCES model as a teaching tool in an Integrated Natural Resource Management in Organic Agriculture (IRNMOA) course taught at WU.

DESCRIPTION OF MODEL

The Farm DANCES model was based on a nutrient cycling model for grassland-based dairy farming operation in the Netherlands (Groot et al. 2003). Farm DANCES is a dynamic simulation model which describes flows of carbon and nitrogen in a dairy production system. It includes three state variables: inorganic nitrogen, organic nitrogen and organic carbon (Nmin, Norg and Corg) and it allows assessment of resource use and economic performance of integrated agricultural systems with a minimum of required input data. The model uses a time step of one year and a sequence of annual results are summarized in an output file. Simulation runs may be of the order of 100 years to evaluate long term trends. The main model components include soil, crops, animals, residues, inputs (e.g. feed and fertilizer) and products (e.g. milk and meat) (Fig. 1a) and these parameters are grouped in a database. By coupling flows of C and N to production parameters (e.g. soil characteristics, land use, herd size, fertilizer use, forage composition, conversion efficiencies for soil organism, plants and animals) both instant results (e.g. animal production and economic performance) and long term changes (e.g. soil organic matter dynamic) are being generated. The user interface is simple and includes a model description and definitions of model parameters. Output is written to an MS Excel spreadsheet which facilitates data access and processing, and farm characteristics, state variables, soil/residues, crops, animals, and farm economics are stored in different worksheets. An example of an output graph for the soil state variables is shown in Fig. 1b.

RESULTS AND DISCUSSION

Farm DANCES was implemented for farm operations in the Northern Friesland Woodlands region in the Netherlands. After explaining the model, student groups implemented it for existing operations and the majority of students were able to operate the model immediately with minimal support. Students then used the model to evaluate economic performance, N use efficiency, and long-term consequences of farm management decisions for different farm operations (Figs. 1c-d). The model was also employed to determine the impact of transition from conventional to organic farming. In most cases students were able to implement the model successfully. It is concluded that despite some inherent limitations due to its simple structure, Farm DANCES captured overall system dynamics in a realistic manner. The model appears to strike a sound balance between robustness, realism, flexibility, and simplicity. Using Farm DANCES allowed students to compare and contrast different farming styles in terms of input use and production efficiency and forced students to think through different processes, system components and interactions. In most cases simulation results were realistic. However, a thorough knowledge of the overall model system by the instructor is essential during initial model calibration for a specific production environment. Extending the model to other animal types and crops may be desirable.

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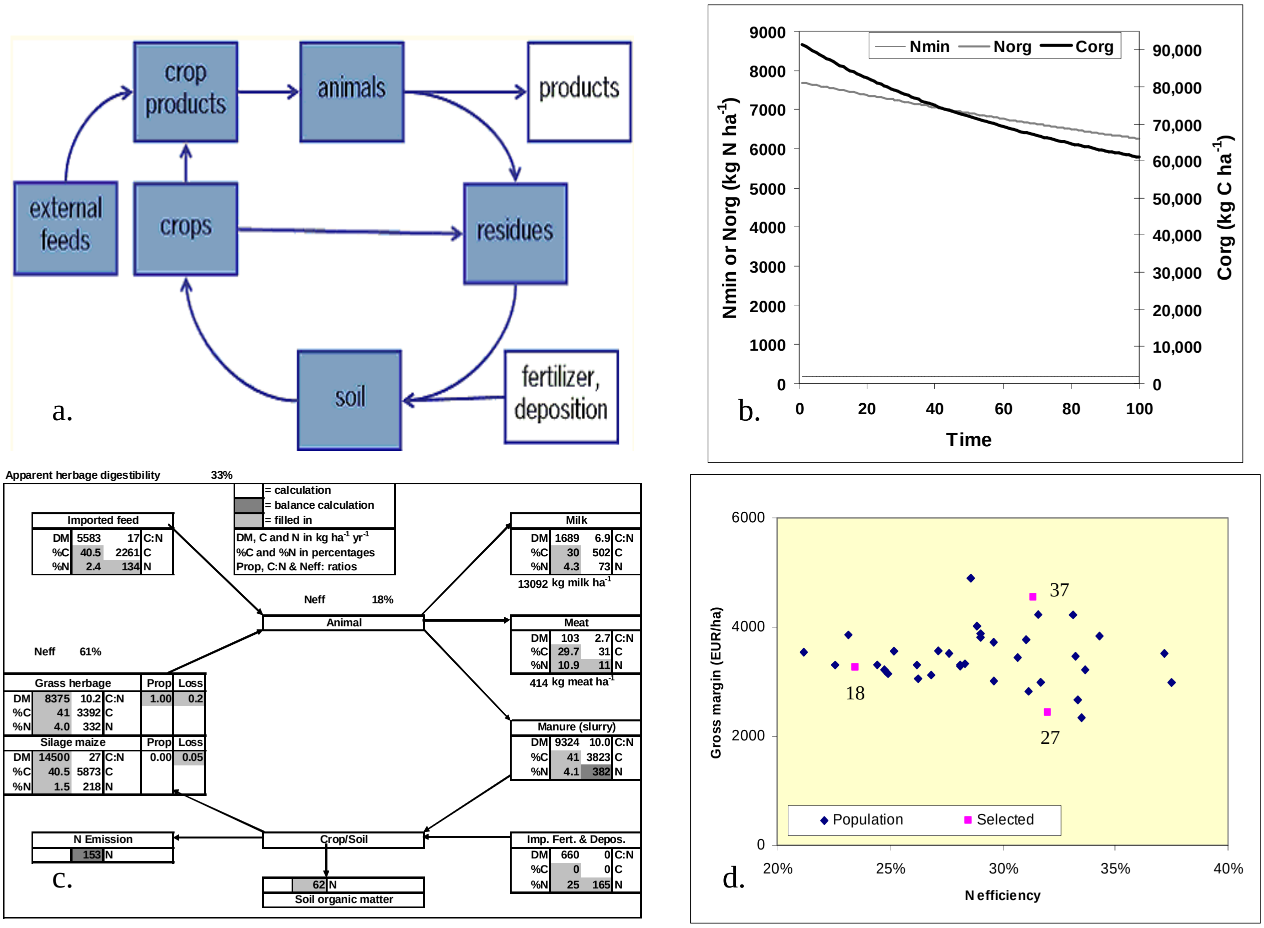

Figure 1. a. Outline of Farm DANCES. b. Results for the soil state variables. c. Overview of C and N cycling. d. Comparison of economic and N efficiency coefficients between farming strategies.

EFFECT OF SOLID MANURE INCORPORATION DEPTH ON CROP PRODUCTIVITY

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INTRODUCTION

Continuous row cropping and intensive tillage are common practices on corn and cereal grower farms with the result that soils loose their organic matter and become more vulnerable to erosion and less productive. The ability of plants to restore soil organic matter is limited and variable. Therefore, farmyard manure has for a long time been recognized as a valuable soil amendment as well as a fertilizer (Coote and Zwerman 1975). Several authors (Davies et al 1972) pointed out that animal manure improved some soils properties such as soil organic matter, water retention, clay soils workability and some mineral nutrients availability in addition to uphold crop yield.

Farmyard manure is generally spread on cropped land, in the fall. After that, a tillage is performed with a moldboard plows down to 20 cm. However, this practice does not mean that crop get the most beneficial effect of that manure application. We need more information on that manure management system. Then, the objective of the study is to evaluate the impact of manure incorporation depth on crop productivity as well as tillage depth on crop return. On a specific way, we want to determine tillage depth when manure is applied and when no manure is used in order to get the most beneficial impact on wheat and on corn silage productivity.

MATERIALS AND METHODS

The experiment was carried on a clay loam soil, in St-Hyacinthe, Quebec, Canada. Two crops, corn silage and bread wheat, were evaluated in two adjacent sites. The experiment involved 10 treatments repeated 4 times (corn) and 5 times (wheat), and distributed according to a split-plot statistical design. The main plot consisted of 2 treatments: manure, no-manure. The subplot consisted of 5 tillage depths: 0, 5, 10, 15, 20 cm. In autumn of the previous growing season, an equivalent amount of 200 t-m/ha (fresh weight basis) (Murphy et al 1972, Weeks et al 1972) of feedlot manure was applied and uniformly spread across the corn plots of 6.3 m * 6.8 m. In addition, a 100 t-m/ha (fresh weight basis).was top dressed on the wheat plots of 1.8 m x 2.8 m. Then, both soil sites were tilled to the appropriate depth. The no-manure plots were also tilled to the same depth.. Corn silage yield (kg/ha) is reported on a dry matter basis and grain wheat yield at 12%moisture. The manure used came from an open feedlot of dairy cattle feces combined with straw and was turned several times to uniformized the manure prior to apply.

RESULTS AND DISCUSSION

The results showed that both studied factors: tillage depth and applied solid manure have positive effect on crop performance. Therefore, corn silage was taking more advantage of manure incorporation than bread wheat. Corn silage yielded, on average, 14% more on manure treatment than on the blank without manure whereas wheat showed light yield improvement of about 5% under treatments with manure compared to no-manure.

Furthermore, the results suggested that the soil management practices should be directed to allow roots to reach moister zone into the soil profile, particularly in growing season with dry conditions. Thus, the need of deeper tillage (15 cm) was obvious on soil without organic manuring as showed by the yield performance of both crops. For instance, corn silage yield averaged, over the trial years, 7.7 t-m D.M./ha on no-till and it progressively increased up to 9.2 t-m D.M./ha on a 15 cm till depth and remained at that level under a 20 cm tillage system. Wheat grain yield increased from 3.8 up to 4.5 t-m/ha from no-till treatment to a 15 cm tillage depth treatment.

Farmyard manure incorporation modified the above trend by providing adequate soil conditions in the superficial soil profile and allow the crop to get higher yield. Corn silage yield increased from 8.7 t-m/ha in a no-till system to 10.2 t-m/ha under a 10 cm till depth. Deeper tillage had no-significant effect on corn silage yield. As far as the bread wheat is concerned, a superficial manure incorporation into the first 5 cm of the soil was enough to allow the plant to get is best performance, and, over that depth; yield remained unchanged. The positive effect of manure on crop production might be related to the improvement of soil conditions particularly through water retention and workability. There was also a significant interaction between organic manuring and year indicating that the corn response to organic amendment was dependent of the growing conditions of every cropping year. Beneficial effect of the applied manure was obtained by limiting in particular the soil water lost and by making available most constant supply of nutritive elements specially during dry climate conditions.

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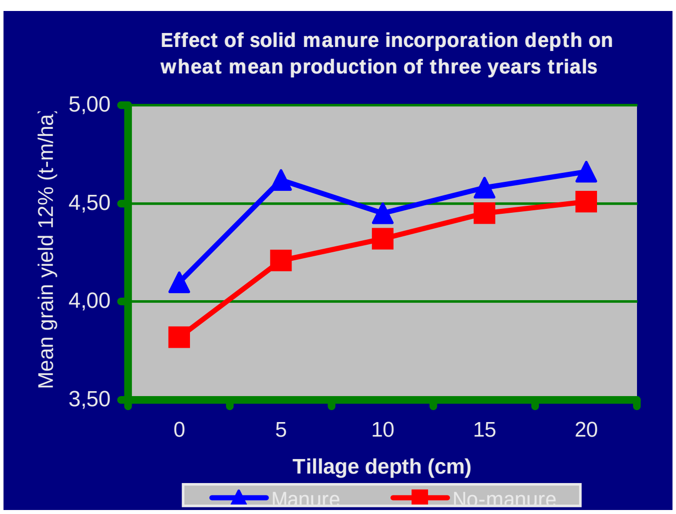

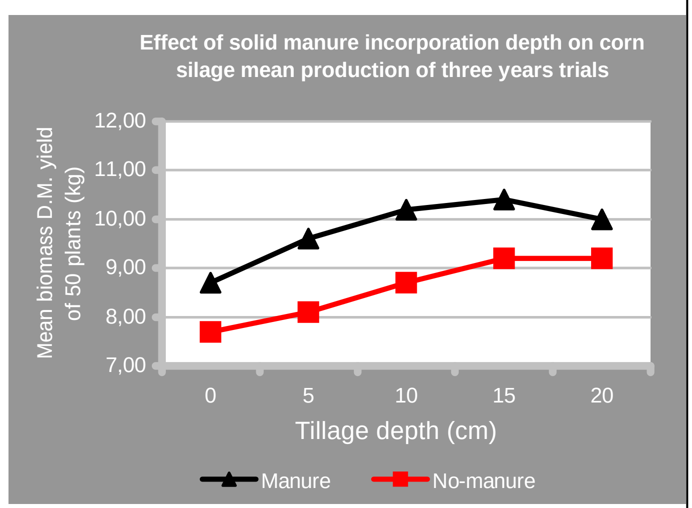

EXTERNAL DRIVERS – THEIR IMPACTS ON INTEGRATED AGRICULTURAL SYSTEMS: RESULTS FROM FARMER PANELS

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INTRODUCTION

Agriculture in the US is undergoing profound changes from increasing urbanization, turbulence in input costs and commodity prices, and shifts in consumer demands and global competition. Future challenges will need to address increasing population with a shrinking land base for agricultural production, food safety and security concerns, and resource preservation and environmental concerns. Knowledge of the fundamental principles of agricultural production systems is critical in order to design agricultural systems and markets that are economically feasible and environmentally sustainable. The Integrated Agriculture Systems Workgroup was formed to explore principles, characteristics and drivers that impact successful agricultural systems for physiographic regions throughout the US. By examining different agricultural systems in detail from various geographic regions of the United States, we will examine the economic structure and primary drivers of US production systems. Understanding the farm economic structure will allow producers, agronomist, and policy makers to develop economically and environmentally sustainable production systems. Our hypothesis is that principles are applicable across regions, but key drivers (economic, social, technological, political, and environmental) interact to influence producer decisions and create different production systems. In this discussion we focus on drives, specifically the social and economic drivers.

MATERIALS AND METHODS

We examined production systems in detail by posing a series of questions to invited panels of producers. University, Federal, and Extension scientists from a range of backgrounds interviewed the farmers, and then met to discuss production strategies and develop drivers, characteristics and principles of operation from these case studies. The working group has held workshops in three regions of the US: Southeast, Northeast, and Midwest. At these workshops, scientists interviewed agricultural producers to examine their production systems in detail and explore production practices, farm enterprises, and the management decision-making process. Panelists were selected who were actively engaged in agriculture from predominant production systems within each geographic region. The goal was to identify the underlying rational for their decisions by discerning the primary factors influencing the implementation of particular production practices. Production systems examined include: row crops (corn, cotton, soybeans, peanuts and potatoes), livestock (cattle, chickens, pigs and catfish), grass-fed beef, organic and traditional dairy, and organic vegetable production. Ancillary enterprises complemented the primary production and expanded the economic return.

RESULTS AND DISCUSSION

The production systems chosen represented a wide range of crop and livestock production, varying by commodity mix, climates and other physical resources, market outlets, participation in Farm Bill programs, and social differences. Results from the workshops demonstrated that many drivers are common among regions, but that interactions between drivers and influences on decision-makers vary substantially to create unique production systems. For example, the internal social driver that values the farming lifestyle is the principle factor that leads people to choose farming. Irrespective of location, farming is first and foremost a lifestyle choice. The type of farming, however, is partly a lifestyle choice (organic versus conventional, e.g.), and partly influenced by other external factors, including economic and environmental issues.

Economics was one of the two most prominent drivers on which producers base their decisions. For producers, economics covers making a living, reducing risk, and marketing the product. Producers in both regions and across all production systems stressed the need to implement production practices with the goal of earning enough to have a decent living. The choice of the crop and livestock mix that the producer used were somewhat dictated by environment but also greatly influenced by the internal social values of the individual.

Marketing strategy changed significantly in the US with the introduction of the Agricultural Adjustment Act of 1933. Originally designed to alleviate the economic crisis of the 1930's, the farm program allowed payments for only certain commodities. In the production systems we examined, government programs reduced production and marketing risks, but also constrained the flexibility of the producer in terms of crops produced. In addition, many of the crops that qualify for program benefits are commodities (lack differentiation from competitors), which also limits the producers flexibility in marketing. Producers of specialty crops which are not covered by the Farm Bill have moved towards contracts with processors or consumers to manage risk.

In keeping with the entrepreneurial spirit and aggressive approach to learning, the producers chosen for the panels were willing to try new technologies, even if unproven, provided the technology fit with their production philosophy. While all producers interviewed were progressive, those in Maine were more aggressive in implementing new technology due to available marketing channels and internal and external social values.

Although there are significant differences between the two regions, such as climate, soils, and types of production systems, certain drivers and principles guided the producers' decision making and were common to both regions. The single largest factor impacting the farmers' decision was the desire to farm. The farmers saw farming as a lifestyle choice, and the particular type of production (conventional vs. organic, e.g.) was also driven by an internal philosophical commitment. This internal social driver was tempered by the need to provide an economic foundation to support the family.

CONCLUSIONS

Although the agricultural systems we reviewed differed in physical resources, climate, and political persuasion, producers followed the same principles to further their goals. They all placed high values on continuity, preserving their natural resources, and contributing to their families and communities. If one principle was preeminent, it was to ensure future generations the ability to maintain the same life style. Second was the commitment to contribute to their communities. These internal social values are important in developing sustainable production systems, and vibrant rural communities. Reconnecting the consumption and production cycles of agriculture is critical to transition agroecosystems towards sustainability. By identifying the responsiveness of current production systems to forces that are shaping agriculture, we have identified successful strategies that will be useful for addressing future challenges to agriculture. New management systems can also be developed that are flexible enough to respond to changing societal demands, and are environmentally and economically sustainable.

SUSTAINABLE DESIGN OF FARMING SYSTEMS USING THE LIFE CYCLE APPROACH: THE CASE OF AGRICULTURAL BIOMASS PRODUCTION

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INTRODUCTION

The number of different applications of life cycle assessment (LCA) to agriculture has increased recently (Hayashi, Gaillard, and Nemecek 2006). Sustainability assessment has also become common for measuring environmental, economic, and social performance of agricultural systems. However, earlier agricultural LCA studies have, in many cases, focused on comparison of alternative agricultural systems; thus, no explicit attention has been paid to design perspectives. Since comparative LCA has been formulated as a problem of selection among discrete alternatives, it is necessary to proceed one step further to generalize comparative studies using design perspectives. In this paper, we present a framework for the sustainable design of farming systems using sustainability assessment based on the life cycle approach.

MATERIALS AND METHODS

A literature survey was conducted to clarify LCA impact categories and evaluation criteria in sustainability assessment, which are used for assessing biofuel production and biomass utilization. Web of Science was selected for the database. Furthermore, case study methods are used for reviewing biofuel production and biomass utilization in Japan.

RESULTS AND DISCUSSION

The focus of attention in earlier LCA studies on biofuel production was restricted to carbon dioxide emissions at the inventory level (or global warming at the impact assessment level) and energy consumption (Cherubini et al. 2009). However, there is an increase in the number of research papers and policy documents related to sustainability assessment (including sustainability criteria and sustainability standards). The results indicate that in order to introduce explicit design perspectives in assessment, selection and combination of agricultural techniques, which are equivalent to decision alternative generation if we use decision analytic terminology, must be analyzed with reference to impacts on sustainability. There is room for further discussion of the appropriateness of indicator generation (integration) using preference construction and many others.

Furthermore, the problems of determining appropriate business sizes and intensities of management in agricultural practices have become important. Although these problems can be considered mathematical programs including bioeconomic models, special attention must be paid to the whole production chain. This is particularly applicable to biorefinery systems for revitalizing rural areas.

Finally, the potential for introduction of design perspectives in agricultural LCA is examined using stylized case studies (Uchida et al. 2009). The cases for biofuel production in Japan can be summarized as shown in Table 1. The table has the following implications: (1) in order to design sustainable systems, systems must be designed on the basis of not only biofuel production but also efficient use of by-products and waste materials and (2) although such regional systems are inefficient compared to biofuel production in, for example, Brazil and Indonesia, the relative advantages change if we introduce land and water use into the assessment.

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Table 1 Summary of biofuel production discussed in this study

Cases in Japan	Feedstock		Sugar beet, sugar cane, rice (ethanol) Rape seed, sunflower (biodiesel)
	Sustainability	Environmental	Biomass utilization, including the use of by-products and cascading, is important.
		Economic	Governmental support may be necessary.
		Societal	Rural revitalization is the principal purpose.
Global trend	Feedstock		Sugar cane in Brazil (ethanol) Oil palm in Indonesia (biodiesel)
	Sustainability	Environmental	Direct and indirect impacts of land use have to be analyzed.
		Economic	Governmental support may be important for commercial success.
		Societal	Labor abuse has to be considered.

LAND ALLOCATION IN AGRICULTURAL SYSTEMS: USE OF A SIMPLE MODEL TO EXAMINE IMPACTS OF EXTERNAL DRIVERS.

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INTRODUCTION

One of the most basic and expensive resources in the agricultural enterprise is land. Optimally allocating this valuable resource among different enterprises can be difficult and has substantial impacts on profitability and sustainability of the production system. Agricultural systems are shaped by economic, environmental, technological and social drivers (Hendrickson et al. 2008) and these same factors impact land allocation decisions. Land allocation is based on environmental, economic and production benefits and producers' preference, risk tolerance and potential income. Producers must consider also future changes in societal values.

In the northern Great Plains of the USA, decision tools that are simple for the producer to use, such as the Crop Sequence Calculator (Krupinsky et al. 2003) have proven popular among producers. We developed a model that uses producer derived and easily accessed information to determine land allocation among different enterprises. The model ultimately provides a means to optimize land allocation, evaluates factors that impact land allocation, and allows for the calculation of specific net returns that shift land allocation from one enterprise to another.

DESCRIPTION OF MODEL

The Land Allocation Model was parameterized using four agricultural enterprises (corn, soybeans, spring wheat, and cow-calf production) common to the northern Great Plains, USA. The model develops a 4 x 4 matrix with the rows being the four different enterprises and the four columns providing indices for environmental quality, economic risk, production feasibility, and producer preference. These factors are used in calculating land allocation weights that shift production from the profit maximizing enterprise based on the importance assigned to these other factors.

Information needed to develop the environmental impact index included residue amount, residue carbon:nitrogen (C:N) ratio, energy required to produce the crop or livestock, the four firm concentration ratio (C4) of the marketing channels, and adjusted number of field operations per enterprise. The economic index is the normalized coefficient of variation for monthly prices for the last five years. Production feasibility index is the normalized value of the required precipitation to produce a product over the actual precipitation received (either annual long-term average or for a single year). If this value is negative then the enterprise is not feasible and is zeroed out in the calculations. The final column in the matrix is the grower preference for each different enterprise. This information was used to develop indices for environmental impact, economics, production feasibility, and producer preference for each enterprise. This matrix is multiplied by a vector that allows different weights to be placed on each of the indices. The resulting vector is multiplied by net return per acre over labor and management for each enterprise. The model allows for optimal land allocation for all enterprises and also the trade-off point between two different enterprises.

Initial data were derived from cropping experiments at the Northern Great Plains Research Laboratory in Mandan, North Dakota. Coefficient of variability in price data was developed using monthly prices for North Dakota from the National Agricultural Statistics Service (www.nass.usda.gov) and enterprise profitability was from the FINBIN database (www.finbin.umn.edu). We used information from 2003 to 2007 in our model.

Crop commodity prices were unusually high in 2007 because of tight supplies and increased bioenergy demand. Therefore net returns in 2007 were approximately four times greater than the highest net returns from 2003 to 2006. The FINBIN data also included the government payments per acre to be included with the net returns. We ran the model using net returns with and without government payments and with and without net returns from 2007.

RESULTS AND DISCUSSION

While the model allows considerations other than profit maximization to impact land allocation, net return per acre and government payments are still primary drivers of land allocation in our model (Fig. 1). The farm program in the USA is focused on crops rather than livestock, so the direct contribution of government payments had the greatest effect on allocations between crops and livestock. Also high commodity prices of 2007 tended to push land allocation to favor crop production over livestock production. However, under more normal net returns and without government payments, land allocation would favor cow-calf production. The model also allows determination of the trade-off point between two different enterprises. For example, using net returns from 2003 to 2007 with government payments, net return for soybeans would need to decrease from $35.06 per acre to $21.84 per acre for the model to allocate the same acreage for soybeans and cow-calf production.

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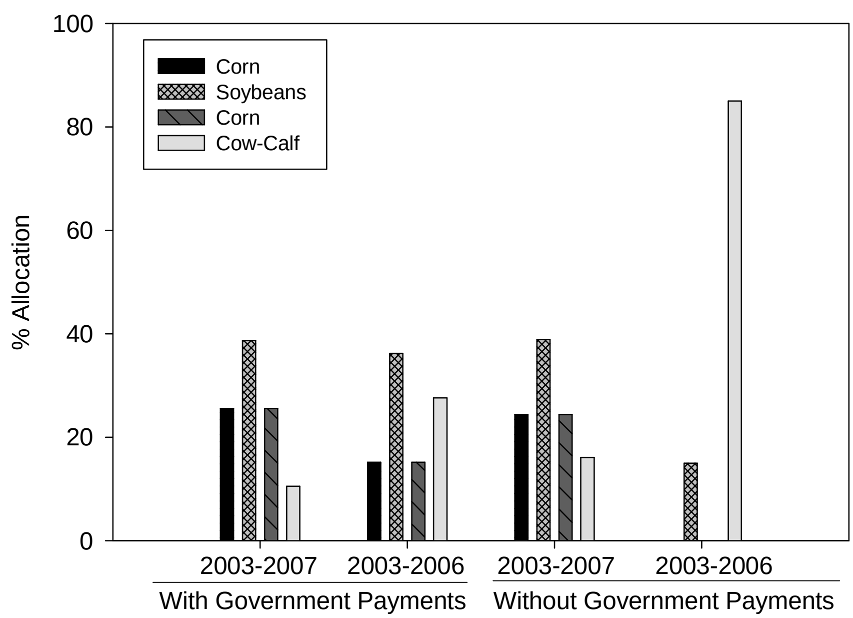

Figure 1. Percent allocation of land resources on a farm

ESTIMATING RESIDUAL N EFFECTS OF CATTLE SLURRY BY MEANS OF A FIELD TRIAL COMBINED WITH A SOIL-PLANT-NITROGEN MODEL

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INTRODUCTION

The majority of groundwater wells in Northern Germany still exceed the EU quality standard (50 ppm nitrate). Measures to comply with the European Water Framework Directive (WFD) include the nitrate directive, which in Germany is implemented by the Fertilization Ordinance since 1996, and implies a progressive reduction of the tolerable N surplus to 60 kg N ha^{-1} within the next years. Dairy farmers will therefore be impelled to adopt strategies which enhance N use efficiency. To this end, an accurate prediction of the fate of slurry-N applied to the soil is required. Besides short-term N release, long-term effects are of great importance for forage maize production, where year after year slurry application is common practice. The objective of the present study was to estimate the long-term slurry N effect in silage maize for a typical sandy site in Northern Germany by extrapolating the results of a 5-year field experiment using a dynamic soil-plant-nitrogen model.

MATERIAL AND METHODS

The fully integrated mechanistic Soil-Plant-Nitrogen model (SPN) of the soil carbon and nitrogen cycles and of plant growth was used. The model was calibrated on plant and soil mineral N data from a 5 years (1997-2001) field experiment in Northern Germany. Treatments were three cattle slurry rates (0, 20, 40 m^3 ha^{-1}) factorially combined with four mineral N rates (0, 50, 100, 150 kg N ha^{-1}). Silage maize production and N content was recorded throughout the growing season. In addition soil mineral N (0-90 cm) was measured in spring and autumn, and leaching losses during winter were estimated by ceramic cups. The plant N uptake, silage yield and the major features of mineral N in the soil were successfully reproduced (Azzaroli Bleken et al., 2009). The calibrated model was thus used in a 36 years simulation study using observed weather data. The initial pools of soil microbial biomass and plant residues assumed maize with abundant mineral N application (20 g N m^{-2}) in the preceding years. Plant N response curves to increasing N applications of either mineral fertilizer ('fert') or cattle slurry ('man') were constructed by means of continuous ('longterm') simulation over the period 1966-2001. The results were compared to similar curves estimated as if there was no carry over effect of the soil pools from year to year ('one year'). Crop management was: slurry application in late April and ploughing the following day, sowing and first mineral N application last of April, topdressing of mineral N 5th June. It was assumed that 50% of the total N in the slurry was NH_4-N. The results were used to estimate the residual and long-term N fertilizer value of cattle slurry, quantified as Relative N fertilizer value (RNFV) for dry matter (DM) and N yield, with RNFV = ANRmanure/ANRfertilizer, and ANR = (yield_treatment – yield_control)/N applied (Schröder et al., 2005).

RESULTS AND DISCUSSION

Simulations for shoot DM yield were within the values observed in the 5 year field experiment (Azzaroli Bleken et al., 2009), see Fig. 1a. Residual N effects on DM yield were reflected by the lower intercept and the higher slope of the 'longterm' (with carry over) versus the 'one year' (without carry over) functions. Consequently, the 'longterm' simulations resulted in higher RNFV values for DM yield, with differences between 'longterm' and 'one year' declining with increasing N input (Fig. 1b). The changes of soil C and N pools with continuous manure applications lead to an increase of RNFV values over time, as exemplified in Fig. 1c for N yield. Averaged over 36 years, a RNFV of 0.8 may be assumed for cattle slurry (Fig. 1d), and above 0.85 for the last 10 years (data not shown). The model assumes that all N applied with slurry is infiltrated in the soil. However, ammonia volatilization may cause N losses up to 30%, which reduces the “true” RNFV for cattle slurry. If 10% of the N in the slurry was lost by volatilization, the RNFV would be around 0.8/(1/0.9) = 0.72, and RNFV would decrease to 0.56 for a 30% N loss. The apparent improved RNFV for very large N applications is a consequence of the increasingly lower efficiency of fertilizer with increasing N rates above what can be utilized by the crop. This reveals the limitations of RNFV as a measure for the N availability of organic fertilizers. At low N application rates slurry gave slightly higher N-loss (leaching + denitrification) than fertilizer. Above 16 g N m^{-2} y^{-1} rate, longterm losses were larger with fertilizer than with slurry (e.g. at a rate of 20 g N m^{-2} y^{-1} the N loss was 6.9 and 5.7 g N m^{-2} y^{-1}, respectively).

Present recommendations about plant availability of slurry-N relative to fertilizer-N vary from 50% (year of application, German Fertilizer Ordinance) to 80% (several years, Agricultural Chamber of Schleswig-Holstein; Schröder et al., 2005). This study confirms that when ammonia volatilization is minimized by immediate slurry incorporation into the soil, the long term RNFV of slurry applied to silage maize in Northern Germany is about 80%, and well above 50% in the first year.

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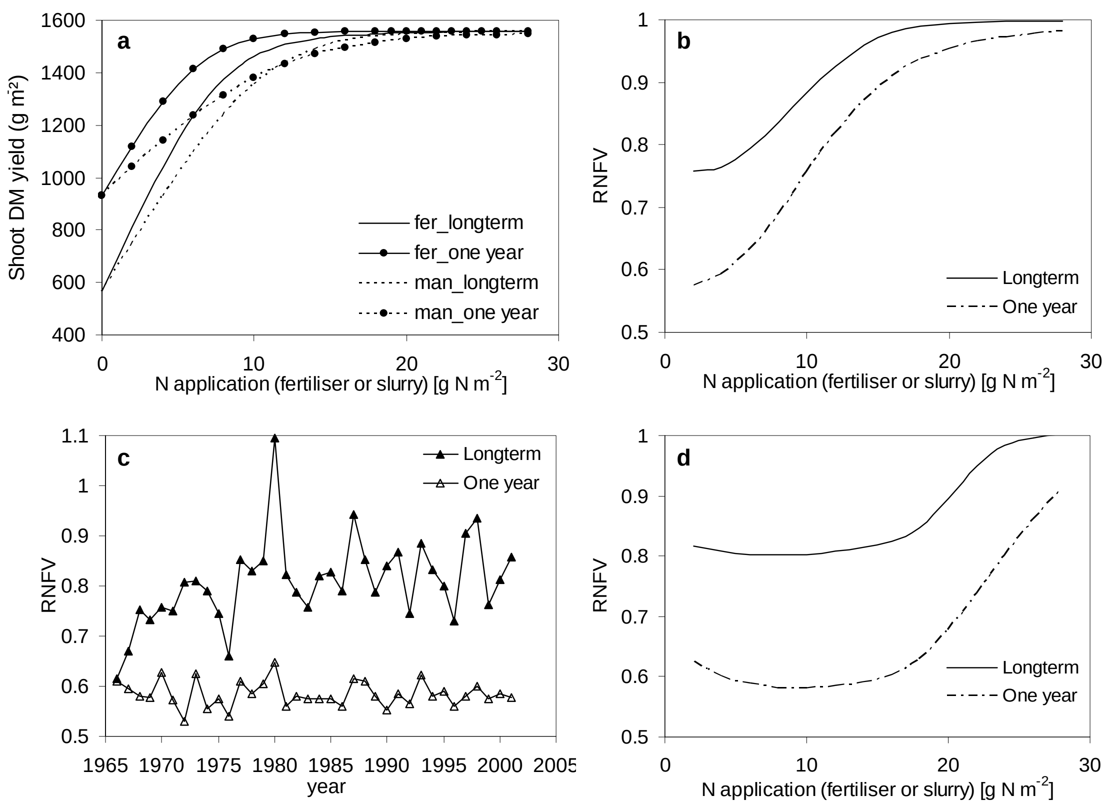

Fig. 1. Simulation results, provided as (a) maize shoot dry matter yield (g m^{-2} y^{-1}); (b) relative N fertilizer value (RNFV) of manure with respect to dry matter yield; (c) RNFV of manure with respect to N yield, time trend with 12 g N m^{-2} y^{-1} (d) RNFV of manure with respect to N yield. (a), (b) and (d) are averages of 36 years.

AVAILABILITY OF YEARLY CROP ROTATION OF COVER CROPS AND SPRING WHEAT AT HEAVY SNOW REGION, SAPPORO, JAPAN

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INTRODUCTION

Crop rotation between commodity crops and cover crops is practiced worldwide due to the improvement of soil quality by cover cropping. Such benefits include diversity of soil microorganisms; control of weeds, disease, and pests; and improvement of water availability (Snapp et al. 2005). In general, cover crops are grown until just before the ripening stage so as to play a role in improving the soil. However, from an economical point-of-view, cover crops need to be produced in a shorter period before commodity crop production in high-latitude regions with heavy snow cover. The growing season is limited in such regions; most crops can not grow during the winter. The objective of this study was to give an assessment of yearly crop rotation with winter-killed cover crops and spring wheat near Sapporo, Japan.

MATERIALS AND METHODS

Hairy vetch (*Vicia villosa*) and bristle oat (*Avena sterigosa*) were sown at the Hokkaido University, Experimental Farm, Sapporo, Japan, (43°04'N 141°21'E) in mid- to late August 2006 and 2007. These cover crops stopped growing by early December of each year and died under snow cover. In the following spring of each year, plant residues were incorporated by rotary tillage or kept on the ground surface under no-till conditions. Spring wheat was grown from late April to early August of both years without any fertilizer application. Dry matter of spring wheat and plant residues of cover crops was weighed. Total nitrogen (N) and carbon (C) of plant materials were measured with a CN analyzer (Vario EL III; Elemental). Inorganic N, ammonium plus nitrate N in the soil at different depth (i.e., 0-5 cm, 5-15 cm, and 15-30 cm depth) were also measured with an auto analyzer (FIA system; Aqua Lab.).

RESULTS AND DISCUSSION

Total N in plant residues of cover crops ranged from 42.3 to 59.3 kg/ha in 2007 and 9.2 to 33.6 kg/ha in 2008 (Table 1). The N content of plant residues at the soil surface was equivalent to 10-60 % of recommended fertilization rates at the farm. C:N ratio of the plant residues was lower in 2008 than in 2007. C:N ratio of plant residues in this study, however, was lower than those during summer production at the same site, which ranged between 24.9 and 40.5 in 2007 (data not shown). Concentrations of soil inorganic N increased by May in both years (Table 1). Mineralization of plant residues were likely affected by N content, C:N ratio, and other chemical components of plant residues; environmental conditions; and soil types (Kuo and Sainju 1998). The concentration of soil inorganic N was highest after hairy vetch production under no-till conditions.

Dry matter yield of spring wheat was the highest after hairy vetch production in both years, but the difference between cover crops was not significantly different (Fig. 1). There was no difference between tillage treatments except for the no-cover crop plots. Growth of wheat under no-till conditions was suppressed by weed growth after fallow conditions (data not shown). Wheat production after cover crop production in the 2-year trial was stable even with no fertilizer application, particularly after hairy vetch production. We conclude that efficiency of N in wheat production was improved by winter-killed cover crop production.

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Table 1 Total nitrogen of plant residues and soil inorganic nitrogen (depth 5-15cm) after cover crop production.

		2007						2008					
		plant residue (4/10)*		soil inorganic N (mg/100 g)				plant residue (4/11)		soil inorganic N (mg/100 g)			
	cover crop	Total N (kg/ha)	C:N ratio	depth 5-15 cm 4/12*	5/1	5/15	7/17	Total N (kg/ha)	C:N ratio	depth 5-15 cm 4/11	4/30	5/23	7/14
No-till	Bare	-	-	0.65 a	0.60 a	1.06 c	0.63 a	9.5 b	16.4 c	2.50 a	2.70 ab	2.51 a	2.08 a
	HV	59.3 a	15.4 c	1.97 a	3.12 a	3.25 a	0.62 a	31.6 a	13.3 d	4.52 a	5.50 a	4.71 a	3.24 a
	HV+BO	50.5 b	24.3 b	1.65 a	2.19 a	1.94 b	0.53 a	32.2 a	18.6 b	3.65 a	3.80 ab	4.72 a	2.73 a
	BO	42.3 b	34.1 a	1.62 a	2.56 a	2.52 ab	0.56 a	24.3 a	20.8 a	2.88 a	3.60 ab	3.04 a	2.41 a
Tillage	Bare	-	-	0.65 a	0.74 a	1.13 bc	0.69 a	9.2 b	17.6 b	2.20 a	2.40 b	3.16 a	2.41 a
	HV	59.3 a	15.4 c	1.97 a	2.42 a	2.44 ab	0.71 a	28.9 a	13.6 d	4.61 a	5.15 ab	5.49 a	3.58 a
	HV+BO	50.5 b	24.3 b	1.65 a	1.31 a	2.18 b	0.83 a	33.6 a	16.3 c	4.21 a	5.14 ab	3.60 a	2.89 a
	BO	42.3 b	34.1 a	1.62 a	1.54 a	1.51 bc	0.66 a	23.1 a	18.1 b	2.57 a	2.95 ab	4.45 a	2.53 a

Bare= no-cover crop, HV= hairy vetch, BO= bristle oat, HV+BO= mixture of hairy vetch and bristle oat
The values followed by the same letter within a column are not significantly different at P=0.05.
* The samples at April 2007 were not distinguished by tillage conditions. '-' = not enough biomass to collect.

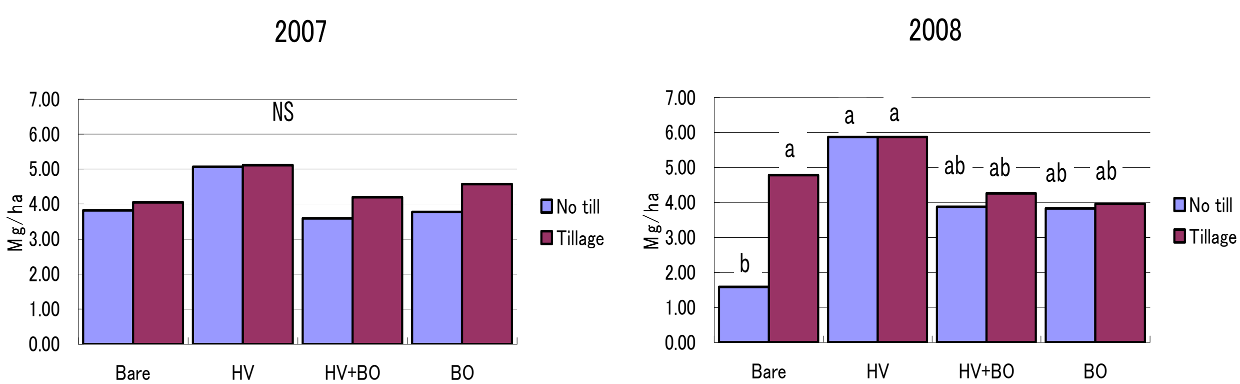

Fig. 1 Dry matter yield of spring wheat after covercrop production.
Bare= no-cover crop, HV= hairy vetch, BO= bristle oat, HV+BO= mixture of hairy vetch and bristle oat
The values followed by the same letter are not significantly different at P=0.05. NS = not significant.

FARMING SYSTEM INFORMATION FOR POLICY DEVELOPMENT AND ENVIRONMENTAL ASSESSMENTS

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INTRODUCTION

Agricultural and environmental policy and program development in Canada relies to a considerable extent on field, farm and regional economic and environmental models. These models use a variety of biophysical and production data, but inputs are usually treated as independent variables. The need for 'whole farm' characterizations to serve the requirements of life-cycle, carbon footprint and environmental goods and services assessments is increasingly being recognized.

MATERIALS AND METHODS

The primary characteristics that define the relationship between a farm and the environment are the manner in which land is used and the type and number of animals held (Colin and Crawford, 2000). A procedure of classifying census farms into "systems" based on combinations of crops and livestock densities (Huffman and Saha, 2009) was applied to all farms in Canada for 2006. To test whether or not these groups could be useful in policy and environmental assessments, differences amongst them with respect to structural, economic and social characteristics was examined using variable-width, notched box-plots (McGill et al., 1978).

RESULTS AND DISCUSSION

The total number of farms in Canada in 2006 was 230,000, and each was assigned to a farming system based on crop distribution and livestock density. The distribution of farms and the mean, median and inter-quartile range of key variables for each system provided the basis for the following descriptions.

Cash crop farms with a mixture of annual and perennial crops constituted 23% of all farms. These are large farms with low per-hectare capital investment levels, low labour and interest costs and moderate economic efficiencies. Operators of cash crop farms with mainly annual crops are generally younger and more likely to live off-farm than those of farms with a balanced mixture of annual and perennial crops. For policy and environmental programs, these farms have no livestock issues, but they rely on large land areas and they use average to high amounts of fertilizer and thus may be prone to water and air contamination.

The cash crop system with a high proportion of perennial crops shows unusual statistics, with a very high average but low median farmsize. Regional data show the system to be made up of 2 groups; many small (presumably hobby) farms with no rented land in eastern Canada and fewer very large farms (ranches) relying on the use of public lands in the west. The system includes 4% of Canada's farms, and they have very low per-hectare capitalization rates, expenses and sales and low economic efficiencies. Operators are generally older, with a greater tendency to live off-farm than other systems. The policy and environmental implications for this group are varied and should be regionally-oriented.

Cash crop farms with a focus on specialty crops (fruit, vegetables, vineyards) make up 6% of all farms and are among the smallest in the country. They are very highly capitalized and have very high labour costs and total expenses and high sales and economic efficiencies. Specialty crop operators are of average age, but have the second highest proportion of female principal operators. The small farmsize and high financial investment have unique implications for land use policy and environmental impact.

Intensive livestock farms are similar to specialty cash crop farms in that they are very small and heavily capitalized and have high operating expenses, sales and financial efficiencies. Five percent of Canadian farms fall into this category, and they house 17% of all livestock, especially poultry, pig and dairy animals. Operators of intensive livestock farms tend to be younger than average and are the 3rd most likely to be female. The very high livestock density and capital investment levels and the high interest costs are of primary concern in program and policy issues.

Mixed crop-livestock systems are the most common type in Canada and define the traditional "mixed farm". They account for 62% of Canadian farms and hold 83% of the livestock. Mixed farms focused on annual crops support high numbers of poultry and beef cattle, those with a preponderance of perennial crops support dairy and beef cattle and those with specialty crops also have high numbers of poultry. Mixed farms without specialty crops have moderate capital investment levels, operating costs and sales, while those with specialty crops are more highly capitalized and have higher input costs, sales and economic efficiencies. Mixed-annual farms have the lowest average operator age, but the highest proportion of male operators of all systems, while mixed-specialty farms show the highest percentage of female operators. The specific combination of crops and livestock, and the lack of a clear commodity specialization should be recognized in developing policies and programs for these groups.

The procedures used in this study provide a means of generating and describing groups of farms with distinct land use, livestock and socioeconomic profiles. These unique combinations of characteristics can be used to tailor policy initiatives and target specific areas and farm types for environmental programs. This paper reports on farming systems at the national level, but the approach can also be applied at regional and local levels, subject to confidentiality limitations. The classification parameters can also be adjusted to suit specific objectives. Modification of current economic and environmental models will be required in order to accommodate the integrated nature of the data inputs, but the methodology appears to be a good first step toward incorporating 'whole farm' analysis into policy development and environmental assessments.

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GREEN AND PROFITABLE FARMING SYSTEMS FOR THE SOUTHEASTERN USA

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Although most of the farms of the southeastern USA are relatively small, they often have profit centers of livestock or high value crops [7] . Thus, agribusiness (livestock, timber, and high value crops) is critical to the region's economy. The region has temperatures that allow plant growth for the entire year, and it has ample but erratic rainfall. While the rain falls on soils with generally low organic matter contents and water holding capacities, the region has the potential to produce significant cellulosic bioenergy [3, 13, 14]. These circumstances present a combination of resource, business, and marketing conditions that can potentially be molded into green and profitable farming systems. To accomplish the desired farming-system innovations, management of livestock waste must be made environmentally benign and sustainable. This can be done with existing and emerging technologies that I) extract and recycle excess nutrients [15, 16], II) destroy pathogenic microbes and pharmaceutically active compounds [17], III) produce bioenergy [2], and IV) create carbon credits [18]. The bioenergy conversion technologies will be compact and thermochemical. They will convert blends of wood, grass, and livestock waste feedstocks into energy [2, 12]. They will also produce a range of products including biochar that can be used to build soil quality and create carbon credits [8, 11]. The farms will use I) conservation tillage to protect and build soil resources [4, 6, 10], II) forage/bioenergy crops including summer legumes such as *Crotolaria juncea* to be used in crop rotations that optimally use nitrogen fixation [1, 3, 9, 13] and III) genetically advanced crops, selected for short-term drought tolerance, to buffer against drought while allowing the benefits of rainfall[5]. With sufficient storage, effective recycling, and subsurface irrigation; water can be ensured for high value crops. In total, the new systems will be high tech, robust, green, and profitable.

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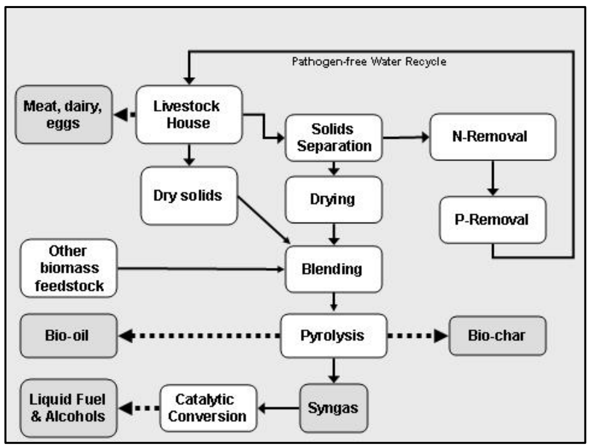

Figure 1. Next generation waste-to-bioenergy treatment system.

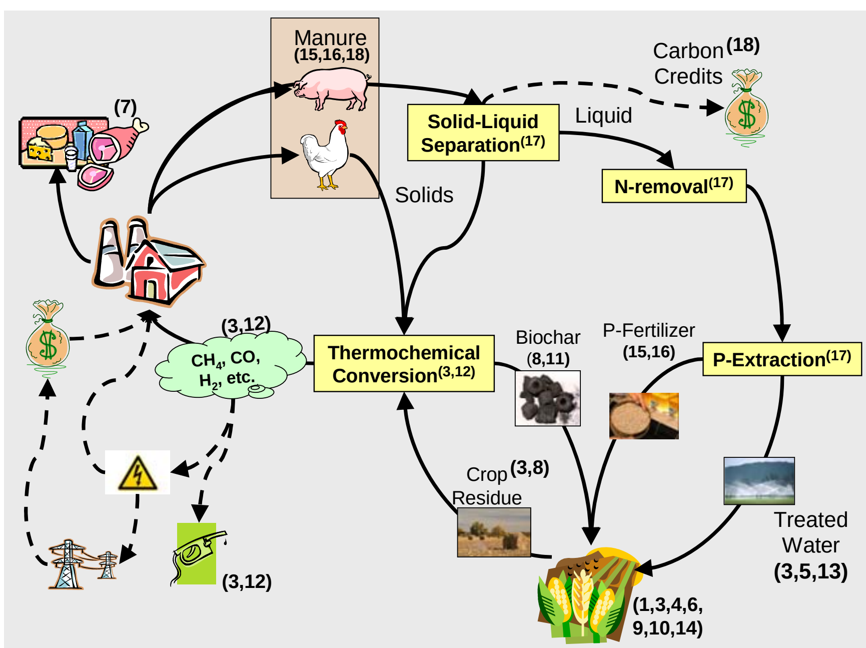

Figure 2. Green livestock farming system promoting the incorporation of biochar production (numbers are citations).

A DECISION TOOL TO MANAGE FOOD SAFETY AND CROPPING SYSTEMS: STUDY CASE OF POLLUTED FIELDS BY THE POP CHLORDECONE IN THE FRENCH WEST INDIES

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INTRODUCTION

In French West Indies, banana producers have been using chlordecone ($C_{10}Cl_{10}O$, CAS registry: 143-50-5), a persistent organochlorine pesticide, for 1972 to 1993 to fight against the banana weevil. This molecule exhibits a high stability, a low solubility and a very low volatility, with non observed biodegradation in real conditions. Its high hydrophobicity allows a great affinity towards soil organic matters ($\log K_{oc}$ = 3.34 to 3.415, Kenaga 1980 in ATSDR, 1995). Morever, it can be trapped by the specific physical properties of allophonic soil (andosol) (Woignier et al 2008). A simple leaching model (WISORCH, Cabidoche et al 2009) accounted for the current soil residue according to the soil type and exhibited different K_{oc} values, between 12 and 24 $m^3\ kg^{-1}$ for andosol and between 2 and 3 $m^3\ kg^{-1}$ for nitisol. Thus, this insecticide led to a heterogeneous and diffuse pollution but the pollution origin is limited to ancient banana fields. Chlordecone molecule is now polluting soils, water and food chains and farmers have to manage the sanitary risk of the molecule transfer to food crops where fields are polluted.

MATERIALS AND METHODS or DESCRIPTION OF MODEL

We first assessed the chlordecone transfer between soil and crops by measuring the chlordecone level in each compartment. We focused our study on the most eaten food crops in the French West Indies: roots vegetables (dasheen, sweet potato and yam), banana, pineapple, Solanaceae (tomato, hot pepper and eggplant). Two soil types were tested (andosol and nitisol) at the 0-30cm depth. All samples were taken at harvest stage in field conditions, repeated 10 to 20 times and stored at -20°C before analyse. All the samples were analysed by the LDA26 at Valence (France), which works under the French norm NF17025 and the "COFRAC" accreditation committee and determined the sample chlordecone rate by GC-MS-MS "triple quadrupole" (Varian, MS1200) after air drying, crushing, homogenising and acetone-hexane ASE.
We calculated the mean and the maximum transfer relationship between soil pollution level and crop contamination, using simple linear models. We considered the maximum transfer rate as anenvelop straight line, which was raised only by root vegetable cortex.
Then, our decision tool integrated these results and the UE sanitary regulation (Maximum Residue Limit, MRL=0.02 mg kg^{-1}FM for chlordecone food residue) in the soil limit calculation.

RESULTS AND DISCUSSION

The food crops sensitivity differed according to soil types, crops and harvested organs. The more sensitive crops are root vegetables and the less sensitive are banana, pineapple and *Solanaceae*. For these crops, chlordecone residues were under the MRL and nearby the detection level for the

harvested and edible part, thus their cultivation is possible on polluted soil, whatever the soil type. For root vegetables, contamination was proportional to the soil pollution (y=0.025x, R^2=0.73). Results dispersion was important because field soil pollution was heterogeneous at the contact surface scale. The root vegetable contamination was lower than soil pollution. This result excluded their use for remediation. We used the maximum transfer line to assess the risk of contamination for root vegetables (y=0.2x) and we translated the MRL value into a chlordecone maximum soil pollution level, under which one the risk of transfer above the MRL was zero (figure 1).
Our tool would help the farmers to anticipate the contamination risk for food products at the planting stage using a soil analysis. In the case of relevant farming system evolution or conversion, it would help them to choose adapted crops according to the field pollution context and the farmers' objectives. Our tool would help too the decision makers to propose pollution management measures and new cropping system practices and orientations. So as a conclusion, simple tools could predict and help to manage the contamination and exposure risks suitably/appropriately. The acceptable soil pollution level could be less binding by a better knowledge of soil-plant contamination relationships for each couple soil type – crop.

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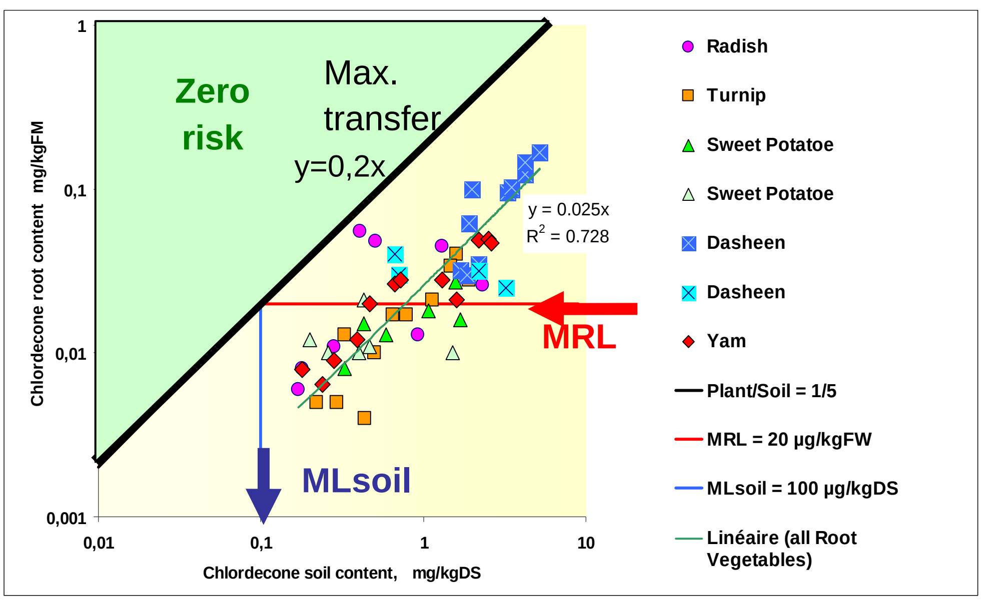

Figure 1: Use of the maximum transfer relationship to manage the contamination risk towards crops at the planting stage, root vegetables case. (MRL: maximum residue limit)

TWO SCALES APPROACH TO CHARACTERIZE FARMERS' PRACTICES

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INTRODUCTION

The wide diversity of French agricultural production sector leads agronomists to produce tools dedicated to categorise farms diversity. These typology methods are supposed to improve the efficiency of technical advisors helping them to adapt advice on techno-economic issues to the different production contexts (Capillon 1993). It also aims at helping agricultural policies. However the typological approaches dedicated to the comprehension of the conditions of appropriation of new techniques are rare. Nevertheless, characterization of farmer practices diversity is a preliminary to evaluate cropping systems, their environmental impact, and finally to rebuild crop management with producers. Agricultural practices result from choices carried out both at the field and at the farm scale. It partly depends on the priorities of the farmers and the way in which he allots the factors of production to the various components of the farming system (Papy 2001). Consequently, which would be the operational value of a diagnosis resting only on the observation of the practices without taking account of the context in which they are implemented ? Then, to be operational, the phase of diagnosis must hang in account data resulting from global farm functioning. For this purpose, certain method mix both types of data, i.e. crop management sequences and global farm functioning, allotting to each one an arbitrary weight (Köbrich et al. 2003). In order to maintain the wealth of information and to guarantee the operationnality of typology, we propose a diagnosis tool which integrates independently field and farm scales (Michels 2005). Our objectives are (*i*) to build up farm types around "aggregation poles" (Girard et al. 2001; Girard et al. 2008; Perrot 1990), (*ii*) to involve advisors in the typology process, and finally (*iii*) to identify practices diversity and to give sense to the existing practices.

MATERIALS AND METHODS

By means of survey and modelling, our method aims at answering two questions: what do farmers use to do on their fields and what is the context of their activity ? One part of the survey aims at revealing agricultural practices at the field scale, the other one analyzes the relationships existing between crops and the global farm functioning. On each information field, a typology is carried out following five stages: (*i*) laying down of the objectives with the advisors and and development of a sample aiming at maximizing diversity, (*ii*) carrying out the surveys, (*iii*) developing in a participative way prototype attributes and their modalities, (*iv*) formalizing typology using three multivariate analysis methods (*v*) crossing the two typologies in order to replace practices in the context of their implementation. The prototype attributes is represented as a bipolar axis presenting, in an ordered way, combinations of practices observed between two logics opposed on a given topic. The prototypes are built combining the different attributes and their modalities, using two methods of multivariate analysis (MCA and hierarchical clustering). Then Fuzzy analysis allows us to measure the resemblance between each farm and the prototypes resulting from typology.

RESULTS AND DISCUSSION

Figure 1 illustrates the result of such a typology process in the case of three emerging "prototypes" or "pole". Each pole is characterised by a set of attribute modalities and must be named by an expression summering the main strategy underlying the crop management for the field scale and the global functioning for the farm scale. Each surveyed farm can then be “located” compared to the various poles, offering the vision of a not partitioned typology. Each farm is thus characterized by two profiles and can be positioned compared to the various poles within each typology. That makes it possible to distinguish the exploitations implementing the same practices in completely different contexts. Such an approach give sense to crop management observed bringing some indications about the production context. Taking into account this double featuring allow advisor to adapt technical advice. Overlapping these two typologies provides basic knowledge to build a relevant network of reference farms. We consider this method as a required step to assess farms sustainability and necessary conditions to transfer new cropping systems.

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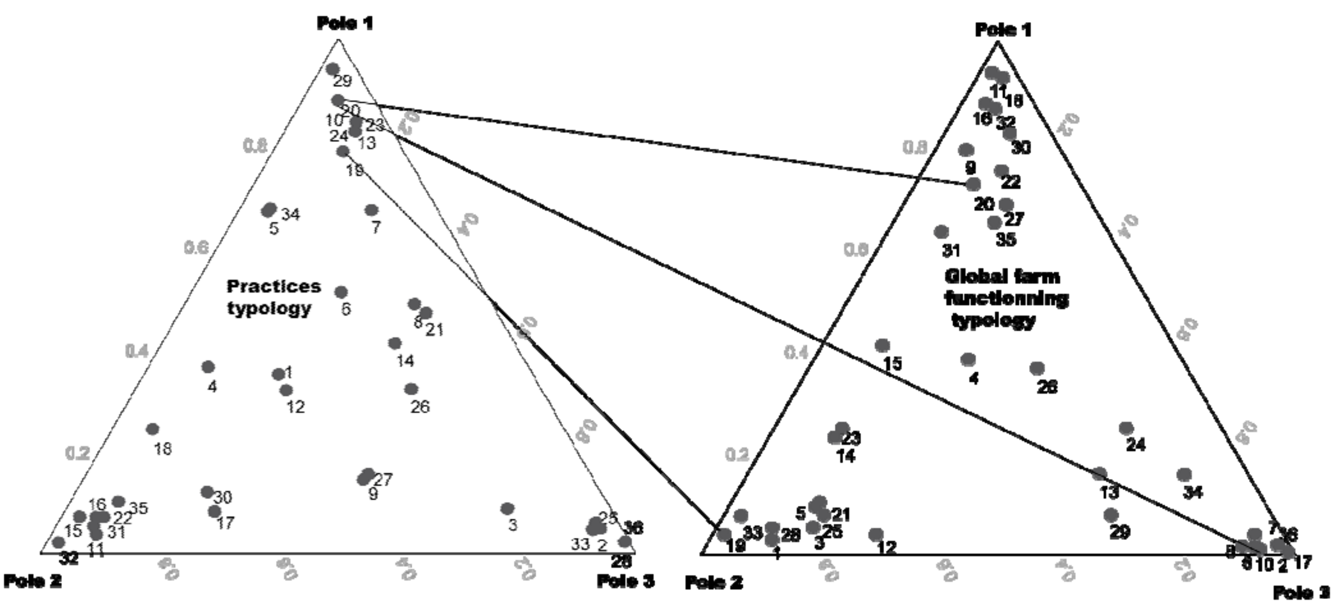

Figure 1 : results of double typologies carried out on the same sample of farms showing for the same crop management the diversity of the context of production

Using agronomic models to predict cultivar performances under various environments and cropping systems

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INTRODUCTION

The diversity of the environmental stakes among locations and the development of new outlets for agricultural products favour the diversity of crop management systems, including the choice of adapted cultivars (Loyce et al., 2008).

Multi Environment Trials (METs) are often conducted to compare the response of genotypes under a wide range of soil-weather conditions and, more rarely, of cropping systems (CS). In these METs, significant genotype (G) by environment (E) by Cropping systems (CS) interactions are often observed, representing 10-25% of the total yield variation. Various statistical methods have been proposed to analyze G by E interactions (Brancourt et al., 1997). Yet, they do not help to predict the performance of cultivars in various cropping systems or landscapes. Therefore it is difficult to use the results of METs to choose the suitable cultivars for a given cropping system or landscape or to design the crop management systems most suited to a given genotype. Finally, this experimental device has a poor predictive quality, particularly in the environments and cropping systems not included.

Dynamic crop models have been used to assess various performances of genotypes only since 10-15 years. More recently, spatially explicit models simulating gene flow or disease epidemics have been used to support breeding and cultivar evaluation. This paper reviews the potential and actual use of a diversity of agronomic models for predicting cultivar performance under various environments and cropping systems.

FOUR USES OF MODEL-BASED PREDICTIONS OF THE INTERACTION CULTIVAR*CROPPING SYSTEM

Four types of uses of model-based predictions of the Genotype x Environment x Cropping System Interactions (GECSI) can be identified in the literature:

(1) help defining breeding objectives, i.e. identifying the morphological and physiological traits to breed for a given aim. The criteria used by breeders as breeding targets are not always chosen taking into account of their impact on the complexity of the crop functioning. Agronomic models, making possible a rapid and multi-criteria evaluation of genotypic traits in interaction with various environmental conditions, can limit this problem (Fargue et al., 2005). The analyses of the model sensitivity to the studied trait allow to quantify the influence of the studied trait on the crop performances during the whole cycle, in various conditions of environment and cropping system. However, most studies use a weak representation of the environments and cropping systems, evaluate a low number of criteria, and assume that phenotypic traits are independent.

(2) help cultivar experiment management, i.e. characterizing the environments in order to optimize METs, and understand GECSI observed on a MET. Crop models are useful tools to characterize the limiting factors endured by the crops. Indeed, they can simulate the evolution of varying environmental states, which are difficult to measure continuously.

(3) Models can also be used to predict new cultivar behaviours in a larger range of conditions than those encountered in the experimental networks. They allow to identify the situations suited ot not to a varietal type.
(4) Models can help defining directions for use of new cultivars, that is to say choosing the best cultivar in a given cropping system, or the best crop management plan for a given cultivar.

HOW TAKING INTO ACCOUNT THE CULTIVAR IN CROP MODELS?

The first step is to choose/design a model allowing the best assessment of GECSI. To favour the link between model and breeding, models should be more efficient if involving relationships between parameters and genes or groups of genes. On the contrary, to define the conditions of use of cultivars, the model should include a simple method for phenotyping but should be robust in taking into account a large range of growth conditions and in giving account of various crop management strategies.

The second step is to identify and estimate the genotypic parameters. A sensitivity analysis to its parameters is a good way to identify those which have the highest influence on the outputs Yet, to choose the parameters it is also important to take into account the forecasted use of the model (and the future use of the genotypic parameters). For the estimation of the parameters, two methods are proposed. The first is based on optimizing model outputs. It aims at identifying the parameter values that minimize the gap between the simulated and observed values of outputs. The results show that, according to the number of parameters estimated simultaneously, the parameter values can be highly different, indicating compensations between the parameters. The biological meaning of the parameters estimated by fitting outputs is then questionable, as the values are directly dependent on the model structure and the values of the other parameters. The other way used in the literature is based on the direct measurement of parameters when possible, or on the fit of relationships in which they appear. Whatever the method of cultivar-parameter estimation, the choice of using specific cultivar parameters in crop models should be based on the comparison between the increase in predictive quality of the model and the increase of cost of measurement of the data required for the cultivar adaptation, which is rarely mentioned in the literature.

The third step is to assess the model for the forecasted uses. Besides the classical evaluation of the predictive quality of crop models, it appears essential to appreciate their ability to take a relevant decision, that is to say to reach the uses aimed by the potential users. Even if the model has a poor predictive quality, it can be a useful tool if it helps to take a better decision than with the available information and tools.

CONCLUSION

While studies on crop models with genotypic parameters are increasing in the literature, few of them are used by people in charge of cultivar evaluation. In this aim, it should be necessary to involve the end users in the design of the model.

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A method to assess farmers' room for maneuvering crop location at the landscape level for biodiversity conservation

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INTRODUCTION

In agricultural landscapes, part of the landscape structure results from the spatial organization of crops and grassland in farmers' fields, i.e. the crop mosaic. Landscape ecologists have devoted much study to the role of permanent structures of landscapes (e.g. hedgerows, woods) in biodiversity, and now there is an increased focus on the structure of the crop mosaic (Baudry et al, 2003). These crop mosaics are mainly the result of individual decisions taken at the farm level (Joannon et al, 2008).

In this poster we propose a method to locally assess the room for maneuvering crop location at the landscape level based on (1) a simulation of farmers' decision making and (2) landscape indicators. We illustrate the method with a case study of an agricultural landscape in Brittany, France.

MATERIALS AND METHODS

The case study is based upon real farm practices as identified from a 2008 farmers' interviews in a dairy area of Brittany, and on a spatially simplified agricultural landscape without field margins (figure 1). The landscape (520 ha with 144 grid cells of 3.61 ha each) is divided into 4 farms, each with 35 fields and one farmstead. The spatial location of farmsteads have been randomly chosen, 10 fields have been allocated to the closest polygons of the farmstead for each farm, and all remaining fields have been randomly allocated to each farm. The fields closest to the farmstead have arable crops and temporary grassland rotations, whereas fields further away have short rotations without grassland. The four farms are classified as either of two farm types depending upon their crop acreage:

- large dairy operations, all the crops are cultivated to feed animals with the main feed being corn silage. The crop acreage is : 55% of corn, 26% of winter wheat and 29% of grassland.
- small dairy operations with cash crops production. Animals are mainly fed on grass. The crop acreage is: 29% of corn, 20% of winter wheat and 51% of grassland.

Using the LandSFACTS model (Castellazzi et al, 2007), we simulated 10,000 times the crop allocation to the fields over the whole landscape during 10 years with the above farms characteristics (Landscape simulations set A). Those simulations were re-run with relaxed crop acreage and crop rotations constraints, allowing variable corn and wheat proportions in the landscape (Set B).

We then analyzed 200 randomly chosen 10-years landscape simulations of the set A and B, to evaluate their impact on two ecological types of species. We used the APILand library (Boussard, 2008) to obtain landscape suitability over years, the method is based on annual habitat patches map (example on figure 2 and 3) and occupation assumptions. The two virtual species habitat requirements are:

- species 1 is an autumn breeder carabid beetle *(Coleoptera)* with medium dispersal power. During his activity season, adults need two crops types close enough (less than 400 m): winter cereals in early summer to forage and corn later to forage and lay his eggs. Immobile larvae and pupae overwintering in the soil are sensitive to spring soil tillage and need a corn-wheat transition to survive.
- species 2 is a syrphid species (*Diptera*). Adults require both, 3 years or more temporary grasslands to forage and cereal fields to lay their eggs since larvae are aphidophagous. Adults need the two habitats to be close (less than 400m) to limit dispersal costs. However, year after year, their dispersal power enables them to recolonize grasslands in early spring, everywhere in the landscape.

RESULTS AND DISCUSSION

For the set A, while the crop acreage is fixed (37% of corn, 23% of winter cereals and 40% of temporary grassland), each landscape is different, with on average 35% of the crop allocations being unique. For the set B, over the whole landscape, the corn acreage varies from 31% to 39%, the winter cereals from 21% to 29% and landscapes have a different crop allocation on an average of 40% of its area. When relaxing the crop constraints, transitions from corn to wheat decrease from 23% (set A) to 14% (set B).

Analyses performed on 200 simulations of each set showed that suitable habitat for species 1 decreases drastically in landscapes B, leading to a majority of population extinctions. For this species, 93% of landscapes are suitable in set A and only 33% in set B. On the contrary, B landscapes are not perceived differently by species 2: there are 80% of suitable compared to 95% in set A.

Through this example, we showed that changing agronomic rules of crop allocation without changing farms' productions can alter the crop mosaics and consequently affects biodiversity. These results are complementary to the ones showing the impact of permanent elements on biodiversity. Lastly, the method presented could be used to support the potential adaptation of agricultural practices at the farm level for biodiversity conservation purposes while taking into account crop rotations and their allocation to fields at farm level. Knowing habitat requirements, we can assess the possibility to create them with and within different cropping systems.

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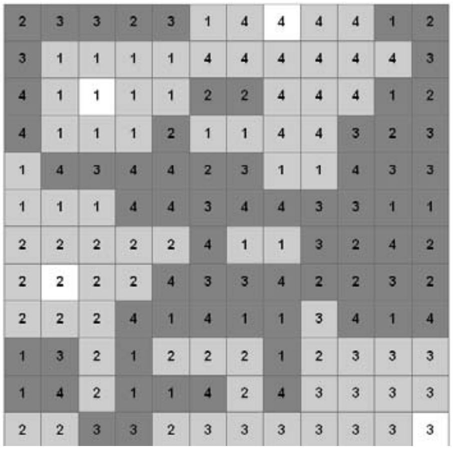
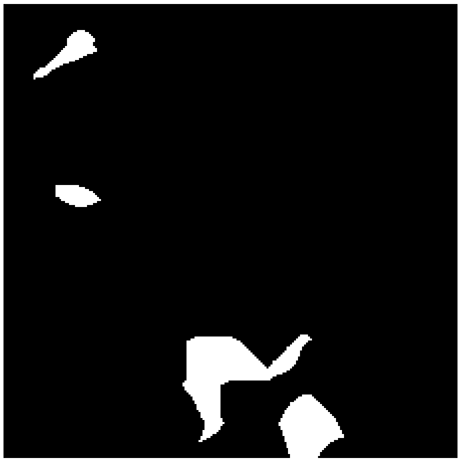
FIGURES

Figure 1 (left): farm territories and spatial constraint on crop allocations : each field is labeled with the number of the farm it belongs to / white polygons: farmstead – light gray ones : rotations with grassland – dark gray ones : rotations with no grassland.

Figure 2 & 3 (middle and right): example of habitat in the tenth year of a simulation, species 1 (middle) and 2 (right). In white: suitable and occupied habitat patches.



INTERCROPPING, AN APPLICATION OF ECOLOGICAL PRINCIPLES TO INCREASE YIELD AND DURUM WHEAT GRAIN PROTEIN IN LOW NITROGEN INPUT SYSTEMS

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KEYWORDS: Land equivalent ratio, N_2 fixation, grain protein content, competition, complementary

INTRODUCTION

Intercropping (IC) - the simultaneous growing of two or more species in the same field for a significant period - is known to use available resources (light, water and nutrients) more efficiently than the corresponding sole crops particularly in low-input systems. Thus, these innovative cropping systems can lead to yield and grain protein increase compared to sole crops (e.g. Hauggaard-Nielsen et al. 2003) which is a major concern particularly in low-N-input systems where N acquisition is low. The aim of our study is to propose innovative cropping managements in order to optimize the use of available resources. We evaluated the potential advantage of durum wheat-winter pea intercrops for total yield and wheat grain protein concentration modified by N-fertilization and wheat cultivars.

MATERIALS AND METHODS

A field experiment was carried out in SW France in 2006-2007 in a clayed loamy soil comparing: i) sole cropped durum wheat (W-SC) sown at the recommended density (336 grains.m^{-2}), ii) sole cropped winter pea (P-SC; cv. Lucy) sown at 72 grains.m^{-2}, iii) durum wheat-winter pea intercrop (IC), each species sown at half of the sole crops densities in alternate rows on November 9, 2006.

Four wheat cultivars named Acalou (Ac), Nefer (Nf), Neodur (Nd) and Orjaune (Oj) were evaluated in sole crops and intercrops. Four fertilizer N sub-treatments were carried out on W-SC and IC: i) no fertilizer-N (N0), ii) one late application of 60 kg N.ha^{-1} (N60) at Zadoks stage 37, iii) one early application of 80 kg N.ha^{-1} (N80) at Zadoks stage 30 and iv) a moderate fertilization corresponding to N80 and N60. Note that P-SC was grown only without any N application.

The experimental layout was a randomized split-split-plot design with three replicates. Grain yield and protein concentration were measured and the percentage of N derived from N_2 fixation (%Ndfa) of pea was calculated using the ^{15}N natural abundance method (Amarger et al. 1979). The IC durum wheat was chosen as a reference crop and we assumed that the correction factor β reflecting the $\delta^{15}N$ of legume shoots that are fully dependent upon N_2 fixation was equal to -1‰. The Land Equivalent Ratio (LER) defined as the relative land area under SC that is required to produce the yields achieved in IC (Hauggaard-Nielsen et al. 2003) was calculated to quantify the advantages of IC (see Fig. 1 for formula).

RESULTS AND DISCUSSION

Without N fertilization (N0) or when N-fertilizer was applied late (N60) LER values were higher than one (Fig. 1) indicating an IC advantage. Conversely, increasing N supply (N80 and N140) resulted in LER values lower than one mostly because of the strong reduction of pea (partial LER values < 0.5). Wheat partial LER values were always higher than 0.5 indicating that the IC wheat yield was more than 50% of the SC wheat yield. Wheat partial LER values were maximum and pea partial LER values minimum for mixtures with Nd and Oj underlining a greatest competitive ability of these cultivars.

The percentage of pea N derived from N_2 fixation was significantly higher in IC than in SC (Table 1) and was reduced by large or early N-fertilizer supply (N80 and N140). Then, pea N uptake from the soil was only 14 kg N.ha^{-1} in IC compared to 83 kg N.ha^{-1} in SC. For all treatments, the IC wheat grain protein concentration (GPC) was significantly higher than that of the SC (Fig. 2). The linear regression indicates that the lower the SC wheat GPC the greater was the increase in IC wheat GPC.

Our work confirms that IC is particularly suited to low N input systems due to the complementary use of N sources of the IC which clearly allowed a better wheat grain filling thanks to: i) high pea N_2 fixation rate in IC, making available for the IC wheat almost as much soil mineral N per square meter as in the SC and ii) fewer wheat ears, grains and yield per unit area in IC compared to SC due to interspecific competitions (Bedoussac and Justes 2009). Then it is recommended to: i) not fertilize IC early and ii) not use too competitive wheat cultivars (tall, early or with great number of tillers) to prevent an adverse effect on legume growth which otherwise do not induce a sufficient reduction of wheat biomass and yield allowing its grain protein concentration increase. We now focus on optimizing these innovative agroecosystems i.e. i) to reveal durum wheat and legume traits suited to IC, ii) to determine the proportions of each species and iii) suited N fertilization management, according to a specific goal (yield, global protein production, low N leaching, low use of chemicals…) or multicriteria objectives.

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Figure 1: Partial land equivalent ratio calculated from yield for the intercropped wheat and pea for the different wheat cultivars and N treatments. Mean (n = 3) ± S.E.

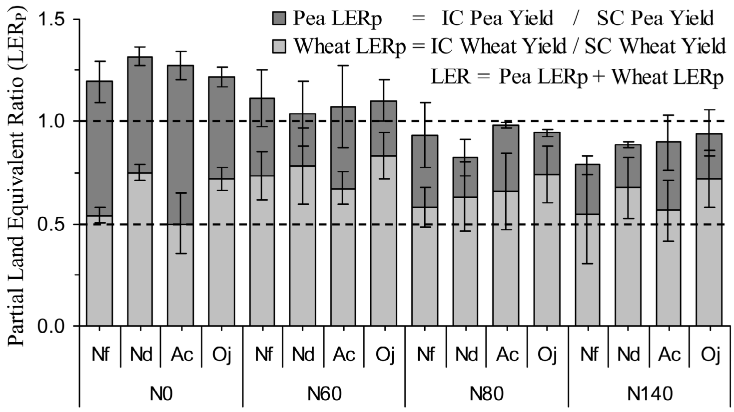
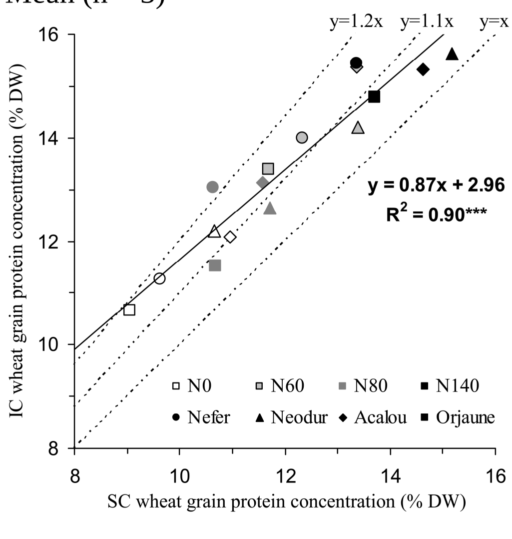


Figure 2: Wheat grain protein concentration in intercrop (IC) as a function of that in sole crop (SC) for the different N treatments and cultivars. Mean (n = 3)



		%Ndfa (% N uptake)	QNdfs (kg N ha^{-1})
SC	N0	52 ± 4	83
IC	N0	84 ± 5	13
	N60	85 ± 7	7
	N80	60 ± 9	19
	N140	70 ± 9	12

Table 1: Fraction of plant N derived from air (%Ndfa) and amount of N derived from soil (QNdfs) of sole cropped (SC) and intercropped (IC) pea for the different N treatments. Mean (n=3) ± S.E.

DESIGNING AND EVALUATING PROTOTYPES OF ARABLE CROPPING SYSTEMS WITH LEGUME SOLE CROPPING OR INTERCROPPED AIMED AT IMPROVING N USE EFFICIENCY IN LOW INPUT FARMING

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INTRODUCTION

Increasing concern about climate change and environmental impacts (including limited availability of fossil energy resources) and present cereal rich cropping systems that sometimes lead to soil erosion, water contamination, increased pests and diseases and weeds resistances (e.g. Jackson and Piper 1989) require transformation of actual cropping systems focusing on enhanced sustainability. To decrease these drawbacks one solution could consist in increasing the diversification of crops across the European countries e.g. by implementing more legumes crops (e.g. Malézieux et al. 2008). Indeed, rotations including legumes and other organic sources of N fertilisation have progressively been replaced with synthetic N fertilizers over the last 4 decades (Crews and Peoples 2004) while increasing the benefits from N_2-fixation and rotational break-crop effects for cereal diseases could reduce the use of fossil inputs.

Growing cereal and legume in intercrops has also been proposed as a solution even if they are rarely cultivated in Europe excepted for animal feed. Indeed cereal-legume intercrops are known to enhance global yield compared to sole crops (Hauggaard-Nielsen et al. 2003) because the species do not compete for exactly the same resource niche and thereby tend to use resources in a complementary way (e.g. Hauggaard-Nielsen and Jensen. 2001; Bedoussac and Justes 2009). For instance, the correct rotational position of the cereal-grain legume intercrops need to be carefully analysed in order to transform existing practises to relevant solutions for low inputs farming, without increasing pests and diseases.

The main objective of this study was to maximize the benefit from leguminous N_2 fixation in low N input systems. Our paper illustrates: i) the design and evaluation of prototypes of arable systems including legumes using jointly medium-term field experiments together with crop modelling at the rotation time scale and ii) the potential of intercrops for improving the: a) global yield and protein content of durum wheat as well as b) the availability of mineral-N for the succeeding crop including risk of nitrate leaching.

MATERIALS AND METHODS

A 6 years field experiment was initiated at INRA Toulouse (SW France) from 2003-04 to study the rotational effects of grain legumes and cover crops (green manure or catch crop function) according to N use efficiency and medium-term soil fertility. The cropping system design was based on a three-year rotation in low input system with each crop grown each year allowing climatic repetition. Six rotations were compared, differentiated by the frequency of legumes in the rotation and the presence or absence of cover crop between cash crops (Table 1). According to Nolot and Debaeke (2003) crop management was based on decision rules in order to adjust technical acts to the soil and crop status and in particular adjusting N application rates to the preceding crop. Simulations at the rotation time scale were carried out using the STICS soil-crop model (Brisson et al., 2003). The main processes involved in the water and N dynamical budgets are taken into account at the same time.

Independent experiments with intercrops (Bedoussac and Justes 2009) of various cultivars of durum wheat and grain legume (winter pea, fababean or chickpea) were carried out in order to analyse the functioning of those innovative cropping systems and identify their potential in arable cropping systems.

RESULTS AND DISCUSSION

The initial five years results show positive winter and spring pea preceding crop effects on durum wheat, due to: i) higher soil mineral N availability at wheat sowing and ii) potentially breaking of cereal diseases cycles. However, higher soil mineral N levels both at harvest and during autumn after pea crops increased the potential risk of nitrate leaching which was efficiently reduced by the introduction of cruciferous catch crops. Catch 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 catch crop residues could be sufficient to compensate in a great part the pre-emptive competition for soil mineral-N when destroyed before winter. The irrigated soybean crop did not increase the risk of nitrate leaching under the present growing conditions, mostly due to i) a late growing cycle, and ii) an efficient N uptake of mineral-N coming from soil mineralization, in complement to N_2 fixation.

Intercrop experiments showed that intercropping durum wheat with winter pea or fababean results in increasing global yield (up to 19%), accumulated N (up to 32%) and wheat grain protein concentration (14% on average) particularly in low N systems whereas these effects were not observed with chickpea.

A number of factors still needs to be optimized before the full potential of these suggested future cropping systems can be appropriately evaluated like: i) intercrop efficiency according to N availability, ii) grain legume species/cultivars including iii) sowing practice (e.g. alternate row sowing or mixture within each row) and design (e.g. density of each component, width between rows,…).

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Table 1: Composition of the experimental 3-years rotation at INRA Toulouse. * indicates that the cover crop was under-sown in the main cash crop, but was abandoned (*1) or replaced by vetch (in 2006) sown after sunflower harvest (*2), due to low emergence of the cover crop.

Rotation	Crop 1	Cover crop 1	Crop 2	Cover crop 2	Crop 3	Cover crop 3
GL0	**Sorghum**	*None*	**Sunflower**	Lucerne (*2)	**Durum wheat**	Vetch/Oat
GL1	**Sunflower**	Mustard	**Winter pea**	Mustard	**Durum wheat**	Vetch/Oat
GL2	**Soybean**	Rape (*1)	**Spring pea**	Mustard	**Durum wheat**	Mustard

A COMPONENT BASED MODEL APPROACH TO EVALUATE CROPPING SYSTEMS FOR BIOGAS PRODUCTION

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INTRODUCTION

The evaluation of the efficiency of different options for bioenergy production in terms of their net reduction of greenhouse gases is of crucial importance for policy makers in order to avoid a misallocation of subsidies and incentives currently used to promote the bioenergy sector. The key elements of the net greenhouse gas effect of bioenergy production with regard to the underlying cropping systems are the productivity of the cropping system in terms of convertible energy (Boehmel et al. 2008), the energy input for the production and changes in the emissions of greenhouse gases due to changes in the land use practices (Clair et al. 2008) and effects on carbon storage in the used soils (Freibauer et al. 2004). All of these key factors heavily underlie influences of the local soil and weather conditions and the crop management. An appropriate evaluation of bioenergy cropping systems should therefore ideally based on a sufficient accurate depiction of the underlying dynamic system by an validated agro-ecosystem model.

MATERIALS AND METHODS

Within a coordinated research project (www.biogas-expert.uni-kiel.de) we are currently developing a system model for bioenergy cropping systems dedicated to biogas production. This simulation model is based on a modular, component based modelling framework (Kage and Stützel 1999). The framework is able support the integration of knowledge and submodels of the different groups involved in the project due to its modular approach, the efficient use of the experimental data by different options for parameter estimation and statistical evaluation of the model results. Thereby existing model modules (soil water balance, evapotranspiration, N-Leaching) are combined with newly developed modules (NH_3 and N_2O-Emission). Prototyping of new submodels was partly carried out using the commercial available modelling system ModelMaker® and a self developed code generator producing source code for the underlying object oriented component library “HUME”.

RESULTS AND DISCUSSION

As an example of the above outlined strategy Fig. 1 shows the re-implementation of a simple dry matter production submodel for rye grass based on (Herrmann et al. 2005). The four steps involve the implementation in the graphic simulation environment of ModelMaker resulting in a partly self explaining model diagram. ModelMaker can export ASCII-files containing nearly the full information of the implemented model. A newly developed tool parses this source code and produces a new source code for the object oriented class library “Hume”. However, because of the missing documentation within the ModelMaker Source, parameter definitions have to be added manually within the transfer tool. Afterwards they are added automatically into the source code.

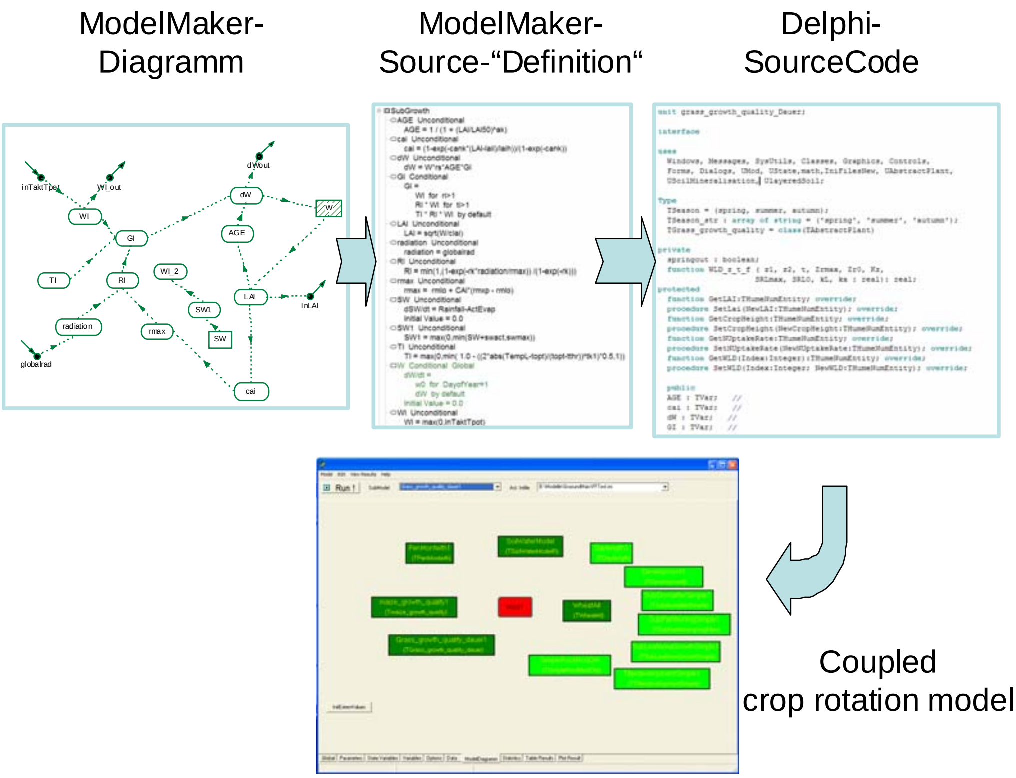

Fig. 1: Example for integration an existing submodel (here a simple crop simulator for DM production of rye grass) into a larger crop roation model.

The outlined approach has similarities with other approaches (Hillyer et al. 2003; Muetzelfeldt and Massheder 2003), however, differs in a number of details. The ongoing application within the collaborated research project mentioned proved its applicability and usefulness.

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A SPATIALLY DISTRIBUTED MODELING APPROACH FOR FARMING SYSTEMS DESIGN AND ECOSYSTEMS SERVICES EVALUATION

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INTRODUCTION

Ecosystems services, precision conservation, bioenergy crops, and a strong trend for landscape-based agroecosystem design can re-shape production systems around the world. Evaluating the tradeoffs among commodities production, resources conservation, and ecosystems services requires and integral consideration of socio-economic, climatic, topographic and edaphic factors characterizing a farming enterprise. While issues such as wildlife habitat are difficult to evaluate at both farm and watershed scales, the on-site and off-site impacts of farming on soil erosion and sediment transport, and N and P losses can be evaluated for entire farms using process oriented simulation models. We present an application of a spatially distributed hydrological and cropping systems model (APEX, a micro-catchment version of the EPIC model, Williams, 1990) to assess different combinations of conservation practices and cropping systems in productivity and environmental impacts in an entire farm. Combinations of annual and perennial crops were evaluated to assess their impact on nutrient losses, soil erosion, sediment yield and redistribution across the farm, separating on-site from off-site effects. The simulated results presented here emphasize erosion and sediments redistribution but outputs pertaining phosphorus and nitrogen are also available.

MATERIALS AND METHODS

A virtual farm was created using as a blueprint the 340-ha USDA-ARS experimental farm at Riesel, Texas. The soils are mostly Vertisols. The mean annual temperature is ~19° C, and precipitation and ETo amount to 900 and 2000 mm yr^{-1}, respectively. The farm was subdivided into hydrologically connected sub-areas based on terrain attributes using the Field Hydro Tool (Duckworth et al., unpublished). The Field Hydro Tool executes a sequence of processes within ArcGIS 9.2 rendering a spatially indexed set of parameter for upland and lowland sub-areas used as inputs in APEX. The subdivision yielded 75 subareas, of which 10 are in lowland positions occupying ~ 30% of the area. Two sub-areas account for 92% of the lowland and are natural sub-catchments outlets. APEX is a model for assessing crop and soil processes in micro-catchments or farms. It runs on a daily time-step and computes the soil water balance, the nutrients and soil carbon balance, crop growth, the removal and transport of sediments and other components in water, the export of nutrients with grain and forage harvest and other net removals, and the impact of tillage practices and structural conservation practices on hydrology and soil properties. Combinations of landscape position and three cropping sequences were simulated for 100 years. The cropping sequences were continuous corn, corn-wheat (one crop per year), and switchgrass. Results are shown as averages of the 100-year simulations.

RESULTS AND DISCUSSION

Continuous corn had the highest productivity and erosion rate (Table 1). Inclusion of wheat decreased soil erosion by covering the soil during spring, when the soil is wet and rain can produce significant erosion. Erosion under switchgrass was negligible. Off-site and on-site effects have markedly different spatial distribution; the most erodible areas within the farm are not the ones contributing the most to off-site sediment yield (Fig. 1). Including switchgrass in either landscape position almost eliminates

Table 1. Harvested grain and residue, carbon returned to the soil, and erosion for each system (C = corn, W = wheat, Sw = switchgrass; lower and upper refer to the landscape position).

System and position		Grain	Straw / Forage	C returned	Runoff	Erosion	Sediment yield	Re-distributed sediment yield	Off-site sediment yield
Lower	Upper	------------- Mg ha^{-1} y^{-1} -------------			mm yr^{-1}	-------------------------- Mg ha^{-1} y^{-1} --------------------------			
C-C	C-C	4.1	0	4.1	247	16.0	11.6	7.3	4.3
C-W	C-W	2.9	0	2.9	182	8.9	5.3	3.3	2.0
Sw	Sw	-	6.5	2.0	135	0.1	0.1	0.0	0.0
Sw	C-W	2.0	2.0	2.7	186	6.6	4.2	3.3	0.9
C-W	Sw	0.9	4.5	2.3	166	2.4	1.1	0.0	1.1

off-site sediment yield; when in upper positions by reducing erosion and when in lower positions by trapping eroded sediments from upper positions. Cropping in steep positions still produced significant erosion; targeting conservation practices or conversion to perennial crops of some landscape sections can reduce off-site effects with minimal impacts on farm-level grain production.

Water content across the landscape was relatively homogenous, likely because the lowland sub-areas were too large to represent the typical accumulation of water in lowlands. With this landscape segmentation, denitrification was relatively homogenous across the landscape (average of 15, 11, and 17 kg N ha^{-1} y^{-1} for continuous corn, corn-wheat and switchgrass, respectively). Crop water stress was slightly higher in upper landscape positions. Thus, while the landscape subdivision allowed an evaluation of spatially distributed erosion and sediments redistribution and yield, it was apparently insufficient to represent appropriately other processes.

Landscape discretization for modeling purposes can be challenging as different scales can be suitable for different processes. We are currently working on landscape segmentation methods that render more sub-areas with properties compatible with the algorithms used for routing water and sediment across the landscape; a comprehensive assessment of the effect scale is required for applications of the APEX model. Applications of these models can facilitate producers' access to the evolving ecosystems service markets; however, uncertainties in model outputs due to both model components and landscape discretization need to be carefully analyzed.

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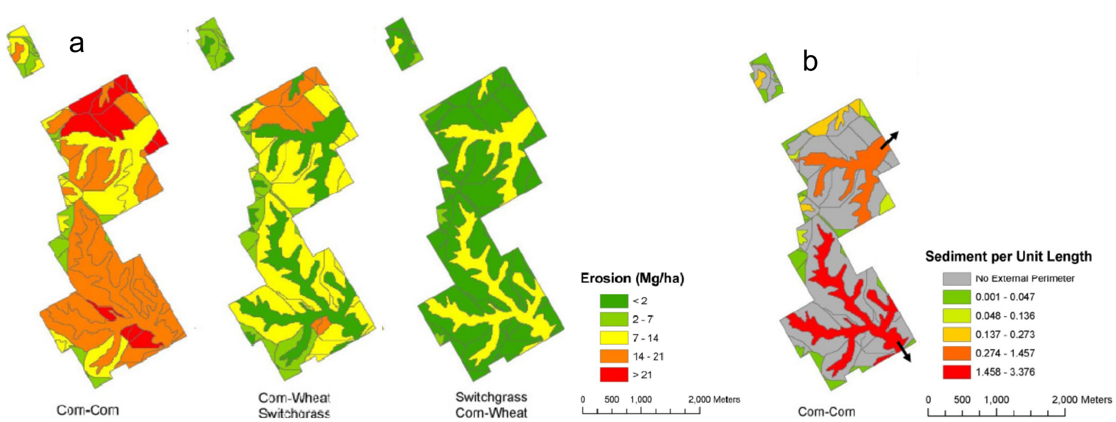
Figure 1. Soil erosion (a) for three cropping sequences, and sediment yield (b) per meter of edge of field for one sequence.



GROWTH, YIELD, RESOURCE PARAMETERS AND INTERSPECIFIC COMPETITION OF INTERCROPPED MAIZE, WHEAT, PEA AND PEANUT IN GERMANY AND CHINA

- A MODEL APPROACH -

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INTRODUCTION

Intercropping, defined as a kind of multiple cropping system with two or more crops grown simultaneously in the same area, is a widespread cropping system in China. China has the largest intercropping area in the world (Li, 2001), with a long tradition and with arable land being scarce, thus land has to be efficiently used in terms of time and space. Besides, there is a so called unconscious intercropping. Because average field and farm size are very small in African and Asian countries (0.1–2 ha), the sum of field borders can be considered as intercropping in a large scale. Thus, intercropping turns into field border cultivation. Within a Sino-German research cooperation, the project “Design, modeling and evaluation of improved cropping strategies and multi-level interactions in mixed cropping systems in the North China Plain” aims to test intercropping systems’ performance in order to detect phenological, morphological and physiological differences between cereals and legumes for increased benefit and synergistic effects and to investigate field-border- cultivation and -interactions at first. After all, data from field trials will be used to simulate and evaluate intercropping systems within the DSSAT crop growth model.

MATERIALS AND METHODS

Field trials with a restricted-randomized complete block design and four replications were conducted in southwest Germany (Ihinger Hof/University of Hohenheim/ø rainfall: 690 mm, ø temperature: 7.9°C) with maize/wheat and maize/pea intercropping and in northeast China (Wuqiao/Chinese Agricultural University/ ø rainfall: 562 mm, ø temperature: 13.1°C) with maize/peanut respectively. During the growing season, three temporal harvests were carried out and dry matter accumulation and grain filling rate determined. For further model evaluation, data for specific DSSAT cultivar coefficients, e.g. phylochron interval, were collected. In addition, N content of soils was analyzed and plants/m² were counted. Microclimate data like soil moisture, soil temperature, solar radiation and wind speed as well as growing stages and plant height were measured on a weekly basis. Yield and yield components were measured after the final harvest. Statistical analysis to detect significance between rows within a plot with different distances from the plot border was done separately for each species and intercropping system in the trial. Analysis was done using the mixed procedure of SAS 9.2.

RESULTS AND DISCUSSION

The results from Germany were divided into microclimate and yield and yield components results, measured at the borderline, in different row distances and in monocropping (= subplots). Soil moisture, air humidity and air temperature were not influenced by intercropping. For soil temperature, only the borderline of wheat was different in top soil layers whereas in pea and maize as well as in deeper soil layers nearly no differences were found. Competition for solar radiation in the first 0.5 m and an increased wind speed in the first rows of all crops were the driving forces for crop performance in intercropping systems. Increasing wind speed in the first few rows may lead to a better CO_2 assimilation rate, but also to an increased transpiration rate. In addition, linear shading patterns in dependency of neighbouring plant heights were detected for wheat/maize and pea/maize intercropping systems for model evaluation. Assuming that the shading above the monocropping canopy equals zero and in dependency of the neighbouring plant height, the shading in percent of the first row could be calculated. Differences in solar radiation (Ball and Shaffer, 1993; Baumann et al., 2002) are considered to be a first step for modeling different intercropping scenarios. In wheat, those effects increased yield. N concentration of the plants was not influenced in both, wheat/maize and pea/maize systems. Concerning yield, wheat profited from being intercropped with maize and pea at least did not suffer from being intercropped with maize. Maize intercropped with wheat suffered at the beginning of the growing season and reacted with less plant height and less dry matter accumulation. But as wheat was harvested earlier than maize, maize showed a compensation growth resulting in maize borderline yielding as high as maize monocropping. Intercropped maize with pea yielded higher in the borderlines than in monocropping.

In comparison to the German wheat/maize and pea/maize (LER > 1) intercropping system, the Chinese peanut/maize intercropping system did not result in an enhanced Land Equivalent Ratio (LER = 1). The LER compares the performance of monocropping vs. intercropping systems with LER > 1 indicating that intercropping performs better than monocropping in a whole. As the economical vulnerability of the divers intercropping systems has been rarely calculated, indexes like the LER are used for estimating their advantages or disadvantages in comparison to monocropping. Intercropping increases the land utilization rate, but the rate does not reflect economic, nutritional or sustainability concerns. In Chinese experiments, maize benefited from being intercropped and was higher yielding in intercropping than in monocropping. The increased yield resulted from a slightly higher number of kernels per ear, a higher TKW and an increased dry matter accumulation within the first few rows. In contrast, peanut suffered from being intercropped. Peanut yield in the first rows was reduced. As well as in the German field trials, the effects of interspecific competition were restricted to the first few rows, so intercropping could be defined as a borderline effect (Chen et al., 2005; Ghaffarzadeh et al., 1994; Iragavarapu and Randall, 1996; Li et al., 2001; 1996).

In conclusion, increased soil temperature in wheat borderlines, shading patterns and increased wind speed in the borderlines of wheat, maize, pea and peanut were the main effects influencing crop performance within intercropping systems. Interspecific competition within intercropping could namely be determined by those parameters and build up the starting point for further modeling approaches. To predict plant growth within an intercropping system, those parameters have to be modified for and within each intercropping system, because one intercropping system does not resemble another.

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INTEGRATED APPROACH TO SUSTAINABLE AGRICULTURAL PRODUCTION IN THE CZECH REPUBLIC

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INTRODUCTION

The current status of the agricultural production in the Czech Republic (CR) has been historically shaped and is a consequence of the development during periods of socialism (1948-1989), transformations following the fall of socialism (1990-2004) and the recent joining of the European Union (EU) (2004). Consequently, the resulting political, economic and social environment and societal pressures have undergone similar changes during this period of time. From the sustainability point of view, the main weakness is in solving economic problems at the expense of agronomic and social issues (Doucha 2007). Therefore, more detailed analysis of problems of current crop production systems was carried out.

MATERIALS AND METHODS

For the assessment of the Czech agriculture as a whole, the statistic data for the period of 1989-2008 published by the Czech Statistical Office and by the Ministry of Agriculture of the CR were analyzed. The following data sets were used: farm size, share of rented land, number of employees in agricultural production, livestock density, inputs of nutrients, organic matter and pesticides, yield of field crops. Complex analyses of many individual agricultural enterprises were carried out in the years 2005-2008. Modified methodology proceeding from works of Vereijken (1992) and model Repro (Hülsbergen 2003) were used.

RESULTS AND DISCUSSION

After 1989, position of agriculture in the national economy has gradually but significantly changed. Political changes were followed by shift in farming practices with a few years delay. Since the period of collectivization, the size of farms remained large (73 % of arable land was in farms larger than 500 ha), but the farm inputs were reduced. The economy became the limiting factor. Consequently, the following changes have occurred:

- Since 1989, livestock and especially cattle numbers decreased nearly by one half. In April 2008, there were 0.51 $LU.ha^{-1}$ in total livestock and only 0.33 $LU.ha^{-1}$ in cattle. Consequently, there is lack of quality farmyard manures.
- Demand for fodder crops decreased and farmers have focused on economically effective crops, which leads to improper crop structure and avoiding regular crop rotation.
- Fertilizer use declined to 65 kg $NPK.ha^{-1}$ (46 N, 11 P, 8 K $kg.ha^{-1}$ in pure nutrients) in 1991 and since then it has been modestly going up to 105 kg NPK ha^{-1} (78 N, 16 P, 11 K $kg.ha^{-1}$ in pure nutrients) reported for 2006 and 2007 with the highest increase in N application. Pesticide use was the lowest in 1993. Since then it has been slightly going up, which has been improving crop protection together with the higher efficacy of pesticides currently used.
- Most land is not owned by farmers but rented for relatively low rent (1-2 % of land price). It can lead to lower responsibility for sustaining soil fertility and also to uncertainty about sustaining current status of agricultural enterprises due to raising the rent or termination of low rent contracts.
- Number of workers in the sector of agricultural production decreased by 73% compared to 1989. Currently less than 150 000 (2.6 %) of population are employed in the Czech agricultural sector.

Many academically educated people left the agricultural enterprises, which has led to high demand for advisory services and lack of sufficient transfer of agricultural research to practice.

After about 10 years influence of these factors, the inter-annual variability in crops yields started to increase. Moreover, the aforementioned situation is also exasperated by frequent reoccurrence of extreme weather during the last few years. The coefficient of variation of cereal crops increased more than twice from 4.07 % (average yield 4.18 $t.ha^{-1}$) in the period between 1991 and 2000 to 8.39 % (average yield 4.65 $t.ha^{-1}$) in the years between 2001 and 2008.

Farmers and agricultural businesses must face controversial requirements of adaptation to current market demands and of sustainable farming. This could be realized through proper agrosystems design at a variety of scales (crop, field, crop rotation, whole farm, etc.). Due to the fact that the average farm size is large, the evaluation of farming sustainability is of great importance (Kren, Valtyniova, 2008). However, most sustainability assessment criteria originally developed for conditions typical for West European countries, i.e. mostly for smaller farms owned and not leased by farmers and in countries with stable economies (Hülsbergen 2003). Therefore, the same criteria may not work well in the CR and the following problems need to be considered:

- The predominant approach to farm data analyses is based on average or cumulative values for each individual farm therefore, if analyses are carried out for farms of large sizes, some information on systems heterogeneity can be lost and results can be biased.
- There is a problem with the approach to data collection in agricultural systems because on-farm economic and agronomic records may be incompatible.
- By present way of farming, preferably right crop sequence on the individual fields will be used rather than fixed crop rotations.

After more than 15-year period of soil resource depletion and the insufficient replenishment the current status of arable farmlands in the CR can be characterized by: (i) negative nutrient balances, especially of phosphorus and potassium, (ii) low diversity of grown crops due to departure from the practice of using proper crop rotations and expanding minimum soil tillage practices at about 1/3 of arable land, (iii) low quality of organic matter coming from cereal crops residues with a wide C:N ratio.

The farming practices used reduce the homeostasis of agrosystems, increase their sensitivity to weather extremes which is reflected in higher field crop yield variability. Overcoming the abovementioned difficulties in a short time will be a challenge because of the fact that farmers are lacking motivation. Therefore, sustainability of the current agrosystems can be at stake in the future.

Acknowledgements

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ENHANCING OPTIONS TO ADAPT TO CLIMATE RISK AT THE FIELD SCALE: AN AUSTRALIAN EXAMPLE OF INTEGRATING EXPERT KNOWLEDGE, CROP AND CLIMATE SCIENCE IN MIXED CROPPING SYSTEMS

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INTRODUCTION

Many Australian agricultural systems are likely to be adversely affected by climate change, particularly if current farm management does not adapt to the changing climate (Howden et al, 2007). For the most part, farmers have not begun to think strategically about adapting to climate change due to a lack of practical information about the effectiveness of tactical adaptation options to increase resilience to climate change. In this paper we examine the likely impacts of climate change on mixed cropping systems in New South Wales (NSW), eastern Australia, and use a participatory engagement approach to examine and evaluate practical adaptation options to enhance yield and gross margins in the face of climate change.

MATERIALS AND METHODS

Simulation models integrate critical climatic, soil and crop physiological variables to examine the effects of climate variability and change on crop production systems. The Agricultural Production Systems sIMulator (APSIM (Keating et al., 2003)) was used to simulate crop rotations on one paddock at each of eight case study sites within NSW. Climate data required to run APSIM were sourced from the SILO climate database (Jeffrey et al., 2001), and soil data, broadly representative of each study site, were drawn from the APSIM database.

A simple, typical, crop rotation was modeled using 50 years of historical climate data as a baseline, and a modified climate record to reflect future temperature and rainfall conditions likely within NSW for 2030 and 2050 under moderate and high climate change scenarios. Atmospheric carbon dioxide (CO_2) concentrations were also varied to reflect levels likely under emission scenarios of moderate and high climate change. Potential adaptation options to improve the yield and gross margin performance of the benchmark rotations under the climate change scenarios were identified via farmer interviews and group workshops. Gross margins were calculated based on 2008 commodity prices and input costs. Throughout this process, ongoing engagement with farmers was central to ensuring that 'real' cropping systems and feasible adaptation options were simulated. Of the adaptation options nominated by farmers, the most common in each region were modeled to assess their individual impact on crop yields and gross margins. These were: introducing a regular fallow into the rotation; splitting nitrogen fertilizer application throughout the growing season and limiting later applications if in-crop rainfall was low; and either introducing a legume into the rotation or shortening the growing season of the main (i.e. wheat) crop in the rotation.

RESULTS AND DISCUSSION

Comparison of present day wheat yield and gross margins to those simulated for 2030 under a moderate warming scenario at a case study site suggest that yields and gross margins are likely to decrease under the warmer, drier, future climate, notwithstanding the positive impacts of elevated CO_2. APSIM estimates indicated that there was greater divergence between the present day and 2030 results (for both yields and gross margins) as the extent of the rainfall decline increased (Figure 1).

Introducing a regular fallow into this continuous cropping system increased yields in the wheat crop following the fallow. However, average gross margins were reduced by around a third (-32.6% to -34.7%) regardless of the change in rainfall. The initially attractive adaptation option of a regular fallow is less appealing when considered in terms of farm income as well as average crop yields.

The use of participatory engagement practices between the scientific and farming communities increases the value and usefulness of outcomes by ensuring that model simulations reflect, as accurately as possible, 'real' cropping systems and feasible adaptation options, and by engaging rural communities in discussions based on sound climate change science.

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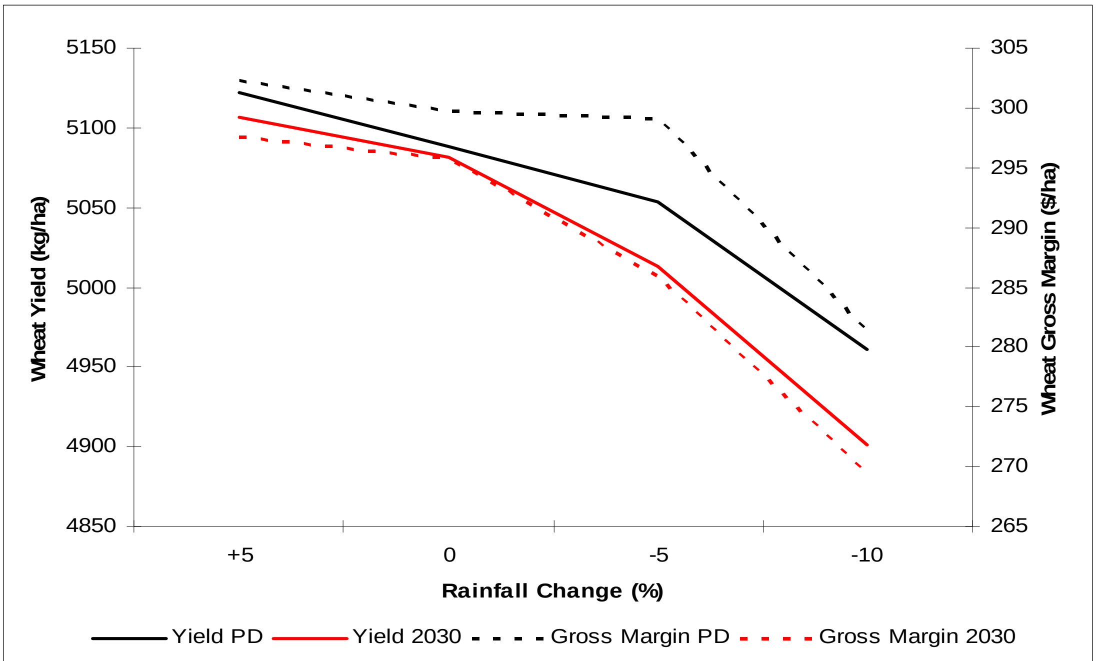

Figure 1: Yields and gross margins simulated for present day (PD) and under a moderate warming scenario for 2030 at a case study site in south eastern NSW

IDENTIFYING POTENTIAL NITROGEN HOTSPOTS IN A FARMING LANDSCAPE THAT THREATEN A RIPARIAN AREA

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INTRODUCTION

Recent advances in yield monitoring and logging equipment attached to grain harvesters allow farmers to map the spatial variation of crop yield across a farm (Cook and Bramley 1998). Assuming fields are uniformly fertilised, this variation in crop yield may generate variations in the amount of nutrients remaining in a field once the crop has been harvested. This may lead to spatial variation in the amount of nutrients remaining in a field that may pollute an adjacent waterway with unexpected environmental consequences (Hodgkin EP and Hamilton BH 1993). We explore the scale and extent of variations in crop yield on a farm in the Young River Catchment using simple yield-nutrient balance relationships to predict the location of nutrient hot-spots on the farm. We combine these data with a digital elevation model to determine the likelihood that regions with excess nutrients may threaten the water quality of a nearby stream.

MATERIALS AND METHODS

The study was conducted on a 5000 ha farm at Cascade, 125 km north-west of Esperance in the South East South Coast of the Western Australian (mean annual rainfall 375mm). Cereals are grown in rotation with canola and lupins and approximately 70% of the farm is cropped annually. The fields border a tributary that flows into the Young River and a delicate estuarine habitat. If nutrients were applied evenly across a field with a relatively uniform level of fertility to satisfy the demands of a 3 t/ha crop, those regions that produce considerably less than 3 t/ha will have high levels of nutrients remaining after harvest. Yield information was extracted from the farmer's combine harvester in 2005, 2006 and 2007. Yield maps were produced from each field in every year that it was cropped to a cereal. Four of the twelve fields were cropped to cereals twice and a composite yield map was produced, where at each location the maximum yield was chosen from either year (Figure 1). Assuming a ton of wheat removes 20 kg N (12% protein) and this represents 50% of total plant N (Halloran and Lee 1979) and we assume there is 20 kg/ha in the soil, a further 100 kg/ha of N must be supplied for a 3 t/ha crop. Thus N remaining can be derived as:

$$\text{N remaining (kg/ha)} = 120 \text{ kg/N} - \text{Crop yield (t/ha)} * 40 \text{ kg/ha} \quad (1)$$

The effect this might have on the river system was subsequently modified to include overland flow of water. Overland flow was calculated by applying the focal length function in ArcGIS to a digital elevation model of the farm. Focal length equates to the distance water will flow across the landscape unimpeded into the riparian zone and takes into account the effect of topography assuming constant flow velocities. We therefore calculate a relative and implied N risk as:

$$\text{N risk} = \text{N remaining (kg/ha)} * 1/(1 + \text{focal length}/100) \quad (2)$$

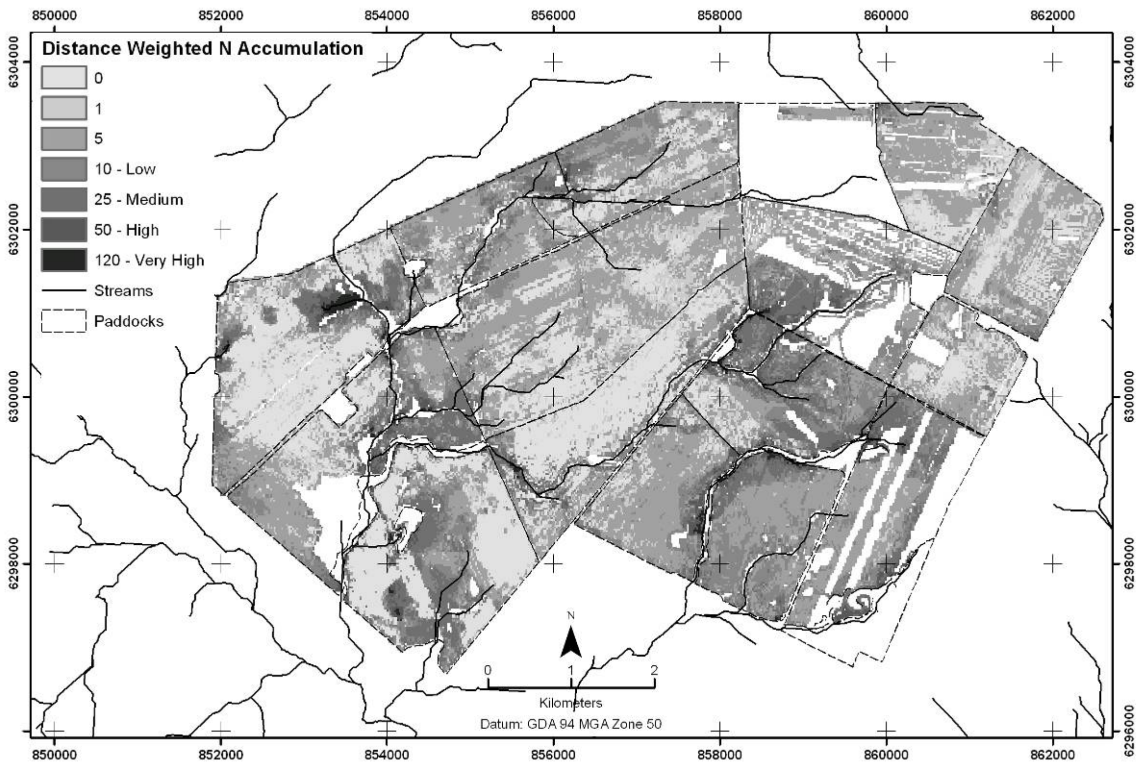
RESULTS AND DISCUSSION

Forty four percent of the farmed area yielded 3 t/ha or more and it is unlikely that residual N would exist in these regions. An additional 38% of the farmed area yielded between 2 t/ha and 3 t/ha and these areas would have relatively low levels of residual N following a cropping programme. The remaining 18% of the farmed area that yielded less than 2 t/ha, and from equation 1 would have high levels of residual N if the land is fertilised for an expected yield of 3 t/ha. The geographic location of poor yields directly translates into zones that potentially have more residual N than other areas. Twenty five percent of the total farmed area had moderate to high levels of residual N of 50 kg/ha or more. These regions were tightly grouped, and were not randomly spaced throughout fields or the farm.

The potential for ecological problems caused by excess N may be sensitive to the distance water travels unimpeded to the riparian zone. In the scenario where distance was calculated as the focal length to the river, it reduced the area of farmland with threatening levels of residual N from 25.1% of the landscape to just 1% (equation 2, Figure 1). Areas very close to the river with low yielding crops were identified as threats. Other low yielding areas would have a minimal impact on the ecosystem as nutrients were unable to move laterally across the landscape into the riparian zone (Figure 1).

In conclusion, the amount of fertiliser applied to the low yielding areas could easily be reduced with little or no economic loss to the farmer. Moreover, the method employed here can be extended to other farms and catchments, providing they have yield monitoring equipment and a digital elevation model. This information can inform policy decision on land management at a regional scale, while the spatial information derived from the yield monitoring equipment can direct the farmer to parts of the landscape that suffer from a soil constraints that limit crop yield. It may be possible to ameliorate the constraint and reduce the likelihood that N would accumulate in this part of the landscape.

Figure 1. Hot Spots of nitrogen on a farm close to a river system.



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A PARTICIPATORY METHOD TO DESIGN INNOVATIVE SUSTAINABLE CROPPING SYSTEMS FOR CITRUS PRODUCTION AT THE FIELD SCALE IN THE FRENCH WEST INDIES

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INTRODUCTION

Designing innovative sustainable cropping systems requires from agronomists a comprehensive approach of both agricultural practices and agro-ecosystems. Design and evaluation are often strongly linked in the process and are generally used repeatedly to form interactive loops of progress. Authors generally agree in identifying different steps in the design/evaluation process. The first step aims at diagnosing the production system constraints. The second step consists in the elaboration of the prototypes (Vereijken, 1997) and the co-construction of assessment indicators (Sadok et al., 2008). The third step evaluates and adjusts these prototypes while the last step assesses and validates them at the farm scale. Their adoption by farmers always requires a close collaboration between farmers and researchers from the beginning (Cloquell-Ballester *et al*. 2005) and moreover the integration of social, economic and environmental constraints, the different stakeholders' interests, and the consumers' demands. In recent years, the environmental impacts of agricultural productions have been regularly denounced by the society. A participatory method based on these principles and preoccupations was set up to build innovative citrus cropping systems in the Caribbean with lower chemical inputs.

MATERIALS AND METHODS

Our methodology (see figure) includes two main steps based on the results of an environmental assessment of the impact of farming practices (diagnosis phase). The method was applied on 41 farms that included citrus cropping systems in Guadeloupe (16° N 61° W). Farmer's practices were compared with a reference cropping system using assessment indicators (Boullenger et al., 2008). It allowed i) the identification of the system constraints and their determinants, ii) the definition of a reference cropping system including constraints (RCS) to designing an innovative cropping system (ICS). Step 1 of the method consisted in building up and evaluating cropping system prototypes in a field experiment. These prototypes were built thanks to technical discussions with the producers and redefined with a group of 3 farmers. At the same time, an expert group, composed of citrus chain stakeholders (consumers, government technical staff…), contributed to the determination of indicators set to assess the performances of ICS. Step 2 consisted in the prototypes validation by the expert and stakeholder groups in a network of experimental farms. Best prototypes became ICS. Finally, the redesign process of this method allowed ICS to become RCS and followed the same improvement process from step 1 as long as new constraints emerged.

RESULTS AND DISCUSSION

The overuse of pesticides in citrus farm was shown to depend on 2 major constraints: weed management and *Diaprepes* spp. control. *Diaprepes spp.* is a major pest for young citrus trees in Guadeloupe, but biological control has been proved efficient (Mailloux *et al*., 2009) and was integrated in the prototype construction. Weed control was crucial particularly in areas where mechanization of orchards was not possible. At step 1, 5 cropping system prototypes were tested to fit with these constraints. Two are considered as reference cropping systems of current producers' practices. Prototypes were then adjusted according to iterative loops of production/assessment/improvement when innovative practices were introduced by researchers and an actor group of farmers. Ten performance indicators have been constructed according to the 3 pillars of sustainability (social, economic and environmental) for an *ex post* assessment. The validation of the prototypes is currently underway. First results show reductions of herbicide use by a 3 factor. Next step will allow the evaluation of ICS in comparison to RCS with our indicators in a network of pilot farms. The time step along the perennial cropping systems limits the possibilities for frequent innovation. Our method allows gradual changes in farming practices along with the stakeholders' demands. This participatory characteristic is essential to limit error.

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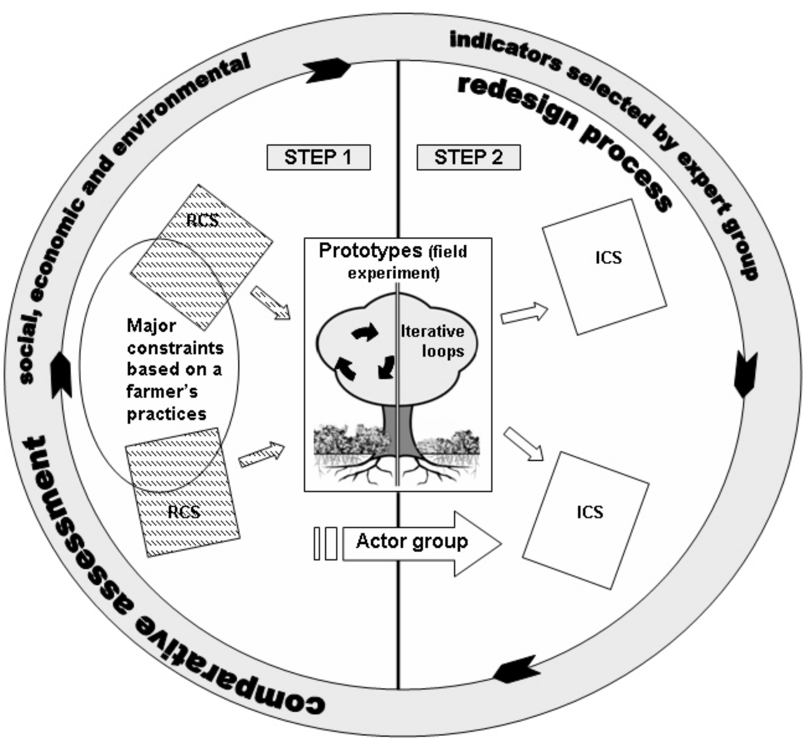

Figure: **Participatory method to redesign and to assess innovative sustainable cropping systems for citrus production. RCS**: Reference cropping system, **ICS**: innovative cropping system, **Actor group** composed of farmers, **Expert group** composed of citrus chain stakeholders, **Step 1** consists in building up and evaluating cropping system prototypes, based on a farmer's practices. **Step 2** consists in validating the prototypes in a network of experimental farms. **Redesign process**: ICS becomes RCS and follows the same improvement process as for step 1.

A SYSTEMS PERSPECTIVE IN DESIGNING WATER AND ENERGY EFFICIENT WHEAT-MAIZE SYSTEM

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INTRODUCTION

Wheat-maize double cropping is the most important system producing staple food grains, animal feed and raw industrial materials in North China Plain. Since winter wheat grows during the driest and most windy period of a year, heavy irrigation is necessary to obtain a satisfactory yield. In a scenario of greater food demand, increasing water scarcity and rural labour increasingly involved in non-farm activities, efforts of managing and designing the wheat-maize double cropping system have been put on improving productivity, water use efficiency and profitability on an intensive base.

MATERIALS AND METHODS

A survey covering 389 farmer households at 18 villages in 6 counties was conducted in 2006, and data from maximum yield experiments in the same counties were collected in the same year. A simulation model was built to simulate crop productivity under typical ecological conditions without nutrient and water stress.

RESULTS AND DISCUSSION

The survey reveals a 13.7 T ha^{-1} (wheat 6.5 T ha^{-1} + maize 7.2 T ha^{-1}) average annual productivity of the system. According to simulated data and recorded maximum yields of wheat and maize, an annual productivity of 50% higher is achievable. Problems limiting the productivity of the system include unsatisfactory land preparation before wheat sowing, too high wheat seeding density, too thin maize plant standing, too early wheat sowing, too late maize planting, unbalanced nutrient application, untimely and improper irrigation, untimely and improper pest and diseases control, etc. Demonstration outputs has proved that solving the existing problems by integrating on-shelf techniques can easily obtain a 30% higher annual productivity and an even higher profit increase. However, it is not easy, and in some cases not necessary, for the farmers to achieve a further higher yield. In order to make it feasible and profitable for the farmers to pursue a higher productivity of the system, infrastructures should be improved and a better support system should be provided.

While mechanization and reducing unnecessary field operations are potential solutions to increase labor productivity, strategies of increasing water use efficiency (WUE) rely mainly on delicate irrigation scheduling to reduce soil water evaporation as well as improving seeding quality in the field. Reduction in the cost for residue and soil management should also result in a significant decrease in energy consumption. The presently popular system, direct drilling of maize under wheat residue + chopping and rotary-hoeing maize residue into the shallow surface soil, is low cost but has problems of shallower tilth (10-15 cm), hard-to-compact seed bed and lower seed emergence & seedling stand. Maize residue in the current system does not prevent soil water from evaporation but increased cost for residue chopping and adds the need of compacting after sowing and ‘freezing irrigation’. Since production cost of the wheat-maize system consists 36.8% for fertilization, 27.3% for irritation, 20.6% for machinery, 10.4% for seeds and 4.9% for chemicals, to reduce irrigation frequency and field entrance of machines should be an effective way of reducing energy cost and improving profitability. Adoption of conservation Agriculture techniques together incorporated with residue collection for animal fodder might be a potential solution. It has been proved that, from nil to triple, one more irrigation of 75 mm can increase wheat yield by 300 kg ha-1. Obviously increase of WUE and highly yielding are two conflicting objectives. Socially, there is a big demand for food grains in the country and wheat is the major staple food in north China; ecologically, wheat field reduces soil wind erosion during the windy winter and spring. Thus, farmers would continue to grow wheat in this area, while it is important to find a breakeven point for optimum irrigation strategy —this may need an integration of economical, ecological, agronomic and mathematical approaches.

It seems that there are plenty of ‘available’ techniques to increase crop productivity, to eliminate residue burning, to save water, to reduce production cost, to balance nutrient application and so on, but few of those have been widely adopted by farmers. There are four major reasons in technology research and development resulting the current situation: (1) neglect of social-economical environment and farmers’ actual situations; (2) lack of cooperation between relevant disciplines and between research and extension; (3) weak linkages between relevant stakeholders; and (4) top-down pattern in research and extension—farmers are being treated as objects to get data from and to be educated. Some results from the experimental fields are being directly ‘taught’ to the farmers or even in a manner of giving one recommendation to all farmers in various circumstances by administration order.

Therefore, system approach should be employed in technology development that implies three aspects in technology development: (1) considering the overall context of a farming system to make the technology being developed compatible with the social economical environment in which the farmers are operating the system; (2) Ensuring adequate and efficient participation of relevant stakeholders and disciplines；(3) contextual design of farming system to improve efficiency of resources (which also include climate, radiation and land/soil fertility apart from water and fertilizers) use—to apply/use the right resource in right place, right time, right quality/ratio and right quantity.

It is important to clarify the following issues before deciding to make any intervention on the current system: **What** problems exist with the current system— Are those problems to the farmers, to the government or governmental officials, to the researchers, or to the machine producers? And what/whose problems should be solved; **Why** the performance of current technology is not satisfactory? For example, why crop yield has been increased or decreased? At what level it has been increased or decreased? Is it caused by the technique itself or by any operation/s in implementing the technique —Being aware of the differences between experimental fields and farmers’ fields is important; **Who** pays and who benefits? Goals of all relevant stakeholders should be compatible and achievable；and **How** to solve the existing problems — On-farm, transdisciplinary and participatory research is needed.

In summary, new technical design in the system should be mechanized, be easy to operate, be able to reduce soil evaporation, and be able to guarantee seeding quality to be water-and-energy efficient—all these objectives should be achieved with one integrated package. Such a system could only be developed by employing systems approach that would satisfy both governmental officials, farmers and researchers.

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DEXI-PM: A MODEL FOR *EX ANTE* SUSTAINABILITY ASSESSMENT OF INNOVATIVE CROP PROTECTION STRATEGIES

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INTRODUCTION

In the last decade, crop protection strategies which rely mainly on chemical control have been more and more put in question. In this context, alternative or innovative protection strategies based on non-chemical methods (*e.g.* genetic, cultural or biological) and exploring the potential of new approaches (habitat manipulation, cropping systems) or new technologies (DNA-based tools, new traits, *etc.*) are studied within the ENDURE EU project, for arable crops cropping systems. Before being tested in fields, these innovative cropping systems need to be assessed *ex ante* for their sustainability in order to select the most promising ones. The aim of our work was to develop a new tool, DEXi-PM, for the assessment of innovative cropping systems using fewer pesticides.

MATERIAL AND METHODS

DEXi-PM, based on other assessment methods such as MASC (Sadok et al. 2009), is a hierarchical qualitative multi-criteria model supported by the software DEXi (Bohanec, 2009). It consists in a decision tree which decomposes the overall sustainability of cropping systems into more and more specific criteria, starting with environmental, social and economic criteria (Figure 1). Criteria are qualitatively estimated, and aggregated with if-then decision rules, fixed according to scientific data or expertise, or adaptable by the user according to priorities or context. The importance of each criterion is characterized by weights. In order to test the model, two cropping systems have been assessed under a French context (limestone plateau of region Bourgogne, with shallow soils): i) a current cropping system (CS) with a typical winter oilseed rape-winter wheat-winter barley rotation, with high amount of mineral fertilizers and pesticides, high sowing density, usual sowing date, and reduced tillage (no deep tillage), ii) an innovative cropping system (IS), with a longer crop sequence (alfalfa-alfalfa-winter wheat-sunflower-triticale-WOSR-winter wheat-spring barley), no pesticide, lower sowing density, shifted sowing dates to reduce pest pressure, use of resistant cultivars, lower mineral fertilizers amount, and reduced tillage.

RESULTS AND DISCUSSION

DEXi-PM presents 75 basic attributes and 112 aggregated attributes along the decision tree (Figure 1). Simulations show differences between CS and IS in the overall sustainability as well as for assessment criteria: the IS was much better in terms of environmental sustainability. They highlight the interest of such a model: DEXi-PM allows the assessment of the overall sustainability of a cropping system in a given context, and can be used as a dashboard displaying weak and strong points of the system, for discussions around innovative cropping systems. It is also possible to test context modifications (*e.g.* pedo-climatic or politic) necessary to render an innovative system acceptable or profitable. A limit of the tool is the qualitative assessment of the criteria but this can facilitate the implementation in case of lack of quantitative data.

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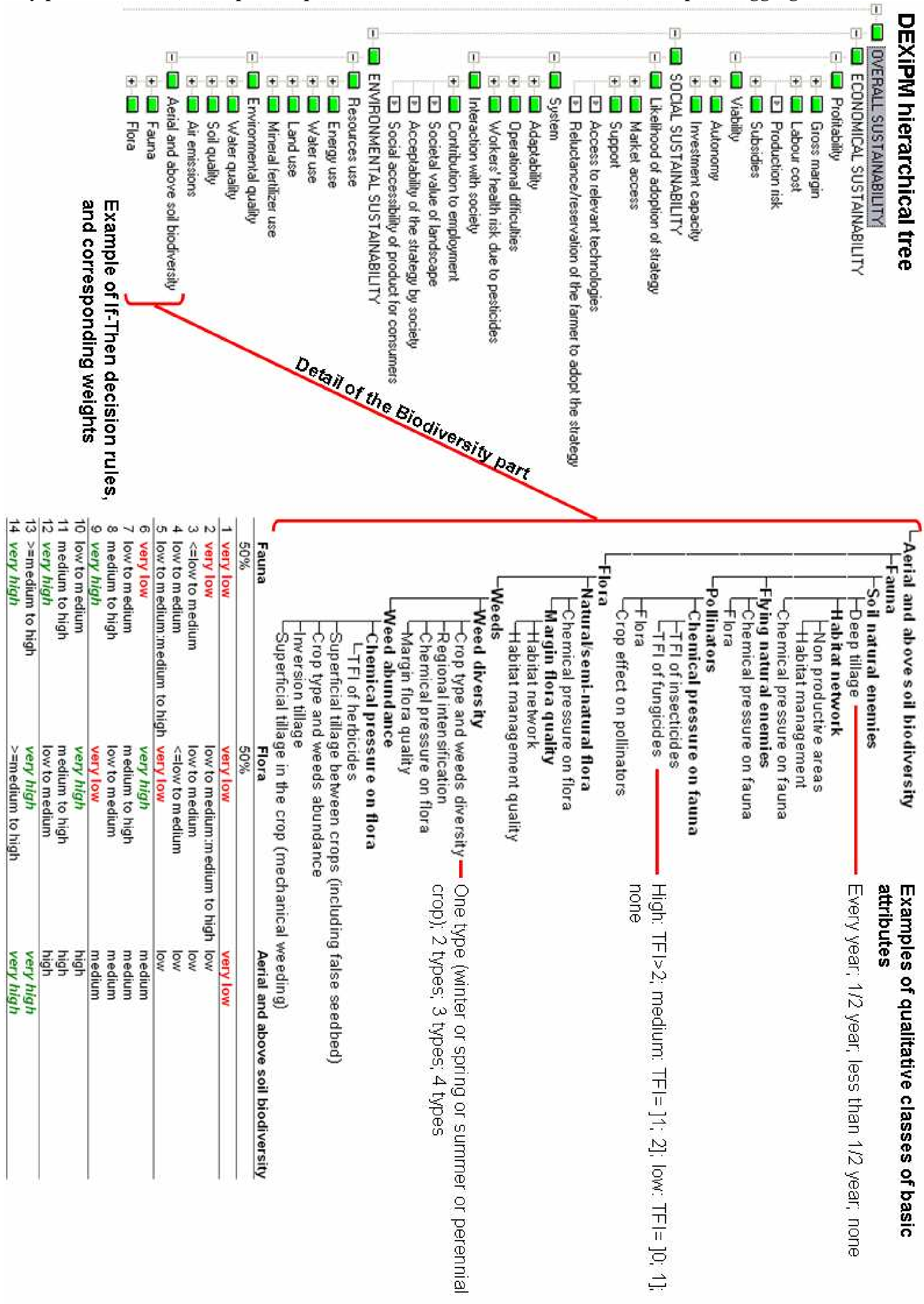
Figure 1. DEXi-PM hierarchical tree for multi-criteria assessment of cropping systems. Details for the aerial biodiversity part of the tree, examples of qualitative values for basic attributes, example of aggregation rule.



SIPPOM, A SIMULATOR FOR INTEGRATED PATHOGEN POPULATION MANAGEMENT: A MODEL TO HELP DESIGN INNOVATIVE CROPPING SYSTEMS FOR INTEGRATED CROP MANAGEMENT STRATEGIES AT THE REGIONAL SCALE.

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INTRODUCTION

Given the impacts of the intensive agriculture of the developed countries, it is necessary to design new cropping systems with limited environmental impacts and that are profitable as well as acceptable for the farmers and society. In the framework of crop protection, the concept of Integrated Crop Management (ICM) has been proposed in that sense: combination of control methods satisfying economical, ecological and toxicological requirements. Concerning crop protection, the main challenges for cropping system design are to find alternative control methods that limit excessive pesticide use, and preserve the efficiency of control methods over time. Models are useful tools for innovative cropping system design and evaluation, particularly for the control of airborne diseases that needs to be reasoned at regional and pluriannual scales, where experiments are not feasible.

SIPPOM-WOSR has been developed to simulate the effect of spatially distributed cropping systems on phoma stem canker of winter oilseed rape (WOSR) and on efficiency of specific resistances. Phoma stem canker, caused by the species complex *Leptosphaeria maculans*/*L. biglobosa*, has a major economic impact on oilseed rape yield world-wide. Several practices have been identified as efficient to control the disease, such as the cultivar choice (specific and/or quantitative resistance), sowing date and density, tillage to reduce the amount of inoculum, chemical treatments. SIPPOM allows studying the effect of their combination as well as their spatial distribution, and ranking systems according to ICM requirements.

MATERIAL AND METHODS

SIPPOM is a spatially explicit model, composed of 5 sub-models simulating primary inoculum production, dispersion of ascospores, changes of the genetic structure of pathogen populations over time, infection and yield loss, and crop growth dynamic (Lô-Pelzer et al. 2008). Output variables are epidemiologic (disease severity index and the associated yield loss), agronomic (yield), economic (margin), environmental (Treatment Frequency Indices and energy cost of the cultural practices) and genetic (pathogen population structure and size).

Most sub-models have been evaluated independently. Data (cultural practices, disease severity, genetic sampling) were collected in a small region in central France since 2006, where cultivars with a new specific resistant gene have been introduced (Pinochet et al. 2007). They have been used to assess the general behaviour of SIPPOM. A sensitivity analysis has also been carried out in order to identify parameters which variation leads to a modification of the ranking of control strategies.

Preliminary simulations were carried out to show the potentialities of SIPPOM in terms of possible use, and to highlight necessary improvements of the model. Simulations were performed with a simplified 3 km * 3 km landscape with 144 fields presenting a WOSR-wheat-barley succession, typical of north France. Two crop managements (CM) were tested: one favouring the decrease of pathogen population size and disease level (ploughing, early sowing, low density), and the other maximizing the potential yield (high density), but with only a fungicide treatment against phoma. Strategies simulated consisted in combining a choice of WOSR cultivars and their spatial distribution, and a choice of crop managements.

Two hypotheses were tested. The first hypothesis (H1) supposed that the association of the CM limiting pathogen population size to the fields with a specific resistant cultivar (to limit the number of virulent ascospores on these fields) should reduce the selection pressure and therefore enhance the durability of the specific resistance genes. In order to test H1, the CM limiting pathogen population size was associated with WOSR fields with a specific resistant cultivar, whereas the other CM was associated with the susceptible cultivar. This was compared with CM applied indifferently to all WOSR fields. The effect of spatial distribution was also tested, hypothesising that maximising the distance between fields that are source of inoculum (wheat fields, corresponding to WOSR the year before) and new WOSR fields should limit infections (H2). Two annual simulations were carried out, comparing a random distribution of WOSR fields with a situation where the distance between source and target fields was maximised.

RESULTS AND DISCUSSION

The main added values of SIPPOM are i) possibility to design control strategies at the regional scale, combining cultural, genetic and chemical control methods, ii) simulation of interactions between crop development and pest populations dynamic under the effect of cultural practices, evolutionary forces and climate to simulate the disease severity and monitor the durability of resistances, iii) proposal of genetic, epidemic, agronomic, economic and environmental outputs to assess performances of cropping systems.

Submodels evaluated independently showed correct to good predictive quality. Evaluation of the overall model is difficult given the spatial and temporal scales dealt with, and the number of input and intermediate variables (the evaluation of the predictive quality *sensu stricto* is nearly impossible). However, comparisons with observed data was a way to assess the general behaviour of SIPPOM in realistic situations, and it showed that the evolution of pathogen population is correctly predicted, but that SIPPOM needs improvements in the calculation of the disease index. Results of the sensitivity analysis showed that classification of contrasted crop management situations is stable when parameters vary.

Simulations proved that SIPPOM-WOSR can display the effect of cultivar deployment in association with crop management on disease and pathogen population structure evolution. Preliminary simulations were consistent with expected results. Simulations also highlighted new results that can not be proved using classical experimental approaches, without a tool as SIPPOM. They demonstrated the possibility to combine WOSR resistant cultivar with a crop management limiting pathogen population size to increase the durability of the specific resistance (H1). They also showed that the spatial distribution of fields (maximisation of distance between sources of inoculum and WOSR fields) is a lever to decrease the disease severity (H2). The simulations were simplified situations, but SIPPOM will be used to simulate more complex strategies in realistic situations, limiting the risk of loss of efficacy of specific resistance (keeping in mind that the key point to reach this aim seems to be the reduction of virulent pathogen population size), and limiting disease risk (for example by testing strategies of spatial distribution of cropping systems). SIPPOM therefore appears as an appropriate tool to help design ICM cropping systems at the regional scale, and could be adapted to other pathosystems.

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DESIGNING ALTERNATIVE CROPPING SYSTEMS BASED ON DURUM WHEAT INTERCROPS IN THE SOUTH OF FRANCE. PERFCOM, AN INTERDISCIPLINARY PROJECT FOR INTEGRATED MULTI-SCALE ANALYSIS

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INTRODUCTION

Increased demand of land for different purposes in Europe implies a further intensification of cropping systems. Such intensification will not come from greater use of inputs but rather increased input use efficiency. The intensification of ecological processes in agro-ecosystems for increase resource use efficiency is today the basis for the design of alternative and more sustainable farming systems (e.g. Griffon, 2006).

The concepts of niche complementarily and facilitation, which have been developed in ecology, could enable to design more functionally diverse plant communities and increase input use efficiency in cropping systems. Intercropping (e.g. cereal/ legume intercrops) or multi-variety cereal cropping systems can enhance fertiliser use efficiency as a product of increased capture, by accessing different pools of N and P in the soil, as well as increased assimilation rate of nutrients by processes of facilitation among species.

Although intercropping systems are broadly spread among small scale farmers in the tropics and greater resource use efficiency has been widely documented, their implementation in farming systems across Europe has been limited until now. In order to understand the ecological processes involved in intercropping systems and identify the main limitations and opportunities for their implementation in durum wheat systems in the South of France, we have developed the PerfCom project (2009-2012) (Hinsinger, 2008), which is presented in this paper.

PERFCOM

PerfCom is an interdisciplinary French project led by INRA aiming at developing innovative agricultural practices for durum wheat production based on the design of more diverse (either pluri-specific or pluri-genotypic) crop plant communities to increase the efficient use of soil N and P resources in the context of low input agriculture in conventional and organic farming systems .

Understanding the main processes determining the performance and possible implementation of intercropping systems requires a multi-scale approach, from the rhizosphere, to the field plot, to the farm, to the production chain or region. In PerfCom, we have created different WP's (Figure 1) carrying out coordinated research activities using a wide range of techniques (i.e. controlled pot experiments in glasshouse or growth chambers, field experiments and on-farm participatory research) which combine competences of bio-technical and socio-economic disciplines.

At the rhizosphere scale (WP5) we attempt to identify functional traits determining the facilitation mechanisms of complex plant communities. Traits investigated include those related to root-borne functions and those related to associated microorganisms and soil fauna implied in the multitrophic interactions that drive the biogeochemical cycles of soil N and P. At the genetic level (WP4) the aim is to identify the phenological characteristics of durum wheat varieties suitable for intercropping systems as well as to identify and evaluate ideotypes of durum wheat in relation to their N and P use efficiency under limited conditions.

At the field scale (WP3) the objectives are to evaluate the performance of different intercropping systems at different levels of N and P availability as well as to understand and model the dynamics light, water and nutrient use efficiencies along the crop cycle.At farm scale (WP2), our objective is to evaluate in a participatory manner the performance of different intercropping systems under real management conditions and identify the best adapted combinations for two regions in the South of France (Camargue and Pays Cathare). Also in this WP interviews with grain collectors and traders are being carried out to identify the main limitations of intercropping systems in the whole production chain.

PerfCom has ambitious plans in relation to the interactions of several disciplines to understand such complex intercropping systems. It also has engaged in several training and education programs at different levels as well as in the diffusion of knowledge to the different actors interested in intercropping systems (WP1).

PRELIMINARY RESULTS

Harvest of the first field experiments is underway and results on the yield performance different intercropping systems can not be presented here. However, several field visits and interviews have been held with farmers and technicians in order to have a preliminary assessment of the intercropping systems tested (durum wheat with faba beans, chickpea, pea, lentil, alfalfa) in terms of crop management. Farmers evaluate well the crop development of intercropping systems and do not consider major technical difficulties for sowing and management. However, concerns have been raised on the technical challenges posed by mechanical harvest of a grain mixture (calibration of combined harvesters) and its associated losses (e.g. fallen and broken grains). Also, concerns on the sorting of grains with similar sizes (eg. durum wheat, peas and lentils) and the need to increase the stocking infrastructure is an issue of concern. Further interviews with grain collectors and traders as well as with agricultural machinery experts are being carried out.

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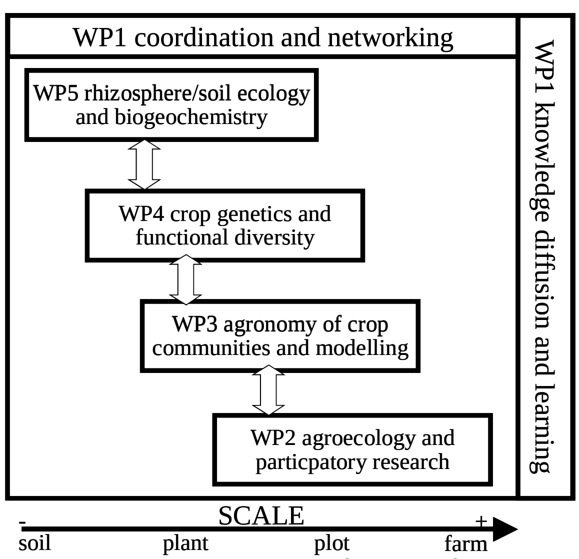

Figure 1. Structure and WPs of the PerfCom project

Growing winter wheat cultivars resistant to diseases under integrated crop management systems: economical, environmental and energetic evaluation

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INTRODUCTION

Since the 80's, winter wheat management in France has focused on cropping high-yielding semi-dwarf cultivars with an intensive use of external inputs. However, the breeding of effective resistances to fungal diseases such as eyespot (Doussinault et al., 1983) has received higher priority for the past ten years (Lonnet, 1997). Meanwhile, integrated low-input strategies have been developed to save on costs and to meet environmental targets (Meynard, 1985; Vereijken, 1989). They could serve as a basis to extend cultivar evaluation to a broader range of crop management systems. The paper aims to evaluate cultivars (Cv) resistant/sensitive to diseases under various crop management systems (CM) in order to assess their economical, energetic and environmental performances.

MATERIALS AND METHODS

A multi-environment experimental network (28 sites, 3 seasons) was carried out to test the combinations of Cv and CM over a wide range of growing conditions. On each site, four rule-based CM were defined, based on a decrease in input level (seeds, N fertilizer, fungicide protection, plant growth regulator) from CM1 to CM4. Three cultivars were used in all sites: Isengrain and Trémie (current, modern, high-yielding and disease-susceptible cultivars) and Oratorio, a cultivar resistant to multiple diseases.

Two economic indicators were used: profitability ($€.ha^{-1}$) and production cost ($€.t^{-1}$). We allowed variations of several factors to assess the vulnerability of Cv-CM combinations to changes in the economical context and to integrate recent increases in grain and oil prices: (i) grain price varied from 80 to 280 $€.t^{-1}$, involving seed cost variations from 0.48 to 0.68 $€.kg^{-1}$, (ii) oil price was $29 a barrel (as in 2000) or reached $144 a barrel (the peak observed the 3rd of July 2008) which affected N fertilizer and fuel costs. N balance ($kg.ha^{-1}$) and Pesticide Frequency Index were chosen to indicate the risk of N losses to air and water and the level of pesticide use respectively. Lastly, the energetic evaluation was based on two indicators: energy efficiency ($t.MJ^{-1}$) and energy costs ($MJ.ha^{-1}$). We expressed some indicators on a per ton of production basis to focus on the efficiency of crop management systems (Charles et al., 2006).

RESULTS AND DISCUSSION

When the oil price reached $29 a barrel (Figure 1a), Isengrain grown under CM1 obtained the best frequency of assignment to the group of high profitability (Fa) from ~120 $euros.t^{-1}$. Among the satisfying combinations regards to Fa, Isengrain-CM2 and Oratorio-CM3 were more robust against wheat price variations than Isengrain-CM1. When the oil price reached $144 a barrel (Figure 1b), a

higher Fa was obtained by combining Oratorio with a low input system (CM4 and CM3) till ~180 euros.t^{-1}. In addition, Oratorio-CM3 was less vulnerable to grain price variations than Isengrain grown under CM1 and CM2. For both scenarios of oil prices and with seed costs equal to 0.48 €.kg^{-1}, Oratorio grown under CM4 and CM3 obtained the lowest production cost, while the highest values were reached by Trémie and Oratorio in CM1. Oratorio grown under CM4 and CM2 achieved the highest values of N balance (indicating low risks of N losses to air and water) and Trémie grown under CM1 the lowest. As expected, the Pesticide Frequency Index (PFI) decreased from CM1 to CM4 with a diminution by 49% between CM2 and CM4. Oratorio grown under CM3 and CM4 obtained the highest energy efficiency. Besides, the decrease of energy cost from CM1 to CM4 amounted to 40.3%.
As a conclusion, results showed that it is environmentally and energetically sound to grow resistant cultivars under low-input crop management systems. Such combinations also reduced production costs and lowered the profitability sensitivity to wheat price. Lastly, they were the more often profitable when grain prices were low, and in a context of average grain prices combined with high oil prices. However, an integrated assessment needs to be implemented at a larger scale to include the loss of non-food ecosystem services provided by natural land brought into production, which remains a major issue for winter wheat at low level of production (Glendining et al., 2009).

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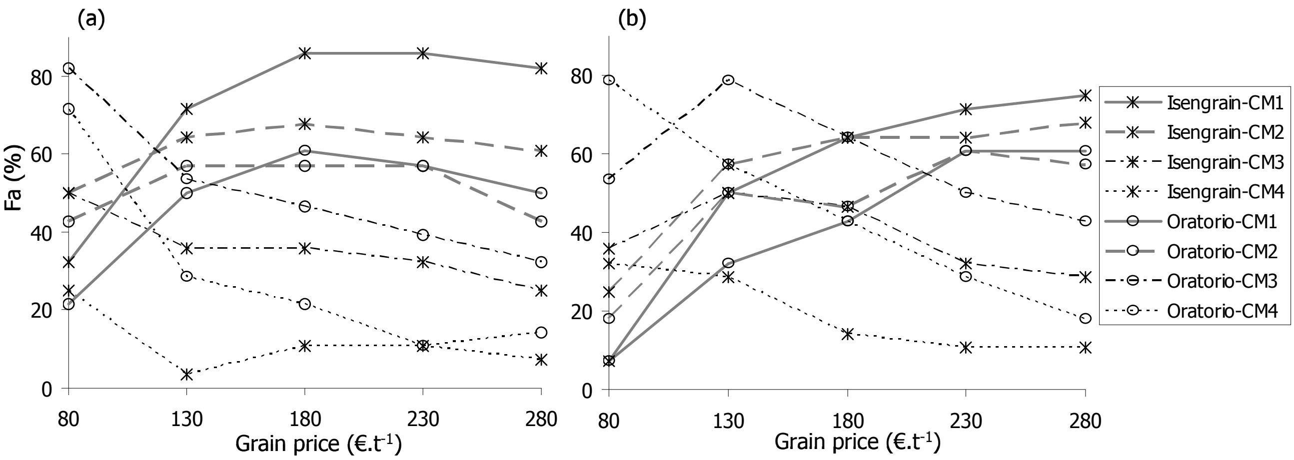
Figure 1: Frequency of assignment Fa (%) of the combinations cultivar–CM to the group of highest profitability as a function of grain price. (a) Oil price: $29 a barrel (b) Oil price: $144 a barrel. Trémie was not represented to ensure a better readability.



SELECTION AND COMBINATION OF MODELS FOR CROPPING SYSTEM DESIGN

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INTRODUCTION

Models can provide useful information to farmers, extension services, and policy makers. Given a practical problem, it is unlikely that only one model needs to be considered; an output variable of interest (crop yield, soil water content etc.) can generally be computed using different types of models with various levels of complexity. The traditional approach is to take a model selection process to find a model from which one makes practical applications. With this approach, it is necessary to define a criterion for assessing the candidate models and to estimate the criterion value from experimental data for all models (e.g., Makowski et al., 2009). Predictions are then based on the selected model only.

Various methods of model selection are commonly used by scientists but, generally, the uncertainty in model selection is basically ignored once a final model is found (e.g., Draper, 1995). Yuan and Yang (2005) showed that, when the model errors are large, a selection process is likely to lead to a completely different selected model when a slightly different dataset is used. Several statisticians emphasised that, in some cases, it may be better to mix all the available models than to use the single selected model. The basic idea is to use a weighted sum of the individual model predictions instead of the prediction derived from the single 'best' model (e.g., Raftery et al 2005).

This paper summarizes the results of a project funded by the French National Research Agency. Its purpose was i) to analyze the instability of the outcomes of several selection processes when slightly different datasets are used, ii) to review available methods for mixing all candidate models instead of using the single selected model, iii) to study the potential interest of model-mixing methods for crop scientists. These issues were addressed through several case studies and a statistical package was developed to help crop scientists to analyze instability of model selection processes and to implement model-mixing methods.

MATERIAL AND METHODS

Model-mixing methods generate a large set of models for a given set of candidate explanatory variables (at least 2^p models can be generated if p candidate explanatory variables are considered) and compute a weight for each model from experimental data. Predictions are then derived using a weighted sum of the individual model predictions. Various model-mixing methods were recently proposed; they use different type of weights based on the Akaike criterion (Aic) or on the Bayesian information criterion (Bic). With the most advanced model-mixing methods, model weights are computed using re-sampling techniques.

The package MMIX was developed to assess the instability of stepwise selection techniques and to implement model-mixing methods with the freely available R statistical software. This package was applied to several datasets in order to assess the value of model-mixing methods compared to i) two stepwise procedures based on Aic and Bic respectively, and ii) a naïve approach which consists in including all candidate explanatory variables in the model. This paper presents the results obtained in a case study where the grain number of organic winter wheat was predicted using 64 linear models including between one and six candidate explanatory variables. Each candidate explanatory variable corresponded to a potential limiting factor like nitrogen nutrition index, weed density, water balance etc. The performances of the selection and model-mixing methods were assessed by computing the relative increase of prediction errors resulting from the use of these methods instead of the naïve approach. A series of datasets including 10 to 50 observations was used to select the explanatory variables, estimate the model parameters, and compute the model weights. The instability of the two stepwise methods was assessed by bootstrap.

RESULTS AND DISCUSSION

Results obtained by bootstrap showed that the frequencies of variable selection resulting from the implementation of the two stepwise selection techniques were close to 0.5 (i.e. to the frequency obtained by a random selection) when the number of available observations for variable selection and parameter estimation was lower than 15. The instability of stepwise techniques was thus large with small datasets. Model-mixing methods performed better than stepwise techniques with small datasets. With datasets including less than 15 observations, model prediction errors were increased by 5 to 20% when a stepwise selection technique was used instead of the naïve approach (Fig. 1). Relative prediction errors were decreased when a model-mixing technique was implemented instead of stepwise selection. This reduction reached 35% for small datasets and advanced model-mixing techniques (Fig. 1). When the number of available observations was higher than 30, all methods showed similar performances (Fig. 1). These results show that model-mixing methods can be useful for crop scientists when a limited number of observations are available for parameter estimation. These methods can be easily implemented with different types of models by using our R package.

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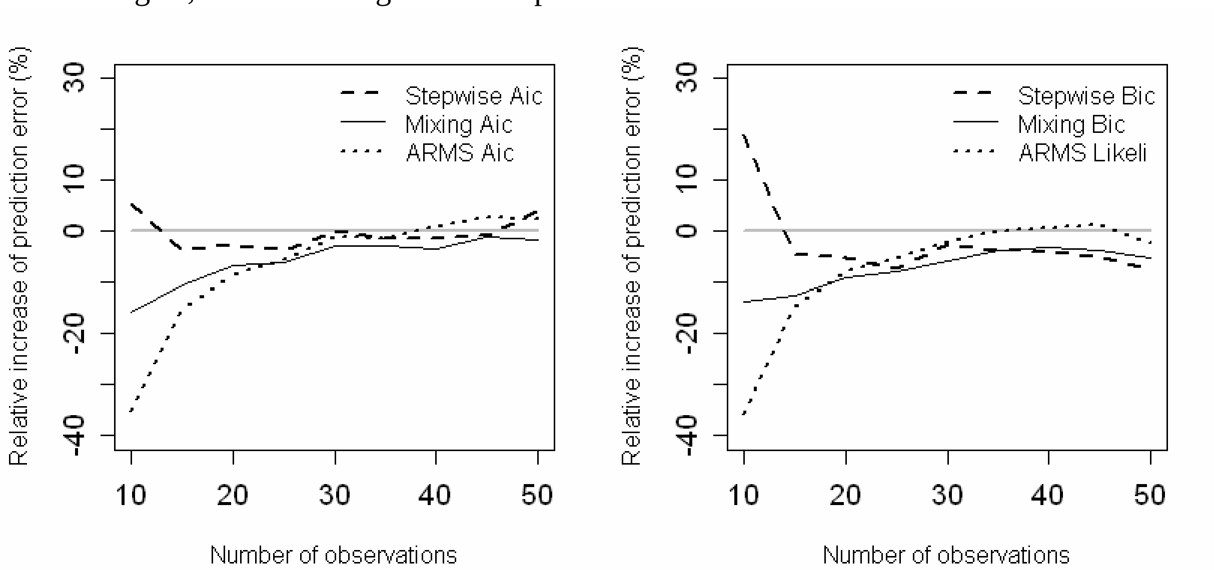
Figure 1. Relative increases of prediction errors (%) for grain number per m² in organic winter wheat crops in France. The increases resulting from the use of two stepwise procedures (Stepwise Aic, Stepwise Bic), two standard model-mixing techniques (Mixing Aic, Mixing Bic), and two advanced model-mixing techniques (ARMS Aic, ARMS Likeli) were expressed relatively to the error level obtained with the model including all candidate explanatory variables. Datasets including 10 to 50 observations were used for selecting the explanatory variables, computing the model weights, and estimating the model parameters.



Software environments for implementing the particle filter with dynamic models

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INTRODUCTION

Numerous dynamic crop models have been developed by crop scientists since the 1960s. Some of these models can be used to improve agricultural practices like, for instance, crop protection or crop fertilization. Nonetheless, their errors are often large due to uncertainty in parameters, input variables and equations. A *filter* is an algorithm that provides an efficient computational means to estimate the state of a dynamic system from a series of measurements. Filtering techniques can be used to improve model predictions by updating the model state variables sequentially *i.e* each time an observation is available.

Different filtering methods have been proposed and some of them have been implemented with crop models (see Makowski et al., 2006 for a review). One of these methods, the *particle filter*, has become very popular over the past few years in statistics and related fields (Doucet et al., 2001). The particle filter is a Bayesian method which can be used to approximate the sequence of probability distributions of the model state variables using a large set of random samples of state variable values, named particles. These particles are propagated over time by the model equations and weighted using the available data. The resulting weights are then used to represent the uncertainty about model predictions through probability distributions. It has been recently applied to improve the predictions of a dynamic winter wheat crop model (Naud et al., 2007).

As the particle filter requires a very large number of model runs (typically, 10,000 model runs at each time step), an efficient software environment is needed to implement this method. The objective of this paper is to compare several software environments based on two open source softwares (the Virtual Library Environment-VLE (Quesnel et al., 2009) and the statistical software R) for implementing the particle filter with dynamic crop models. VLE is a software developed in C++ based on the Discrete Event Specification (DEVS) formalism defined by Zeigler et al. (2000).

MODEL

The particle filter is implemented using the following equations:

$$X_t = f(X_{t-1}, Z_t) + \varepsilon_t \quad [1]$$

$$Y_t = g(X_t) + \eta_t \quad [2]$$

where X_t is the vector of the state variables (e.g crop biomass, soil carbon content, weed density) at time *t* computed using a function *f*, Z_t is the vector of input variables at time *t* (e.g agricultural practices, climate), Y_t is an observation related to X_t by a function *g*, ε_t and η_t are two random terms corresponding to the model error and the measurement error at time *t* respectively. The purpose of the particle filter is to approximate the posterior probability distribution $P(X_t | Y_t)$ i.e the probability of the state variables at time *t* conditionally to the measurement.

The particle filter was implemented at each time step using a four-step procedure (Doucet et al., 2001) defined as follow: i) generate *N* values of the random error term ε_t from a predefined probability distribution, ii) compute the corresponding *N* values of X_t (the particles) using Eq.[1], iii) compute a weight for each particle using a likelihood function based on Eq. [2], iv) sample *N* new values of X_t from the weights. This procedure was implemented using three different approaches:

1. Implementation of all steps using R.

2. Implementation of all steps using the Virtual Library Environment (VLE).
3. Implementation of steps i, iii, and iv using R, and implementation of step ii using VLE.

Two models running at a yearly time step were used for the comparison; a model simulating weed densities in field crops (Munier-Jolain et al., 2002) and a simple soil carbon model.

RESULTS-DISCUSSION

The principle of the particle filter is illustrated in Fig.1 with the weed population model. Fig.1a shows that the ranges of simulated weed density were very large before the correction step of the particle filter, especially at the beginning of the simulation period. Fig.1b shows that the ranges of values were narrowed by the correction step. The results of the comparison of the software environments show that the computation time can be strongly reduced by using VLE instead of R for running the model. The efficiency of VLE is due to the fact that *N* models (one for each particle) were generated at the beginning of the simulation period and that the states of these models were updated at each time step using the particle filter algorithm.

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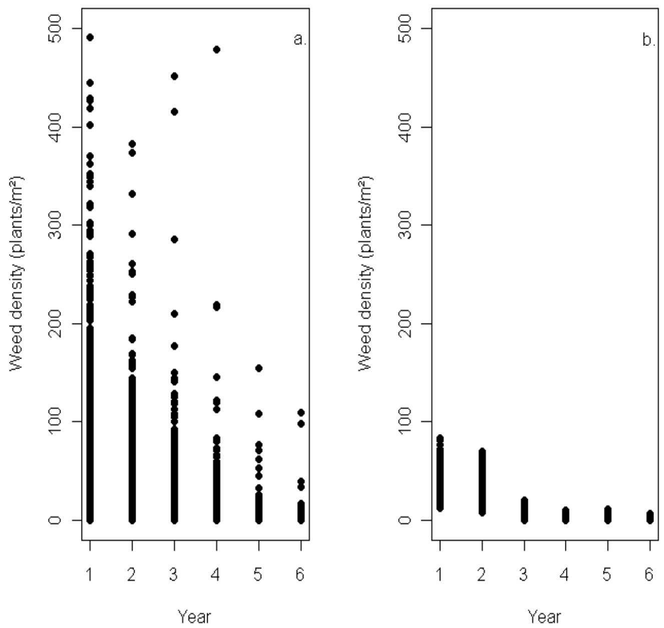

Figure 1. Particles generated by a stochastic weed population model for one plot during six years before correction (a) and after correction using yearly weed density measurements (b) (*N*=10,000).

Designing ecologically intensive horticultural systems for pest control in the tropics

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INTRODUCTION

Fruit and vegetable growers in the tropics are faced with plant protection issues resulting in food insecurity and low-income in low-input traditional agrosystems. In intensive systems, pesticide-induced adverse impacts on human health and the environment may occur (e.g. in African periurban areas and French overseas islands). In order to provide more and better food to populations of both the southern and northern hemispheres, setting up an "ecologically intensive" horticulture by modifying agrosystems to mobilize natural regulation mechanisms taking ecological processes as a source of inspiration, has therefore become a major challenge. It became necessary to shift from a « tactical » curative approach with chemical treatments (agrochemistry) to a « strategic » prophylactic approach to pest/pathogens infestations/infections (agroecology)(Deguine et al., 2008). Horticultural cropping systems, which are basically multispecies-based, provide ideal frameworks for studying the effect, either positive or negative, of the planned introduction and management of plant species diversity (PSD), on pest & disease impact. The Cirad Omega3 project (Ratnadass et al., 2008) addresses such questions. It builds on case studies taken in various cropping systems, representing a range of PSD levels, scales and deployment modalities, according to an *a priori* typology of pest and diseases based on life-history traits the most amenable to manipulation by PSD. From the study of such a broad range of PSD situations, robust and generic results are expected, namely: i) knowledge on ecological pest & disease regulation processes that can be mobilized in agrosystems; ii) tools & methods for incepting & evaluating innovating cropping systems. We expose here the approach followed and some first results obtained within this framework, with a focus on horticultural case studies.

MATERIALS AND METHODS

An operational flow chart of the Omega3 project is provided in Fig.1.The case studies considered correspond to experimental testing of specific potential PSD effects.

To check the hypothesis that the introduction of service plants with sanitizing/allelopathic effect managed as green manures in market gardens results in a reduction of soil infectious potential by bacterial wilt (BW) *Ralstonia solanacearum*, the host/non-host status of 12 plant species was evaluated in the glasshouse in Martinique. BW symptoms were monitored on the candidate species, then *R. solanacearum* was detected/quantified in the soil and plants 45 days after inoculation. BW incidence was then assessed on susceptible tomato plants transplanted in pots with soils where candidate species had been grown.

To assess the potential of pigeon pea and sorghum as perimeter trap crops/barriers for reducing infestation and damage of Tomato fruitworm (TFW) *Helicoverpa armigera* and Cotton whitefly (CWF) *Bemisia tabaci* on okra, a field test was conducted in Niger in plots (resp. 2 with above-mentioned trap crops as borders, and 2 controls with no trap crop borders, resp. unsprayed and insecticide-sprayed). TFW and CWF populations were monitored resp. by visual inspection of plants and yellow sticky traps, and pest damage symptoms to fruits were recorded at harvest.

In order to select cultivars and/or adjusting sowing dates of both crops to optimize trap crop (attractive) and visual camouflage of maize vs TFW *H. zea* (plus barrier effect vs CWF) to protect the tomato crop, a comparative study of the phenological stages of maize (cvs Java, Challenger F1 & Sugar Jean) and tomato (cv HeatMaster) was conducted in Martinique.

RESULTS AND DISCUSSION

In the BW study, 6 service plants were found promising. The testing of the host/non-host status of 8 more candidate plants is underway, and the allelopathic potential of all 20 species will be tested. This will serve as a model process for selecting service plants which can be used for sanitizing soils in horticultural systems, following a scope statement.

In the study conducted in Niger, TFW infestation and damage on okra were significantly lower in the insecticide-sprayed and pigeon pea-bordered treatments, than in the other 2 treatments. The same study is repeated with more treatments (cotton being added as a potential trap crop) and studies of phenological stages of okra, pigeon pea and sorghum, and of the insect-repellent or insecticidal effect of plant extracts (Neem and Jatropha) in an assisted "push-pull" strategy, are underway.

In the study on trap crop in Martinique, maize cv. Java was found to have a potential as a barrier vs CWF, whereas none of the varieties of maize covered the attractive phenological stage of tomato. The test continues with new planting dates, and the emphasis is placed on the research of "dead-end" potential of maize, either thru bottom-up (antibiotic resistance) or top-down (predation) effects.

These results on case studies on a generalist disease and polyphagous pests with resp. low and high dispersal ability, will provide decision rules which will help set up mechanistic models to predict the impact of PSD deployment modes on disease/pests with similar life-history traits. Existing models can also be used if adequate parameter setting. For instance, Tixier et al. (2006) developed a model predicting nematode population dynamics with variations in PSD. As shown by Potting et al. (2005) modelling approaches can be used to show differences in trap crop population regulatory effect between species.

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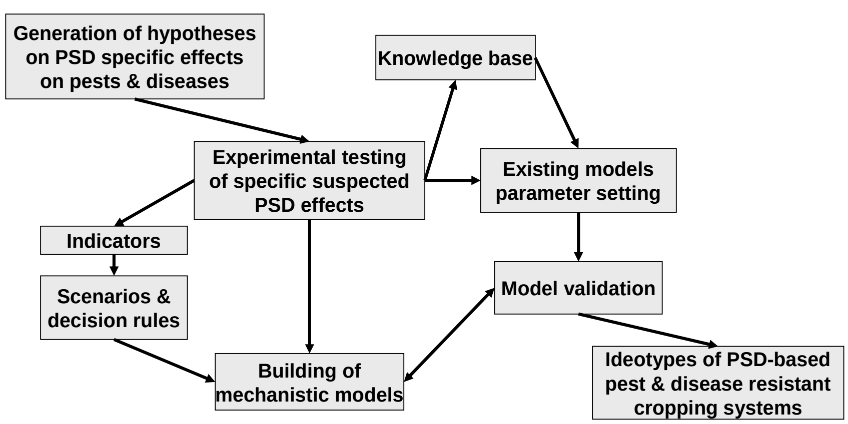

Figure 1. Operational flow chart showing the place of modelling in Omega3 project research process

A Model Framework For Simulating Plant Disease Epidemics

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INTRODUCTION

Crop growth models (CGMs) are key tools for estimating the biophysical behaviour of agricultural production systems in response to the interaction of weather, soil and agro-technical management options. Although CGMs account for many processes of these complex systems, some important processes which may have a severe and variable impact on production system are not included in the simulations. Among these processes, modelling plant diseases development, impact on plants and agro-management is key to estimate the potential diffusion of plant pathogens in new environments and in climate change scenarios. The Diseases software component, developed initially within the APES (Agricultural Production and Externalities Simulator) project, provides a generic framework for the simulation of disease development and for the estimation of the impacts of plant diseases on plant growth and yield. The component architecture follows the design summarized by Donatelli and Rizzoli (2008) in order to enhance its reusability and possible extension by third parties, .The component is composed of four modules: 1) Disease progress, 2) Inoculum pressure (initial conditions), 3) Impacts on plants, and 4) Agricultural management impact on pathogen populations. The current development of the Disease progress module, developed as a generic model framework to simulate the epidemics caused by fungal pathogens, is briefly described..

DESCRIPTION OF MODEL

Data-types called the domain class are defined encapsulating the variables used to model the domain. They contain interrelated elements of a generic pathosystem of the Diseases component gruped as States, Rates, Auxiliary, Exogenous and External States. Domain classes encapsulate an explicit ontology via a set of attributes for each variable: name, description, maximum and minimum value, default value, the measurement units. Models, either taken from peer-reviewed sources or elaborated ad hoc, are implemented in discrete units called strategies. Alternate approaches can be available to model a single process, allowing for composition of new models. Current approaches use an hourly time step to estimate rates of change of state variables in response to weather and agricultural management. Approaches and terminology used in the model development follow Vanderplank (1963), Campbell and Madden (1990) and Rossi et al. (1997). The current documentation of models is available at http://agsys.cra-cin.it/tools/diseases/help/.

RESULTS AND DISCUSSION

The Disease progress module simulates the epidemics of a generic air-borne fungal pathogen, considering the following components of the infection process (auxiliary variables): infection, incubation, latency, infectiousness, sporulation, spore dispersal and landing. These processes, driven by weather conditions and interactions with the host plant, are modelled as a function of meteorological variables and parameters specific for each host-pathogen couple.
Proportions of the host tissue affected by the disease are classified in different states on the basis of the following disease stages: incubation, latency, infectiousness, and lesion senescence. The states of the host tissue are, therefore: i) healthy, ii) latent (with latent infections not yet visible), iii) visible (with visible but no sporulating lesions), iv) infectious

(with sporulating lesions), v) old (with old and sterile lesions, i.e. no longer sporulating). States ii to v represent the total proportion of host tissue affected by the disease (Figure 1).
Healthy tissue enters the latent state when infection occurs. Infected host tissue in the latent state evolves to the state of tissue with visible lesions once the incubation period is over. The subsequent two states of host tissue with sporulating lesions and with old lesions occur when the latent and infectious periods are finished, respectively. The incubation, latent, and infectious periods are estimated as a function of temperature using parameters specific for the pathosystem under simulation. The portions of health host tissue which become infected and therefore evolve to the state of host tissue latent, are estimated based on portion of host tissue vulnerable to infections (susceptible and not affected yet) and rate of infection. The infection rate depends on two factors: sporulation which is estimated as a function of temperature and vapour pressure deficit, and dispersal which is simulated as a function of either rainfall or wind speed . Once deposited on the surface of a vulnerable host tissue, new infections take place under favourable conditions of temperature and humidity. The Disease progress module estimates the proportion of host tissue affected compared to the total host tissue. It uses a set of functions which can be used to simulate the progress of the epidemics caused by several pathogenic fungi on several crops, by simply changing specific model parameters. The same approach is used to simulate the effects of agriculture management options on disease progress (fourth module of the Diseases component). The model framework is implemented as a software component ad it will be publicly available within 2009, inclusive of the plant damage and agro-management modules.

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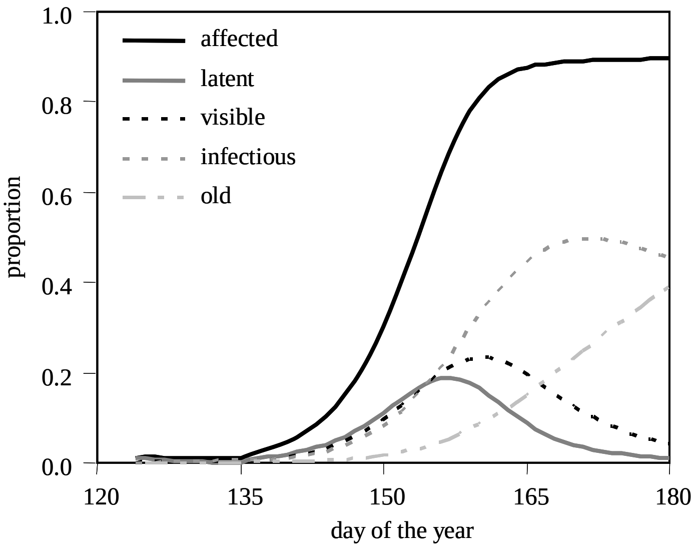

Figure 1. Outputs of the model simulating the progress of plant disease epidemics. The host tissue affected results from the sum of different tissue's categories with respect to the infection process: latent, visible, infectious, and senesced fractions.

SHOP: A HERD DYNAMIC MODEL TO SIMULATE THE INTERACTIONS BETWEEN BATCH FARROWING SYSTEMS OF SOW HERDS

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INTRODUCTION

To respond to their work load expectation, French swine farmers tend to i/ explore new batch farrowing systems (BFS) in order to have new periodic rhythms of work and ii/ simplify reproductive protocols in order to control their daily schedule or mitigate weekend work load. We developed the herd dynamics model SHOP (Sow Herd Operation and Productivity) based on a previous sow herd model (Martel et al., 2008a) to simulate the interactions between BFS and sets of reproductive protocols and to study their consequences on herd productivity and work load distribution.

DESCRIPTION OF THE MODEL

SHOP is a stochastic, dynamic and animal-centred model. Animal biology is modelled with normal univariate distributions (number of piglets born, number of teats, duration of pregnancy…) and by probability thresholds (fertility, abortion, mortality…). All parameters values and equations used in the simulation were obtained from the analysis of the french Technical Sow Herd Management System (TSHMS) database (year 2008) (IFIP, 2009). Reproductive protocols used by farmers and included in the model were formalised with an on-farm survey (Martel et al., 2008b) and concerned farrowing supervision, cross-fostering, weaning, oestrus detection, insemination, and culling and replacement rules. One protocol defined activities, their period of occurrence and their frequency. For instance, oestrus detection activities start the Monday following weaning and end the next Friday (period) and is performed twice daily (frequency). Figure 1 represents the interaction between animal biology and reproduction protocols for the determination of sow fertility threshold value : 1) the highest fertility that a sow is able to obtain is dependant of its productive history (Figure 1a); 2) the level of fertility varies during oestrus period, according to time of ovulation (Figure 1b), 3) oestrus detection protocol determines the moment when the farmer will be aware of the sow being in oestrus, while insemination protocol defines the timing of each insemination (Figure 1c).

In order to test the ability of the model to represent various systems, a series of simulation experiments was realised. We simulated three BFS (4-week (4W), 3-week (3W) and 1-week (1W)) with 10 or 35 sows per batch. For each of these BFS we tested 5 sets of reproduction protocols. In the control protocol (C) oestrus is checked twice daily during 10 days after weaning, inseminations occur 12 hours after detection of oestrus or after previous insemination with a maximum of 3 inseminations, cross-fostering is realised between sows from the same batch or from other batches when available. In the second protocol cross-fostering was only allowed between sows from the same batch (CFI). In the third protocol no cross-fostering is performed (NCF). In the fourth protocol (5OD) the period and the frequency of oestrus detection are reduced to 5 days and once a day, respectively and first insemination occurs only 24 hours after the oestrus detection. In the last protocol (5ODIA) oestrus detection is the same as for 5OD but insemination protocol is adapted according to the weaning-to-oestrus interval (WOI).

RESULTS AND DISCUSSION

The average number of total-born piglets simulated for the control experiments (14.1) is similar to the performance observed in TSHMS (14.0). The simulated number of weaned piglet tends to be higher (11.8 vs. 11.2) in agreement with the high quality of piglet management assumed in C protocol (farrowing supervision, help to piglets, cross-fostering). Due to the high number of teats per sow (14.4) compared to the number piglets of born-alive piglets (13.1), the number of cross-fostering involving sows from another batch is low (1 sow for ten batches). The BFS affects the WOI, due to the enhanced capacity to keep infertile sows in 3W and 1W BFS compared to 4W BFS. The distribution of work load is in agreement with the description made by Caugant (2002) and independent of the number of sow per batch.

The CFI protocol does not produce any significant modification in the herd performances. This is related to the few number of cross-fostering occurring between batches in the C experiment. All the systems simulated in the NCF experiment have a decrease of about 0.2 piglets weaned per litter. It can be concluded that when the average number of teats per sow is higher than the average number of piglets born alive, the cross-fostering practices have a relatively low importance.

In the 5OD experiment the WOI and the weaning-to-conception interval (WCI) increased. This is related to two factors: a shift in the day of oestrus detection with fewer sows detected on Monday and Tuesday and more sows detected on Wednesday and Thursday compared to the C protocol. This shift explains the increase of WOI. The change in insemination protocol and the shift in oestrus detection induce an increase in the number of sows inseminated after ovulation and consequently a decrease of sow fertility leading to an increase of WCI. Another consequence is the shift in the parity of sows at culling. The number of gilts and primiparous sows as well as the number of sows with more than 8 parity increase in 5OD protocol compared to C. The modification of the insemination protocol (5ODIA) results in a fertility similar to the control in the 4W and 3W BFS and an intermediate fertility in 1W. The difference resides in the management of sow with a delayed oestrus. In the 1W BFS those sows are still detected because oestrus detections occur each week but they are often detected after the ovulation and so still have a reduced fertility. In the others BFS those sows are not seen at all.

From these preliminary results, SHOP appears an interesting tool to represent various sets of practices and their implications on sow biology and herd performances.

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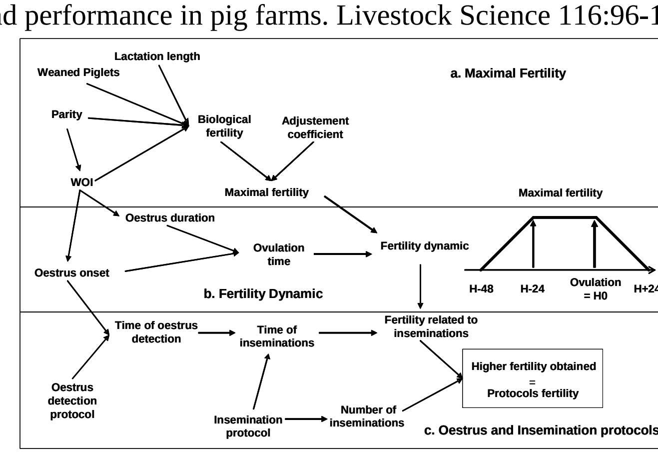
Figure 1:
a. Operations to calculate the maximal fertility of each sow
b. Operations to generate a fertility dynamic during oestrus
c. Operation to combine reproductive protocols and sow fertility



TAKING ADVANTAGE OF GRASSLAND AND ANIMAL DIVERSITY IN MANAGING LIVESTOCK SYSTEMS: A SIMULATION STUDY

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INTRODUCTION: THE MANAGEMENT CHALLENGE

In grassland-based livestock systems, grass production is highly heterogeneous and variable in space and time. This fact reflects the between-field differences of vegetation types in relation to management intensity and environmental factors, mainly soil conditions and topography. Weather variability within and between years is another explanation. Through organizational and in-situation decision making, farmers strive to make efficient and opportune use of grass production by livestock grazing or mowing. The overall objective is to secure the feeding of the herd in compliance with desired and attainable grass production.

The idea that livestock farming systems should further integrate consideration of plant species, grassland, animal, and farmland diversity is now commonly acknowledged (e.g. White *et al*., 2004). All three constitute a source of flexibility that can be used in organizational and in-situation decisions to cope with uncertainty of environmental factors such as weather. For instance, grassland diversity enables farmers to have fields that are suitable for different and sometimes multiple uses fitting with the feeding requirements of different livestock classes. In addition to this organizational flexibility, within-field plant diversity makes it possible to take advantage of timing flexibility in grassland management, i.e. the extent to which the use of a given grassland may be brought forward or deferred on a temporal interval at various times of year. This paper describes the SEDIVER model-based approach that aims to design grassland-based livestock systems and management strategies that enable efficient exploitation of diversity in plant species and grassland against weather variability.

DESCRIPTION OF THE SIMULATION MODEL

The SEDIVER model is a dynamic farm-scale simulation model intended to be used by researchers. In the SEDIVER model, the production system can be decomposed into evolving and interacting subsystems, manager, operating system and biophysical system (Fig. 1). The biophysical system is considered as a set of managed entities, such as plot or cow, that are themselves changing over time through interacting processes such as herbage growth or animal intake implemented in dynamic biophysical submodels. The manager is an explicit system that produces decisions and eventually implements these decisions into actions. The simulation model harnesses this structure and the interactions among subsystems, such as those occurring between the weather, the biophysical system, and the farmer's decisions and actions. This is supported by the modeling framework DIESE (DIscrete Event Simulation Environment) that relies itself on a generic conceptual model of agricultural production systems (Martin-Clouaire and Rellier, 2009).

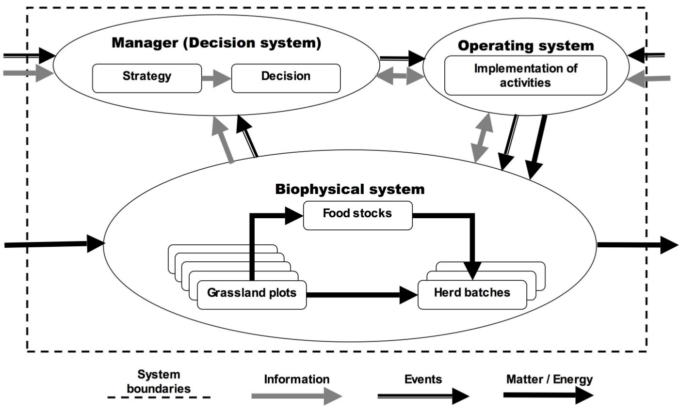

Figure 1: Livestock production system

The two main novel features of the SEDIVER model are (i) a representation of diversity in plant species, grassland, animal, and farmland into an encompassing farm-scale model, (ii) a representation framework in which realistic management strategies can be expressed through flexible activity plans. Such a plan is the result of the farmer's reflection on prior experiences and conveys the temporal organization of activities that the farmer sets up to meet his particular goals and anticipate likely occurrences of important events. Due to uncertainty, plans must be flexible and adaptable to circumstances. Different climatic scenarios lead to different realizations of the plan.

RESULTS AND DISCUSSION: A SIMULATION-BASED EXPERIMENTATION

The simulated example concerns a grassland-based production system of 6 to 8-month old just-weaned beef calves (Gasconne breed) in the French Pyrenees Mountains. In this area, long and cold winters preclude grazing-based feeding for several months. About half of the farms have access to roughly 20% of external hay supply to cover winter feeding of their herd. Forage self-sufficiency during winter is thus a key performance factor for such systems. Management of forage stock production and grazing are closely interdependent. These have traditionally been based on dates and herbage allowance characterized by height or biomass and stocking rate. Increasing herbage utilization rate to reach forage self-sufficiency requires careful consideration of the diversity of grassland production patterns encountered within a farm through their temporality, productivity and nutritive value. Indeed, the trade off between herbage growth and senescence, which depends on leaf life spans and phenological stages of grassland plant species (Duru *et al.*, 2009), has strong consequences on production and nutritive value.

We conducted a simulation-based experiment over 7 real year-long weather series to evaluate the advantages provided by an alternative forage stock production and grazing management mode paying increased attention to plant species and grassland diversity. We compare it with a traditional management mode. The results (Tab. 1) showed that while maintaining animal production performances, the alternative management mode allowed harvesting almost twice the quantity of forage with the traditional management mode. This tendency was accentuated in favourable years, diminished but remained substantially higher, i.e. one-and-a-half-fold, for years including a prolonged drought event. Average nutritional value of harvest increased as well by .05 $kg.kg^{-1}$, and grazed herbage nutritive value rose by .04 $kg.kg^{-1}$. The relative quantity of grazed herbage in yearly animal intake increased during favourable years. Herbage utilization rate increased by 13% on average, and still by 10 % for years including a prolonged drought. All these facts suggest that encouraging farmers to pay increased attention to plant species and grassland diversity in their management would offer them promising potentialities to cope with weather variability.

Table 1 : Minimum, average and maximum values for aggregated simulation output indicators between the traditional and the alternative management modes

Management Mode	Harvested Quantity per Animal Unit	Digestibility Of Harvest	Forage Stock Consumption per Animal Unit	Relative Part of Grazing	Digestibility Of Grazed Herbage	Herbage Utilization Rate	Live Weight Production per Animal Unit
Traditional	457/1373/1780	0.56/0.61/0.67	1814/1951/2091	0.56/0.58/0.61	0.67/0.72/0.75	0.36/0.53/0.61	184/207/219
Alternative	964/2589/4066	0.64/0.66/0.69	1764/1867/2009	0.56/0.60/0.62	0.71/0.76/0.77	0.49/0.66/0.73	183/206/223

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SIMULATING PRODUCTIVITY AND ENVIRONMENTAL IMPACTS OF SORGHUM CROPPING SYSTEMS IN CENTRAL AND SOUTH TEXAS

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INTRODUCTION

Production systems are expected to provide feedstock for the emerging bioenergy industry. In Texas, sorghum is a well adapted crop known to producers, and is therefore a primary candidate to provide grain and lignocellulosic biomass for biofuel production. Of critical concern however, is the uncertainty regarding the impact of the intensification of production systems on on-site land degradation, off-site sediments, nutrients and pesticides pollution, and greenhouse gases emission balance.

Our main proposition is that in annual cropping systems, the most productive areas in Texas as determined by their water availability and soil productivity are the most suitable for production intensification, because their higher grain and biomass outputs can be coupled with low erosion rates and positive or neutral soil carbon balances, and off-site impacts can be minimized with proper application of tillage and structural conservation practices.

As a component of that overall framework, we present an evaluation of the productivity and environmental impacts of sorghum-based cropping systems in central and south Texas under different combinations of tillage (conventional tillage = CT, reduced tillage = RT and no tillage = NT) and structural conservation practices (none = NP, contours = CP, and contours + terraces = CTP), irrigation, and soil type. For this purpose, we used the EPIC model (Williams, 1990) along with soil, weather, and management practices databases for Texas specifically customized for this project.

MATERIALS AND METHODS

Simulations were made for several dryland and irrigated sorghum cropping systems for the top 28 sorghum producing counties in central and south Texas, for a total of 7,302 unique tillage-soil-weather-conservation practice combinations for both dryland and irrigated systems. Each simulation point represents a known acreage of cropland (see Potter et al., 2006).

Benchmark systems and conditions were generated by simulating continuous grain sorghum under CT, RT, and NT for 100 years. After the initial 100-years run, each system was followed by 100 more years of CT, RT, or NT, thus creating for each point a total of nine sequences (CT, RT, and NT, followed by CT, RT, or NT). This allowed evaluating the change in response variables when the tillage systems are changed from the benchmarks.

The Sorghum Variety Trials data from the Texas A&M Agriculture Program (2002-2006) were used to calibrate and test a set of crop parameters representing grain sorghum hybrids grown in Texas. To avoid N and P nutrient stresses, N and P fertilizer was applied using the automatic fertilizer trigger option in EPIC. Grain and biomass yield, SOC evolution, crop available water (CAW), runoff and erosion, and N and P losses are briefly discussed for these simulations.

RESULTS AND DISCUSSION

Following the 100-yr pre-run soil initialization, benchmark tillage systems maintained stable SOC levels over the next 100 years of the simulation, except for the NT system. This stability was conserved on a layer by layer basis (data not shown).The benchmark CT had the lowest steady state SOC content (71 Mg C ha^{-1}), followed by RT and NT (81 and 93 Mg C ha^{-1}). Gains in SOC were obtained when changing from the benchmark CT to RT and NT, and nearly symmetrical losses were obtained when changing from the benchmark NT to CT and RT.

Grain and biomass yields were impacted by tillage system and irrigation (Table 1). Average yield of conservation practices NP, CT and CTP did not differ dramatically (Table 1). Both RT and NT increased CAW. The structural conservation practices had the highest impact in runoff. While NT and CT had similar runoff volumes, erosion was eight times higher under CT. Losses of N and P were slightly higher under NT and CTP due to higher denitrification (7.6 kg ha^{-1} y^{-1}), and higher concentration of P in the runoff water. On average CP and CTP increased the soil water content causing more N leaching, offsetting the reduced N losses by runoff, subsurface flow and sediment. Nitrous oxide emissions were comparable among tillage systems, conservation practices and irrigation systems (data not shown). The generated database will be analyzed setting different thresholds for erosion and nutrient losses, and locating areas above and below the thresholds. Those areas below the threshold will be further analyzed by simulating residue removal or the inclusion of biomass sorghum and oil crops in the rotation. In the areas with losses above given thresholds, conservation should be the emphasis.

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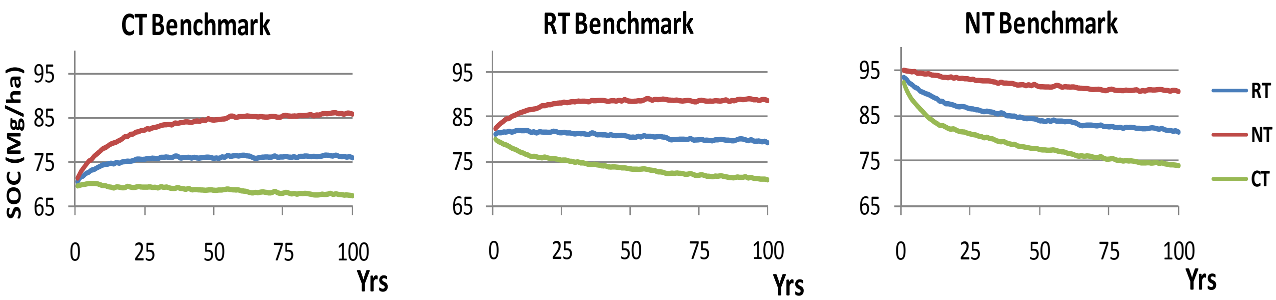

Figure 1. Simulated continuous sorghum SOC evolution under CT, RT, or NT, after a 100 years of continuous CT, RT, or NT (left, middle and right panel, respectively).

Table 1. Tillage cropping system, conservation practice and irrigation effects on sorghum biomass, grain yield, crop available water (CAW), runoff, erosion, and N and P losses.

	Grain yield	Biomass	CAW	Runoff	Erosion	N Losses	P Loss
Tillage system	Mg/ha		mm	mm	Mg/ha	kg/ha	kg/ha
CT→CT	4.1	10.9	468	120	4.0	25.3	1.0
RT→RT	4.9	12.8	479	120	2.0	26.0	1.4
NT→NT	5.2	13.6	480	120	0.5	28.0	2.1
Conservation practice							
NP	4.7	12.3	460	151	2.8	26.2	1.4
CP	4.9	12.7	477	121	2.1	26.6	1.4
CTP	4.9	12.9	491	88	1.7	27.3	1.6
Irrigation system							
Dryland	4.3	11.6	442	122	2.5	27.6	1.5
Irrigated	6.8	16.6	598	114	0.9	23.5	1.4

Designing innovative cropping systems requires the simulation of its biophysical and technical components in interaction: illustration on vineyards

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INTRODUCTION : POSITIONING OF THE PROBLEM

In the current context of agriculture, it is necessary to design Vineyard Cropping Systems (VCS) ensuring agronomic performances while reducing environmental impacts in a context of socio-economic and technical constraints. Grass cover has been introduced in vineyards to overcome problems of environmental impacts of cropping systems by reducing erosion and herbicide applications . The introduction of cover crops in VCS also raised some difficulties at field and farm scale. At field scale, a cover crop uptakes available nutrients and water in competition with grapevine resulting in a potential decrease in the grapevine growth (fig. 1, Celette et al., 2008). This can lead on the one hand to a lower sensitivity to fungal diseases (Valdès-Gomez et al., 2008) but on the other hand to a decrease in yield and quality. As a compensatory technique, farmers have to find a new balance in practices of soil management (in terms of nutrient and water availability) and canopy management to limit the decrease in grapevine growth (fig. 1). Farmers allocate over time and space labour, equipment, water and capital resources to the various operations at farm scale. This involves spatio-temporal dynamics of operations at farm scale and temporal dynamics at field scale (Merot et al., 2008) which complicates the implementation of a new technique such as cover cropping. Therefore to design a new VCS, it is necessary to take into account the multiple interactions between practices at field and farm scale. In this communication, we present the generic features of a framework to model the interactions between the soil-crop-pests system and the practices for vineyard farms in France. It should be used to design VCS.

DESCRIPTION OF THE FRAMEWORK

We defined the VCS as the association of a biophysical sub-system (BS) and a technical sub-system (TS) in dynamic interaction (Le Gal et al., 2009). The BS is a combination of components in interaction related to soil, grapevine and pathogens (powdery mildew, downy mildew…) under the influence of the climate and technical operations (fig. 1). The TS is defined as the whole set of technical operations (from planting to harvest) acting on the biophysical processes. It is under the influence of farmers' decision system and includes pesticide application and their interactions with other techniques. Focusing on the BS offers the opportunity to build the TS by reverse engineering based on scientific knowledge of the biophysical processes assessed with agronomic and environmental indicators. The TS is a good framework to formalize expert knowledge on cropping techniques, in agreement with the farm constraints and resources. We proposed to model in the same framework the TS and BS of the cropping system and theirs interactions. Each component of the BS and TS is analyzed through its relationships with the other components and replaced into the hierarchical analyze (Wu an David, 2002). The approach is largely applied for BS of the VCS. Concerning the TS, the base component is the technical operation which is applied to an homogeneous entity in terms of soil, crop, climate, and management. The technical operation composed the crop management system (temporal dimension) and the workings (spatial dimension). Each operation can be activated, inactivated, on-going, finished, to be priority done, not to be done in priority, reported. In a context of limited resources in the farm, five types of interactions between operations can be defined: activation, inactivation, start, stop, report and priority interactions. The dynamics of the relationships between operations relates to the dynamics of the context, of the farmer's decisions and of the BS. This model was tested on the case of vineyard farms in southern France but it has generic features to be further applied to other types of cropping systems.

RESULTS AND DISCUSSION

The formalization of the TS allowed to take into account the complex interactions between crop protection and other techniques and also to represent the upscaling and downscaling processes between the field (as instances of the BS) and the farm or its sub-entities (e.g. blocks of fields) where the coherence of TS is managed. The approach let us introduce more diversity in the combination of practices implemented to assess the performances of the BS, while designing more sustainable VCS adapted to farmers constraints.

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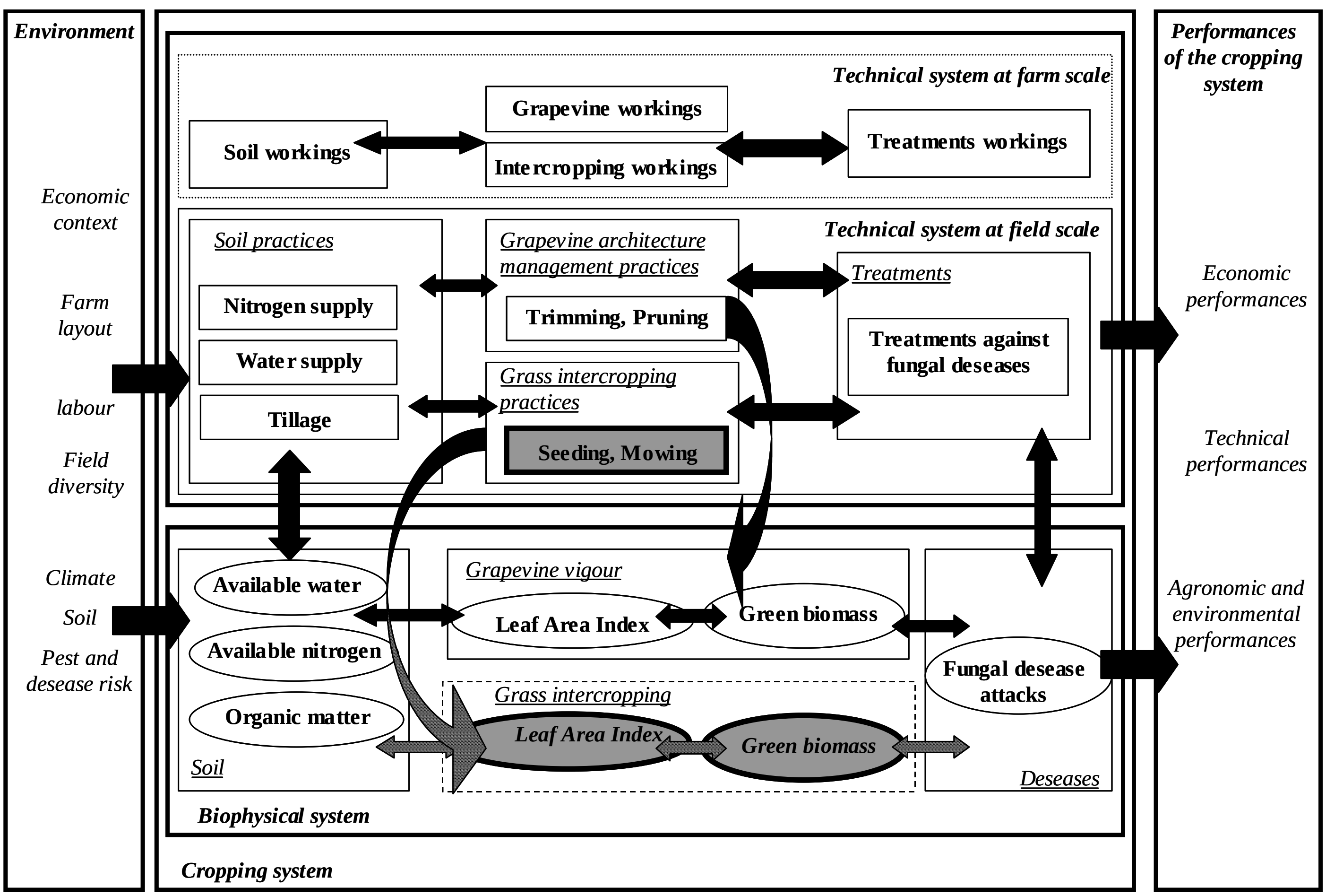

Figure 1 : Conceptual model of the vineyard cropping system with its main components in interaction

Designing farming systems within natural resource constraints – is it possible?

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Farming significantly changes many landscape characteristics; particularly those associated with water balance, water distribution, vegetation and soil properties. Developing sustainable agriculture requires the flows of water, carbon, nutrients and energy in the production ecosystem to be well matched to the flows that have occurred in the landscape as a consequence of its evolution through geological time (Williams, 1991). Significant perturbations of these flows will likely result in production systems which are poorly adapted to the immediate environment and hence will require large, energy intensive interventions to maintain the system. In addition, the flows of water, carbon and nutrient beyond the soil, plant and animal agro-ecosystem that inevitably connect into the landscape will have an effect on receiving ecosystems that are generally not environmentally acceptable.

Much of the damage to natural resources occurs when agricultural production has focused on short-term productivity, ignoring the consequences on other components within and beyond the ecosystem. The focus on productivity has also limited adequate consideration of the longer term implications for hydrologic and nutrient balances. It is unfortunate that the agricultural community, in their preoccupation with short term economic survival continue to under appreciate the place of improved farming systems in regional ecology and hydrology (Williams, 2001). Improved methods are needed to quantify the consequences of short term production goals in relation to longer term natural resource condition and to develop management options that improve the adaptability and resilience of farming systems within a multi-functional landscape. Crop growth, water use and yield models have an important role as part of the new methods needed to change our production systems.

Development of crop growth, water use and yield models initially focused on defining suitably robust process descriptions of the important soil, crop, weather and agronomic drivers (see Hanks and Ritchie, 1991). These models have subsequently been used to examine crop by crop issues such as water management, nutrient supply strategies, species and gene suitability, climate adaptability and financial implications. A wider application of the models has been into farming system or agro-ecological descriptions which necessitates greater inclusion of the boundary exchanges with processes such as run on and runoff, groundwater recharge and upflow, soil erosion and nutrient and salt exchange. Use of the models in this form has enabled more realistic assessment of the farm enterprise i.e. management and financial decisions are taken at the enterprise level rather than at the individual field scale. Now, with greater appreciation that agricultural systems must be more cognizant of their effects on regional ecology and hydrology a new application is identified.

The challenge for agricultural systems modelling is to incorporate the process understanding embodied in the models into descriptions of multi-functional landscapes. This is a new realm for these models as they become just one component in the description of complex social ecological systems. Most often, these systems are considered at a regional scale and incorporate descriptions of biodiversity as well as the agro-ecosystems and the defining social and economic drivers for the region. The aim is to identify the options for future mixing and matching of land uses that will give both agricultural production and biodiversity conservation for the region with the best chance of adapting to changing climate and market conditions and community expectations.

Our experience has been that it is possible to define a system of land use that is close to reaching critical component balances within natural resource constraints. In irrigated areas for example very well controlled water and nutrient additions together with careful placement and intensity of irrigation around the landscape can be shown to meet water and nutrient balances (Khan et al., 2003). However the chance that these changes will be implemented is low because of economic, social and institutional impediments. As Walker et al. (2009) concluded, only with transformational attitude and institutional change will this be possible. In another social ecological system study (Bryan et al., 2007) of rain fed agriculture it was demonstrated that many land use distribution options exist that would meet the natural resource conservation and community expectations. Options depended on the breadth of future climate and commodity price scenarios that the regional community were prepared to contemplate and on the policy that set the level of trade off between foregone production income and natural resource restoration.

Conclusion

It is possible to design agro-ecosystems that could operate within natural resource constraints. Farming system models used within social ecological system models are critical in defining possible options. However there currently are many impediments to implementing these as they are variously economically, socially and institutionally unacceptable. We need new research to refine the options and to help others understand the medium and long term implications of action and in-action.

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TRANSFORMING SOILS, LIVES AND LANDSCAPES: SOIL QUALITY AND ECONOMICS OF DRY LAND WINTER WHEAT CROP-FALLOW SYSTEMS IN WYOMING

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INTRODUCTION

The first agricultural use of the Northern Great Plains was for cattle and early-day conservationists warned of erosion that would take place if the lands were cultivated. Cultivation practices used in the Great Plains have reduced soil organic matter by 30-50% mostly through reduced plant organic matter inputs, increased rates of decomposition following tillage and wind and water erosion losses of top soil. Agricultural intensification in response to initial bio-fuel-related price increases and incentives for carbon (C) sequestration requires that cropping systems conserve soil organic matter (SOM) and increase crop productivity (Norton, 2007). In 2004, most wheat in Wyoming was grown under conventional tillage crop-fallow rotations that have been used for nearly a century on many fields, with only 20% of the wheat acres planted with any kind of conservation cropping systems and less than 5% with no-till (CTIC, 2004). Surrounding states of Colorado, Nebraska and Montana reported a great deal more conservation tillage in wheat production. It has been suggested that Wyoming's challenging growing conditions make use of conservation cropping systems, technologies and approaches more difficult and less profitable (Dalrymple et al., 1993) compared to other regions. Yet growing conditions in Wyoming call for urgent need for conservation cropping approaches if production is to be sustained in the long term as fragile soils are prone to high wind and intense thunderstorms (Krall et al., 1991). Comparing existing Wyoming conservation cropping and conventional cropping systems may provide an opportunity to better understand similarities and differences that could inform improvement of the management approaches with respect to soil fertility. This study was initiated in 2008 to evaluate the sustainability of conservation cropping systems in order to identify and improve management approaches that intensify production and protect soil and environmental quality.

MATERIALS AND METHODS

This study was conducted within fields that have been practicing the systems being studied for more than 10 years in southeastern Wyoming. Variables include (i) two precipitation levels (250-350 mm near Slater, Wyoming, and 350-450 mm near Albin, Wyoming) and (ii) five cropping systems, including conventional tillage (CT), minimum tillage (MT), no-till (NT), certified organic (CO), and perennial grass enrolled in USDA's conservation reserve program (CRP). Minimium till and NT included winter wheat-oat-fallow rotations in the low-precipitation area and winter wheat-sunflower-corn-millet in the high-precipitation area. Certified organic and CT consisted of winter wheat-fallow rotations. Three 15x15m^2 plots (replications) were demarcated in the wheat phase of each cropping system and in a perennial grass CRP field in each area. Soil was collected three times in each of two study years in spring (April/May), summer (July/August) and fall (October). Soil cores from 0-15cm and 15-30cm were collected from each plot. Fresh, field-moist soil samples were analyzed for bulk density, total organic C and N, microbial biomass C, dissolved organic C, and mineralizable C and N. At the end of the season the plots were harvested and the wheat grain yield and biomass determined. Data from the 2008 season are reported.

RESULTS AND DISCUSSION

NT and MT fields yielded significantly more biomass and grain than the CT and CO fields in 2008 (Figure 1), even though they are continuously cropped at Albin (without moisture-conserving fallow) and cropped two of three years at Slater. This suggests that soil properties that allow better use of in-season rainfall and available nutrients, more than made up for the lack of a fallow year. Bulk densities significantly differed between the various treatments, with MT, NT and CRP fields having similiar and higher bulk density (about 1.35g cm^{-3}) than the CT and CO (about 1.20g cm^{-3}) fields, likely due to frequent deep tillage that aerates the soils during the fallow period. Preliminary data show no significant differences in total SOM, but do show differences in C and N pools within the total SOM. Microbial biomass C content was consistently higher under CRP and NT (455 and 376µg g^{-1}) than in CO, MT and CT (304, 296 and 318µg g^{-1}) in the 0-15cm depth but did not vary across treatments in the 15-30cm depth. Pools of potentially mineralizable C and dissolved organic carbon followed similar patterns. Together with preliminary economic analyses from farmer interviews, these first-year data suggest that reduced tillage could improve both income and resource conservation in Eastern Wyoming winter-wheat-based cropping systems.

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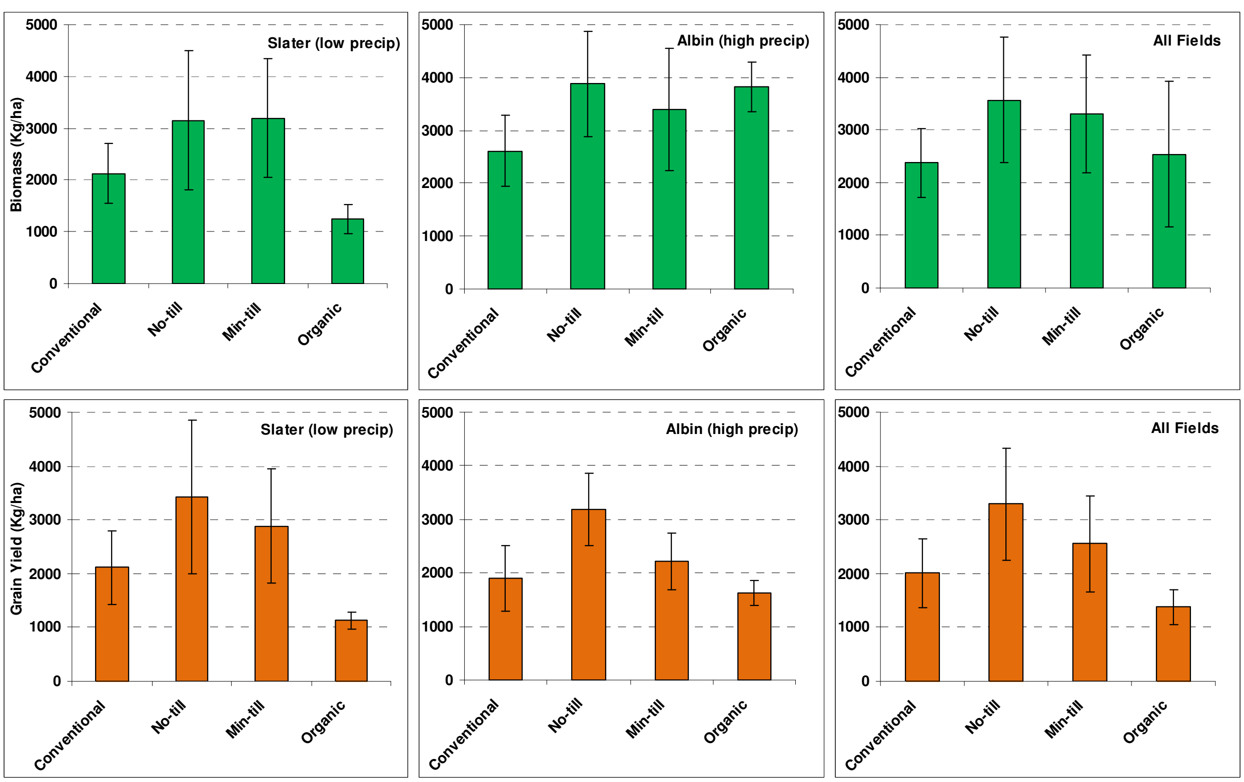
Figure 1. Mean biomass and grain yield from winter wheat study plots in 2008. Error bars represent standard deviations.



USING WEED DYNAMICS MODELS FOR EVALUATING AND DEVELOPING INTEGRATED CROPPING SYSTEMS

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INTRODUCTION

Because of environmental and health safety issues, it is necessary to develop strategies that do not rely on herbicides to manage weeds. It is now well recognized that models that quantify the effects of weed management techniques on weeds dynamics are valuable tools to design weed management strategies. Our research group develops models simulating weed dynamics in cultivated fields as a function of cumulative cropping system effects. Here, we briefly describe the model structure and then present a methodology for evaluating cropping systems and for testing prospective scenarios with the ALOMYSYS model and other indicators based on case studies from a farm survey. The objective was to identify strategies for managing blackgrass without herbicides while limiting environmental impacts and bottlenecks for the labour organisation at the farm level.

MATERIALS AND METHODS

To date, two model versions have been developed, a monospecific prototype (ALOMYSYS, Colbach et al., 2007) for blackgrass (*Alopecurus myosuroides* Huds.), followed by a generic and multispecific update (FLORSYS). Input variables are the crop succession (including catch crops, associated crops, perennials), cultivation and crop management techniques (tillage tools, depths and dates; sowing date, cultivar and density; herbicide rates, active ingredients and dates; fertilisation modalities; dates, tools, working depths and speed of mechanical weeding; harvest dates) and climate as input variables. Both model versions are based on the annual weed life-cycle and on demographic functions depending on cropping systems, in interaction with climate and environmental conditions. Taking account of interactions requires the decomposition of the system into individual processes. For instance, the effect of tillage on seedling emergence is split into several sub-models, describing (a) the effect of tillage on soil structure, light penetration and soil hydro-thermal conditions, (b) the effect of tillage on seed movements, in interaction with soil structure, (c) the effect of the previous variables on seed germination and pre-emergent seedling growth. Crop-weed interactions and weed patchiness are simulated by a 3D model (a) locating crop and weed seedlings of different heights and diameters in space, (b) calculating the light penetration in the resulting 3D canopy, and (c) determining biomass accumulation and morphology of plant individuals as a function of their light environment. In the multi-specific version, the species diversity is integrated by functional relationships. Each species is represented by a combination of traits, and the model parameters (e.g. potential pre-emergent shoot growth) are estimated from these easy-to-measure traits (e.g. mean seed mass). The ALOMYSYS model was evaluated with field observations and shown to predict weed emergence and demography correctly.

Four representative crop rotations were identified from farm surveys in Côte d'Or (France). First, ALOMYSYS was used to simulate the effect of individual cultivation techniques (e.g. sowing date, choice of tillage tools) on blackgrass dynamics. In a second step, the four representative rotations were evaluated for long-term weed dynamics with ALOMYSYS and for their environmental impact with agro-environmental indicators. Last, changes in these cropping systems were simulated to identify solutions for managing blackgrass while reducing the impact on the environment.

RESULTS AND DISCUSSION

In the surveyed rotations, the weed infestation risk increased with the proportion of winter crops in the rotation as these crops are most favourable to blackgrass reproduction (Table 1). Though *A. myosuroides* produces little or no seeds in perennial crops, the latter were not efficient in reducing infestations in this case of direct sowing of lucerne in barley stubbles, as the no-till technique reduced the seed bank decrease through fatal germination (see rotation R4 in Table 1). The rotation with the lowest blackgrass infestation (i.e. R3) was also the one with the highest number of field operations, especially mouldboard ploughing and mechanical weeding (data not shown).

A second set of simulations replaced herbicides by mechanical weeding and then progressively adapted the rest of the cropping system (e.g. rotation, tillage) to control weeds (Table 1.B). These showed that herbicides cannot be replaced solely by mechanical weeding. However, when the latter was combined with additional modifications (e.g. diversified rotation, ploughing before selected crops), weeds were controlled as well as in the herbicide-based reference system.

The alternative strategies reduced the reliance on herbicides and the related environmental impacts (Table 1), but also increased the number of field operations. Further evaluations of those alternative cropping systems are required, regarding for example the energy input and the emissions of greenhouse gases, the potential bottlenecks for labour organization at the farm scale, and of course the economic profitability.

In the present simulations, the different operations were fixed *a priori*, irrespective of climatic conditions or actual weed infestations. The present methodology and simulation results could be improved if the present *actions ⇨ biophysical processes* model were coupled with a decision-rule model, thus having the simulated actions depending on both weed infestations and climatic conditions.

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Table 1 Long-term evaluation of scenarios with multi-year simulations using ALOMYSYS

Scenario		Environmental impact due to herbicides (Ipest[1])	Medium-term infestation (mean of mature plants/m² over rotation after year 13) [2]	Long-term dynamics (% repetitions where scenario >> 0)[3]
A.	**Herbicide-based reference system**			
R1	OSR/WW/WB	0.27	229 c	0%
R2	OSR/WW/sb/WW	0.55	10 ab	0%
R3	m/m/WW/s/WW	0.15	8 ab	100%
R4	3L/WW/WW/WB	0.25	231 c	0%
	OSR = oilseed rape, WW = winter wheat, WB = winter barley, sb = sugar beet, m = maize: 3L = 3-year lucerne			
B.	**Alternative scenarios for rotation R1**			
M1	R4: herbicides replaced by triple hoeing in OSR, sextuple harrowing in cereals	0	490 d	10%
L1	M1 + 3-year no-till lucerne with optimal cutting (OSR/WW/WB/3L)	0	18 b	0%
L3	L1 with tillage before lucerne	0	1 ab	30%
P1	L3 with chisel replaced by mouldboard ploughing before each annual crop	0	0.1 a	20%
P3	L3 with chisel replaced by mouldboard ploughing before WW only	0	0.5 a	0%

[1] Ipest is an indicator of environmental impacts due to pesticide transfers into the various compartments of the environment

[2] Means followed by the same letter were not significantly different at alpha = 0.05.

[3] For a repetition, scenario >> 0 if the Spearman correlation coefficient calculated between weed density and year for years 13 to 27 was significantly higher than zero at alpha = 0.05.

EFFECTS OF CONVENTIONAL DEFICIT IRRIGATION AND PARTIAL ROOT-ZONE DRYING PRACTICES ON "YIELD RESPONSE FACTOR" (k_Y) OF PROCESSING TOMATO GROWN IN SOUTHERN ITALY

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INTRODUCTION

In areas with recurrent water scarcity conventional deficit irrigation (DI) is a common practice to mitigate yield reductions (Kirda et al., 1999). A new evolution of this practice is partial root-zone drying (PRD) in which, alternately, half of the root system is exposed to drying soil while the remaining half is irrigated. This work shows the first results of a study which is aiming to: (i) provide information, for our experimental conditions, about the response of two processing tomato hybrids to different deficit irrigation treatments and (ii) to calculate the "yield response factor" (k_y) that is an important indicator of crop production response to deficit irrigation practices.

MATERIALS AND METHODS

The field trial was conducted during the 2008 crop season in Southern Italy (Capitanata area, Foggia: 41°46' N and 15°54' E). Two processing tomato hybrids (Ercole (E) and Genius (G)) were grown on a clay loam soil with a field capacity (-0.03 MPa) of 35.2% (on a dry weight basis) and a wilting point (-1.5 MPa) of 19.2% (on a dry weight basis). In conformity with the traditional crop establishment used in the zone, tomato was planted, on May 5th, in coupled rows spaced at 160 cm; the distance between the two rows was 50 cm, while the plants of the row were distant 50 cm. In the three irrigation treatments, restoration of 100% maximum crop evapotranspiration (ET_c), 70% ET_c (DI practice), 70% ET_c (PRD practice) plus one thesis without irrigation (0% ET_c) were utilized. A drip irrigation system was used and to adapt the PRD treatment in our crop establishment two small diameter pipes were laid down in parallel along the middle of the coupled row. The two pipes, with drippers of 4 l h^{-1} flow rate and spaced at 100 cm, were arranged in such a way that there was always one dripper between four plants of the coupled row (Fig. 1). We had the option of applying irrigation water through either a single pipe or the two pipes together. If the two pipes were used, all sides of the roots were irrigated, as practiced under 100% and 70% DI treatments. Applying water through a single pipe we watered only a side of the root zone as required under PRD treatment. The wetted side of the root zone was changed by turning on the coupled pipes alternatingly. A three replication split-plot design, with the irrigation treatments in plot and the hybrids in sub-plot was used. At harvest (August 18th) marketable tomato yield was evaluated. Finally, "yield response factor" (k_y) was calculated. Data were analysed using analysis of variance (ANOVA) and the significant differences among mean values were calculated following Tukey's Test.

RESULTS AND DISCUSSION

ANOVA showed significant differences for hybrid x irrigation treatments interaction about marketable yield. No significant differences were registered between 100% and 70% PRD for the two hybrids (E: 66.4 and 64.2 t ha^{-1}; G: 67.4 t ha^{-1} and 62.5 t ha^{-1} for 100% and 70% PRD, respectively). Relatively 70% DI, in E the yield (60.8 t ha^{-1}) showed a lightly lower value than 70% PRD and 100%; in G (56.1 t ha^{-1}), instead, a significant decrease was registered already compared to 70% PRD, evidencing therefore a better yield response under PRD treatment. Finally, yields of 0% were the statistically lowest (28.9 t ha^{-1} for E and 20.1 t ha^{-1} for G). Relative yield decrease of tomato as a function of relative ET deficit can be described with the equation (Stewart et al., 1977):

$$1 - Y*Y_m^{-1} = k_y\,(1 - ET*ET_c^{-1})$$

where k_y is a crop response factor, showing sensitivity of crop to evapotranspiration deficit; Y and Y_m are the yields (t ha^{-1}) corresponding to deficit (ET) and maximum evapotranspirations (ET_c), respectively (mm). As a k_y greater than unity indicates (for a given evapotranspiration deficit) that the expected relative yield decrease is proportionately greater than the relative decrease in evapotranspiration, a k_y less than unity indicates just the opposite tendency. In our case, k_y values were less than unity for both the hybrids so deficit irrigation practices in tomato seem to be acceptable (Fig. 2) contrary to reports by Doorenbos and Kassam (1979). Moreover, while in E k_y of 70% DI and 70% PRD presented the same values (0.86), in G k_y was lightly lower under PRD practice (0.88) than under DI (0.91), suggesting that yield reduction, for a given ET deficit, is lightly less under PRD practice for this hybrid.

Results of the study show the possibility to adopt, in our conditions, deficit irrigation practices (DI and PRD) confirmed by k_y values always less than unity. Under PRD, a slightly better yield response was registered in both the tomato hybrids (in particular in G). Further research is in progress to confirm these preliminary results.

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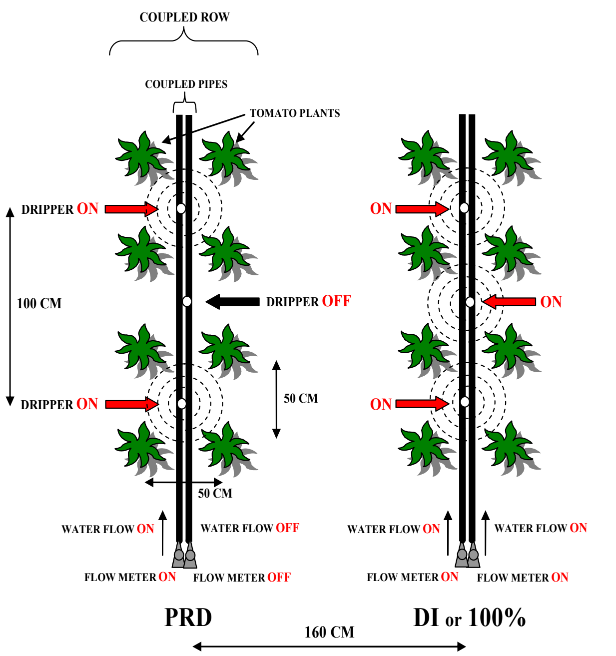

Figure 1. Graphic representation of crop establishment and drip irrigation system used in the experiment.

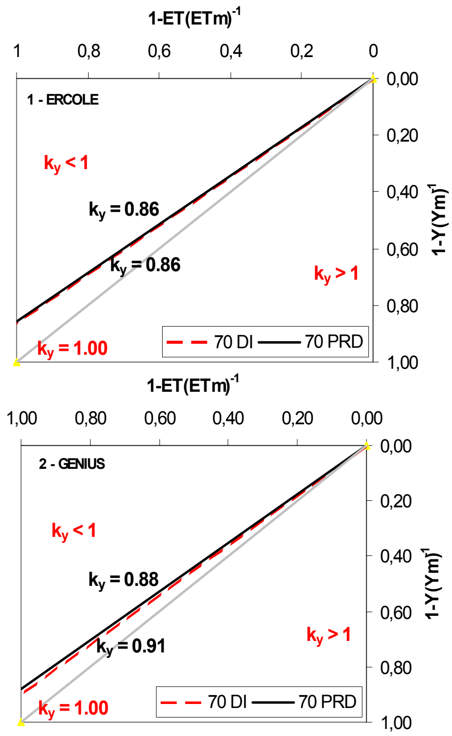

Figure 2. Relative tomato yield reductions, as a function of relative ET deficit, of 70% DI and 70% PRD for E (1) and for G (2).

REDUCING GHG EMISSIONS FROM A RICE PADDY FIELD USING THE DNDC MODEL

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INTRODUCTION

Mitigating global warming has become the biggest concern in the world. A rice paddy field is one of the major greenhouse gas, GHG, sources in the agricultural sector since it emits both methane, CH_4, and nitrous oxide, N_2O, along with carbon dioxide, CO_2. The GHG emissions in wetlands and rice paddy fields have been extensively studied by many such as the group of W.H. Patrick, Jr. of Louisiana State University. Wang et al. (1993) found with the laboratory experiment that methane production resulted from soil redox potential being lower than -150 to -160 mV. Later, Hou et al. (2000) reported that maintaining soil redox potential in a rice paddy field between -100 and +200 mV was effective to minimize the emissions of both of CH_4 and N_2O. Recently, Yu and Patrick (2004) fine-tuned the redox potential window of -150 to +180 mV that minimized the emissions of CH_4, N_2O, and CO_2 after conducting extensive laboratory experiments using eight different soils.

It is well known that the yield of paddy rice varieties largely depends on soil water. Hasegawa and Nakayama (1959) reported that the yield of a paddy rice variety decreased by 22% when it was grown under soil water potential greater than -50kPa because of a poor growth at the panicle initiation stage. Bouman and Tuong (2001) also reported that rice yields were reduced by 10-40% when soil water potential in the root zone reached -10 to -30kPa. For little yield reduction, Noborio (1981) found that soil water potential should be greater than -1kPa during the panicle initiation stage, but could be -10 to -30kPa for other stages. In recent years, the system of rice intensification, SRI, has been popular because it greatly reduces rates of irrigation with maintaining or gaining yields (Stoop et al., 2002). The redox potential window and SRI seem to be promising enough for us to start a feasibility study for developing appropriate water management practices to mitigate GHG emissions in a rice paddy field.

MATERIALS AND METHODS

A comprehensive biogeochemistry model, DNDC, developed by Li et al. (1992) was used to seek the best water management practices to mitigate GHG emissions while to maintain rice yields. Three water management practices, continuous flooding, CF, which is popular in SE Asia, continuous flooding with mid-term drainage on day of year, DOY, 195 for 9 d, MD, which is popular in Japan, and intermittent flooding, IM, with 4 d flooding and 4 d drainage, were examined for a year with weather data acquired in central Japan in 2007 (Fig. 1). It was assumed that rice was grown between DOY 153 and 270 following tillage with plow on DOY 140. For the rest of the year after growing rice, the field was drained and fallowed.

RESULTS AND DISCUSSION

Table 1 showed that the simulated results in yields and GHG emissions. The CF emitted the least amount of CO_2 and N_2O but the largest CH_4. The IM emitted the largest amount of CO_2 and N_2O but the least CH_4. The CF irrigation produced the lowest yield with the lowest CO_2-equivalent GHG emissions, calculated as shown in Table 2, whereas the IM did the highest yield with the highest CO_2-equivalent GHG emissions. A similar trend in yields and CH_4 emission is found in the pot experiments (Minamikawa and Sakai, 2005). In terms of only GHG emissions, the CF was the most favorable. However, if GHG emissions per yield would be of the biggest interest, the IM turned to be the most favorable. Although the DNDC model would be very useful to determine the best management practices, it should be calibrated for local conditions, e.g., clay minerals, hydraulic, chemical, and physical properties of a local soil, and local varieties of rice.

AKNOWLEDGEMENT

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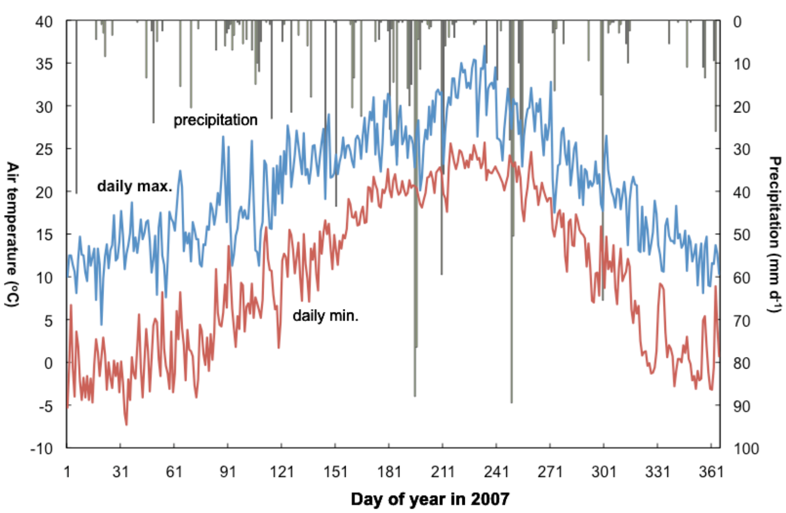

Figure 1. Weather data used for DNDC model.

Table 2. CO_2-equivalent GHG emission

greenhouse gas	global warming potential (GWP)
CO_2 (kgC ha^{-1} y^{-1})	1
CH_4 (kgC ha^{-1} y^{-1})	23
N_2O (kgN ha^{-1} y^{-1})	296
$CO_2\text{-eqv}=CO_2+CH_4\times23+N_2O\times296$	

Table 1. DNDC simulated yields and the amount of GHG emitted for various water management practices.

water management	yield (kgC ha^{-1})	CH_4 (kgC ha^{-1} y^{-1})	N_2O (kgN ha^{-1} y^{-1})	CO_2 (kgC ha^{-1} y^{-1})	CO_2-equivalent (kgC ha^{-1} y^{-1})	CO_2-equiv. per yield (y^{-1})
continuous flooding	139.4	0.26	0.73	4162.57	4421.89	31.72
mid-term drainage	142.5	0.21	0.74	4173.50	4434.91	31.12
intermittent drainage	342.1	-0.09	4.15	4443.36	5888.31	17.21

MEASUREMENT AND MODELLING OF NH3-EMISSIONS FROM FIELD-APPLIED BIOGAS RESIDUES IN NORTH GERMAN ENERGY CROP

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INTRODUCTION

The dramatic spread of energy cropping for biogas production in Germany and other EU countries has resulted in a concurrent increase of biogas residues retransferred as organic fertilizers to agricultural fields. Due to high pH values and high ammonium contents, biogas residues have a high inherent NH_3 loss potential with a possible strong effect on NH_3 emission budgets indicating an urgent need for the quantification of ammonia emissions after field application of biogas slurries. In particular, only little knowledge exists with respect to NH_3 emissions from biogas slurries of exclusively fermented biogas crops (e.g. maize, mono-fermented). Besides the determination of NH_3 losses the assessment of crop productivity and the quantification of greenhouse gas emissions is an urgent need in order to simultaneously evaluate climate protection potentials and environmental effects of biogas production systems. This could only be achieved in a multi plot field experiment with factorial design. Hence, a new approach was introduced for the determination of NH_3 losses in a multi-plot block designed field experiment. In addition, a mechanistic NH_3 emission model was developed for a comprehensive evaluation of NH_3 losses from field-applied biogas residues.

MATERIALS AND METHODS

NH_3 losses were determined in a two-year field trial for investigation of the N cycle and N recovery in typical North German energy crop rotations (maize, silage cereals, rye grass) including the simultaneous measurement of NH_3 emissions from two animal slurries (cattle, pig) and two biogas residues (monofermented, cofermented). Each experimental plot covered an area of 144 m2 (12 m x 12 m). Ammonia losses in the experimental plots were determined with a new measurement approach, Dräger Scaling Method (DSM), a combination of a simple ammonia sampler (Standard Comparison Method, Vandré and Kaupenjohann 1998) and a calibrated dynamic chamber method (Draeger Tube Method, Pacholski et al. 2006). For technical reasons organic fertilizers could not be applied at the same time. Therefore, cumulative losses for identical time intervals were extrapolated by means of fitting of a Michaelis-Menten type function. As a reference, results were compared to simultaneous micrometeorological NH_3 loss measurements on adjacent experimental fields (bLM, backward Lagrangian Stochastic Dispersion Method, Sommer et. al. 2005) with a treatment area of 1600 m2 (40 m x 40 m). Slurries were applied with trailing hoses. The model developed was based on an approach by Sommer and Olesen (2000) strongly modified by the addition of new modules accounting for the effect of rainfall, slurry infiltration, NH4+ nitrification, soil management, evapotranspiration and crust formation on NH_3 losses.

RESULTS AND DISCUSSION

Comparison between the cumulated NH_3 loss determined with the new DSM approach and the micrometeorological method (bLM) showed a very good agreement in all of the 5 simultaneous measurement campaigns (Tab. 1) with on average 4.2% deviation of the DSM losses from the micrometeorological values. The good agreement is based on the past calibration of the Draeger

Tube Method with micrometeorological field measurements. As an example for the simultaneous measurement of NH_3 emissions from several plots Fig. 1 shows the time course of NH_3 emissions after field application of biogas slurries and pig slurry. The DSM approach could detect significant differences in NH_3 losses between the three slurries applied. On average (15 campaigns 2 study sites), significantly higher (51%) NH_3 losses after field application of biogas slurries as compared to animal slurries were observed. The dynamic NH_3 emission model was suitable to describe the temporal pattern of NH_3 fluxes. Simulated cumulative amounts of volatilized ammonia were very close to observed values. Fig. 3 shows an example data set, which was used for the parameterization of the model (r^2 0.92, RMSE 0.32 kg N ha-1). The simulation runs for validation showed likewise good results. However, the model still requires further improvement with regard to the ammonia fluxes at the onset of the emission process.

The new approach for the determination of NH_3 losses in block-designed field trials (DSM) was proven to be sensitive and valid. Ammonia losses from biogas slurries were significantly higher (51%) than from conventional animal slurries. A new NH_3 emission model was successfully implemented for an assessment of NH_3 emissions in biogas production systems.

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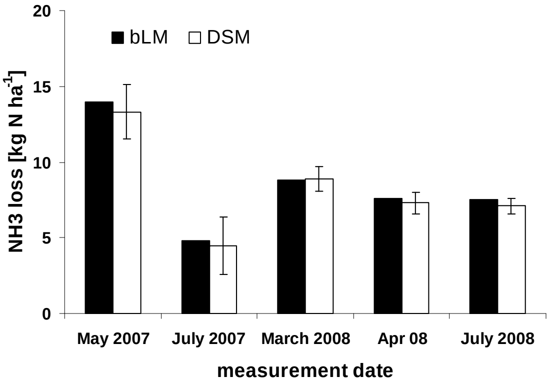

Fig.1

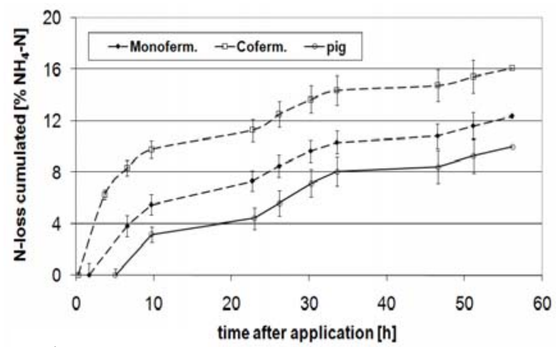

Fig.2

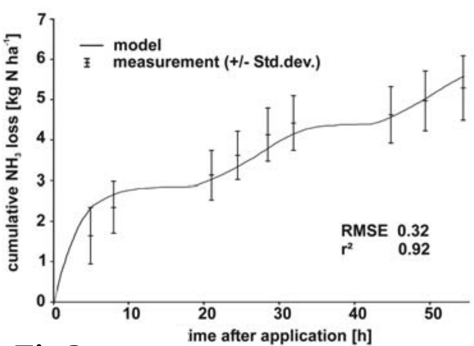

Fig.3

Fig.1: Comparison of cumulated NH_3 losses [kg N ha^{-1}] of monofermented biogas waste measured with DSM (error bars = std. dev.) and bLM

Fig.2: Cumulative N losses from three organic fertilizers, n = 4, 120 kg total N ha^{-1}, May 2008, cut rye grass, sandy soil, DSM (error bars = std. dev.)

Fig. 3: Observed and simulated NH_3 losses after field application of biogas slurries (monofermented), April 2008, winter wheat, 120 kg total N ha^{-1}

EMERGING HORTICULTURE IN AFRICA: TRENDS IN HORTICULTURAL ECONOMY AND TRADE IN AFRICA: THE CASE OF THE SOUTH-WEST PROVINCE OF CAMEROON

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INTRODUCTION

Urban growth has generated considerable change for small scale farming in West and Central Africa as a growing share of farmers live in an urban environment (United Nations, 2006; Parrot *et al.*, 2008a,b,c). Urban growth and the urbanization process of rural areas also reduce the availability of potential arable lands. In this context, horticulture is particularly well suited since it requires small land areas and provides high returns on investments. Horticulture is still marginal compared to staple crops but it is an emerging activity among farmers in Africa. However, the intensification process emerging in Africa for horticulture suggests careful monitoring (Gockowski and Ndoumbe, 2004; Malézieux *et al.*, 2009).

Urban and periurban agriculture emerging as a major driver of agricultural growth

Urban and periurban agriculture is emerging as a major driver of agricultural growth in developing countries (de Bon *et al.*, 2009). In Cameroon, the South-West Province is in the midst of the rise of the coastal growth poles in West and Central Africa (Cour, 2001). By 2020, about 200 million people out of a total of 400 million will live and work in these areas stretching from Dakar (Sénégal) to Douala (Yaoundé).

MATERIAL AND METHODS

In this context, the study of market flows among local food markets can be a good indicator of nationwide trade flows (Almy and Besong, 1990). Our case study concerns Muea, a market town in the South West Province of Cameroon. By just interviewing traders from the Muea market, trade routes could be traced from the Northern to Southern provinces, *i.e.*, from the hinterland down to the coastal provinces of Cameroon. Muea was surveyed in August 1995 and again in June 2004. The surveys included a complete census of households where all houses and households were recorded for a random selection, a household survey where 300 households were interviewed, and a market survey.

RESULTS AND DISCUSSION

Change in Africa at the turn of the 21st century

Urban growth affects household income portfolios. In our case study, household incomes increased by 14% from 1995 to 2004, with a large shift from farm to nonfarm income. The share of non-farm income in the total income of the population increased from 40% in 1995 to 79% in 2004. Within agriculture, main activities shifted from staple crops to horticulture, both for sale and for home consumption, determining important changes in cropping and farming systems. The contribution to employment by the local food market increased, which reveals the social impact of the agricultural sector on employment. However, the turnover of the market declined by 40%. Since households managed to increase their incomes, this result suggests that farmers have now better access to other markets for trade.

Household self-consumption of food crops declined by almost 80% between 1995 and 2004. Self-consumption of food crops also faced a major shift. Self-consumption of horticultural products increased by 48%, while self-consumption of staple crops decreased by 89%. The share of horticulture in self-consumption increased from 6% to 47% of all self-consumption in food crops. In fact, consumer preferences have changed in Muea with new diets and an increased demand for food.

The average number of agro chemical inputs used by farmers doubled between 1995 and 2004. In the town of Muea, chemical expenditures increased from four to five times as it is the case for salt, pesticides and herbicides. Fertilizers and fungicides did not significantly increase during the period but they still remain in large use.

PERSPECTIVES

Horticultural crops provide a better price/weight ratio than staple crops and are well adapted to small scale farming. However, intensification and new land areas remain necessary for keeping up horticultural production with a rising food demand from large cities on the coastal growth pole of Africa. Horticultural crops, as this study revealed, require large amounts of agro-chemical inputs that constitute a potential threat for health and the environment. As perishable crops, they are also vulnerable to the humid and hot climate of Central Africa. Improved storage facilities to reduce waste and improved monitoring of agro-chemical inputs are therefore prerequisites for a sustainable horticulture.

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WINTER WHEAT AS A FEEDSTOCK FOR BIO-ETHANOL: ASSESSING POTENTIAL REDUCTIONS IN GREENHOUSE GAS EMISSIONS

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INTRODUCTION

There is a great potential to reduce greenhouse gas (GHG) emissions by replacing fossil fuels with wheat-ethanol. In the southeastern USA, winter wheat is planted from November to December and harvested from May to June. Increased winter wheat production as a bio-ethanol feedstock could increase the overall farm profitability in this region. In addition, winter wheat followed by a summer crop could reduce risks of soil erosion, increase carbon sequestration, and allow for the harvested straw to be used for cellulosic ethanol production. However, climate and soil variability are causes for a varying winter wheat yield across the southeastern USA. The overall goal of this study was to determine the impact of climate and soil variability on the net emissions of greenhouse gases when wheat-ethanol replaced fossil fuels.

MATERIALS AND METHODS

The reduction of greenhouse gas emissions was determined for two scenarios: ethanol production from winter wheat grain only and ethanol produced from both winter wheat grain and straw. In both scenarios, the produced ethanol replaced gasoline in a mid-size flexifuel personal vehicle. Winter wheat production was simulated with the CSM-CERES-Wheat model, which is included in the Decision Support System for Agrotechnology Transfer (DSSAT) (Hoogenboom et al., 2004). Simulations were conducted for six top producing winter wheat counties in the southeastern USA: Baldwin County, Alabama; Jackson County, Florida; and Jefferson, Laurens, Randolph and Sumter counties, Georgia. These counties also represent different climatic conditions as well as different soil conditions (USDA-NRCS, 2009). Wheat production was simulated for the three most common cropland soils within each county. Weather data were obtained from the Cooperative Observer Program (COOP) network of the National Climatic Data Center (NCDC). Soil profile data for the simulated counties were obtained from the USDA-Natural Resources Conservation Service (2009). Two winter wheat cultivars that are recommended in the southeastern USA (Lee et al., 2008) were included in this study, i.e. AGS 2000 and Pioneer 26R61. Specific parameters for the two cultivars in the CSM-CERES-Wheat model were obtained by a calibration of wheat grain and straw yield against Georgia state wide variety trial data from the growing seasons 2000/2001 to 2004/2005 (http://www.swvt.uga.edu/). After the calibration, winter wheat yield were simulated for 67 growing seasons from 1940/1941 to 2006/2007. For each county and cultivar the winter wheat grain and straw yields were averaged across the simulated years. Within each county, the yields were also weighted according to the relative proportion of each of the three soils. Net emissions of greenhouse gases were calculated based on the averages of the simulated winter wheat yield, literature information about ethanol/wheat conversion ratios and greenhouse gas emissions related to wheat-ethanol production. These calculations assumed the existence of modern grain-ethanol processing facilities and future large-scale cellulosic ethanol production facilities within the region. The effect of gasoline replacement with ethanol on greenhouse gas emissions was determined per km of use in a midsize personal vehicle. Also, indirect fossil fuel replacements by animal feedstuff and electricity co-products were taken into account. Ethanol production was calculated by applying a conversion ratio of 428 L ethanol per Mg dry matter wheat grain and 250 L ethanol per Mg dry matter wheat straw. Greenhouse gas emissions were calculated for wheat crop management practices, transport of winter wheat from the field to the ethanol processing plant, and ethanol processing. Subsequently, the emissions related to the replaced gasoline, animal feedstuff and electricity were subtracted.

RESULTS AND DISCUSSION

Overall, there was a reduction in greenhouse gas emissions across all counties when ethanol from wheat grain, or wheat grain and straw, replaced gasoline. Ethanol from AGS 2000 wheat grain provided significantly ($P<0.05$) higher reductions in greenhouse gas emissions (117.9 g CO_2 equiv km^{-1}) compared to Pioneer 26R61 (104.7 g CO_2 equiv km^{-1}). Also in the wheat grain and straw ethanol scenario, across the 6 locations, the reduction in greenhouse gas emissions differed significantly ($P<0.05$) between the two cultivars: 270 g CO_2 equiv km^{-1} for AGS 2000, and 263 g CO_2 equiv km^{-1} for Pioneer 26R61. Moreover, for both ethanol sources, there was a significant difference in greenhouse gas emissions due to the wheat production county. For the grain ethanol scenario, the greenhouse gas reduction varied between 160.3 g CO_2 equiv km^{-1} for AGS 2000 in Sumter County, Georgia, and 77.2 g CO_2 equiv km^{-1} for Pioneer 26R61, Laurens County, Georgia. For the straw and grain ethanol scenario, the greenhouse gas reductions varied between 300.0 g CO_2 equiv km^{-1} for AGS 2000 in Sumter County, Georgia, and 240.7 g CO_2 equiv km^{-1} for Pioneer 26R61 in Laurens County, Georgia. The differences in reductions of greenhouse gas emissions were due to the spatial variability in local soil and climate conditions in the southeastern USA and to the differences in greenhouse gas emissions related to feedstock transportation. In addition, there was also a considerable variation in the potential reduction in greenhouse gas emissions due to the temporal climate variability among the simulation years. The results of this study indicate that soil and climate variability in the southeastern USA could impact the magnitude of the potential reduction in greenhouse gas emissions from replacement with wheat-ethanol. This impact of site-specific conditions should be taken into account when designing sustainable systems for wheat-ethanol production with the purpose of reducing greenhouse gas emissions. Similar studies could be applied to determine the variation in reductions of greenhouse gas emissions for the use of ethanol and other biofuels from other crops due to climate and soil variability in other production regions.

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ROAD TRAFFIC POLLUTION: HOW SHOULD FARMERS AND RETAILERS ADAPT?

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INTRODUCTION

Increasing urbanisation worldwide is leading to the extension of road and motorway networks, worsening air pollution (Colvile *et al*., 2001). The impact of this pollution is frequently studied in terms of the risks to human health related to inhalation (e.g. respiratory diseases). Some studies have considered the risks associated with the consumption of contaminated food products grown next to major roads (Armar-Klemesu, 2000). We investigated this aspect in the Ile-de-France region surrounding Paris. This region is both the largest urban conurbation in France, with a major road network, and a large agricultural area. At least 50 % of the land in this region is cultivated, corresponding to about 600,000 ha, most of which (94%) is under arable crops (IAURIF, 2006). Recent land use policy in the region has been oriented to maintain periurban agriculture, to promote more environmentally friendly farming systems and to support the marketing of agricultural production at regional level. Road traffic generates various airborne pollutants, some of which are deposited alongside roads, constituting a localised chronic pollution problem (Promeyrat-Qotbi, 2001). Farms located close to roads may be affected by these emissions, which may decrease food product quality. The proximity of food crops to roads raises questions about the spatial compatibility of farming and road networks, although there is currently no scientific consensus concerning potential health risks for producers and consumers. However, some actors in agricultural supply chains (co-operatives, large-scale distributors) have tried to limit potential risks by producing technical guidelines, including isolation distances between major roads and fields farmed under contract (Rémy and Aubry, 2008).

MATERIALS AND METHODS

We analysed these "isolation distances" laid down in technical guidelines and the involvement of actors of the supply chain, retailers and farmers. We used both agricultural science and social science methods to carry out surveys: (i) of supply chain actors - those recommending contracts including an isolation distance from roads, to investigate the functioning of these guidelines and their scientific objectivity; (ii) of farmers in two agricultural zones in the Ile-de-France region (the Versailles and Bière plains), to determine whether they take into account proximity to roads and the associated risks of crop contamination in the spatial organisation of their farms. We hypothesised that safety distances between roads and fields might become generalised to all food supply chains in the future. Then we carried out a cartographic simulation, with ArcGis 9.2 software, of these distances in the zones studied, and discussed possible adaptations with the farmers questioned.

RESULTS AND DISCUSSION

We found that safety distances in the cereal supply chain were included in technical guidelines to create market opportunities in a context of market segmentation, in the absence of real scientifically demonstrated risks. Some agribusinesses, particularly in the aromatic plants sector, took the same view, including isolation distances in quality contracts with farmers and presenting their position as the application of a precautionary principle. Although only a few farmers in Ile-de-France are working under such contracts, these contracts were found to have a considerable impact on farms, in terms of both technical management and total farm area. We observed that the imposition of isolation distances from firms can change and diversify the spatial distribution of crops and their rotation on farm (map 1). More globally, in the studied zones our cartographic simulation showed that an isolation distance of 250 metres currently used in the cereals supply chains may affect between 10 and 50 % of the farm area under arable crops (map 2). Our study shows there is a gap between scientific knowledge and practices in agribusiness world. There seems to be no consensus in the scientific community about the appropriate isolation distance to be recommended for agricultural spaces adjoining roads. There is little scientific justification for these distances, the application of which would lead to an exclusion of a sizeable area from agricultural use — a particularly difficult issue in a periurban region crossed by a dense network of roads. We conclude that more scientific research is required into the health risks associated with farming close to roads concerning the links between the deposition of pollutants, the transfer of these pollutants into plants and risks for human health.

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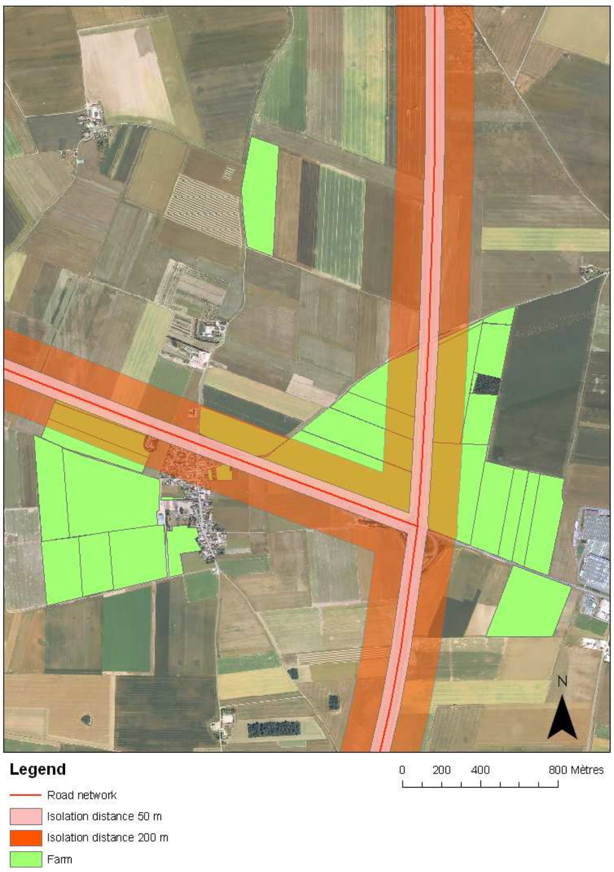
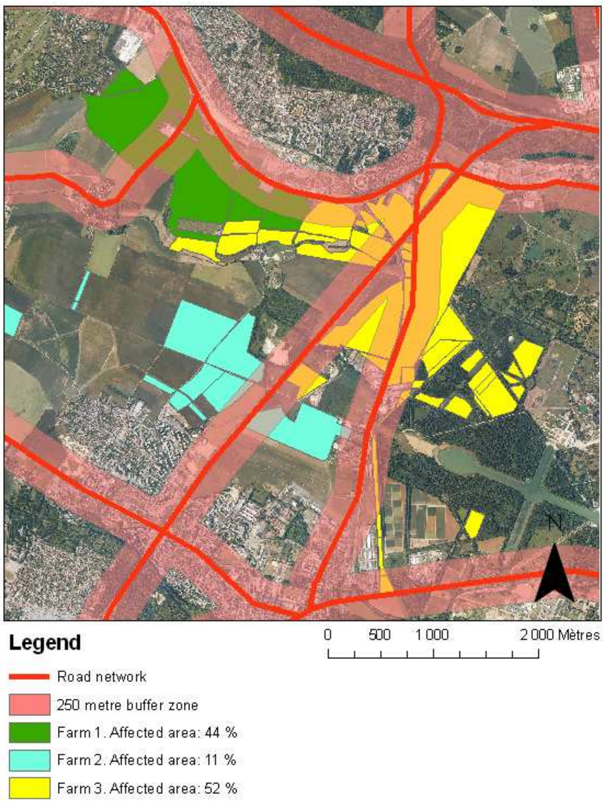
FIGURES AND TABLES



Map 1 : Presence of isolation distance on a farm (50 metres and 200 metres)



Map 2 : Simulation of a 250 metres buffer zone around the roads in the Versailles plain. The intersection of these two elements is used to calculate the agricultural area included in the buffer zone. This area was calculated as a proportion of total utilisable agricultural area.

INTEGRATING SUB-MODELS AT DIFFERING SCALES TO IMPROVE THE PROFITABILITY OF IRRIGATED FARM BUSINESS

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INTRODUCTION

Irrigators are under increasing pressure to maintain profitability with reduced water allocations, rising input costs, and high market volatility. While irrigation growers continuously adapt their management practises in response to changes in their operational environment, medium and long term farm business planning requires far greater levels of information and support to ensure success.

Whole farm modelling approaches capable of generating relevant information to growers are valuable tools to support discussions in participatory research with the aim of identifying more profitable farm tactics and strategies i.e. farm business designs. In this paper we report on results from a participatory research project that uses the whole farm model APSFarm, to explore farm business designs for increased profitability in irrigated cropping businesses in Australia.

MATERIAL AND METHODS

APSFarm is a multi-paddock dynamic simulation environment that uses the APSIM modelling platform (Keating et al., 2003) to simulate the allocation of land, labour, machinery and finance resources at the whole farm level (Rodriguez et al., 2007). In APSFarm, paddock level management rules (e.g. crop agronomy, irrigation scheduling), and farm level strategies (e.g. crop choice, water movement between storages, enterprise mix, risk attitude) are simulated across the whole farm. Model outputs include a wide range of bio-economical and environmental indicators of the performance of the farm business useful to analyse trade-offs between economic, production and environmental outputs, when comparing alternative farm business designs. Using model outputs in discussions with participating farmers allow more integrative analyses of the dependencies and interactions between the economics, finances, biophysics, assets e.g. land, machinery, skills and labour. The model can also take into account the effects of changes in climate, prices, costs, and water allocations.

Interviews with the managers of a number of case study farms were used to (i) describe existing infrastructure, tactics, medium and long term strategies, and key drivers for change e.g. price, costs, water, labour, etc; and (ii) identify relevant research questions to the growers. Here we present initial results from one case study farm located near Dalby, Queensland, Australia. The farm comprises three water storages, i.e. two 500ML water storages supplying two, 252 and 314 ha cropping areas; and a 300ML storage supplying an area of 215 ha. The storages are filled via overland flow and there is capacity to transfer water between them. In addition, the farm has 5 bores with an annual allocation of 610 ML/year. Bore water can be supplied to all paddocks, though at a considerably reduced flow rate. All paddocks are irrigated via furrows, and the run-off from paddocks and irrigation tail-water is captured and recycled within the farm.

Figure 1, shows the implementation of the rotation for the farm business in APSFarm. The circles or nodes represent the states in which any management unit can be found. The arcs between nodes hold the description of the rules allowing the transition between the different states, i.e. rules for planting, and harvesting the different crops. For example to plant maize between September 15th and October 15th, there needs to be available at least 4 ML/ha, and the area planted to summer grain cannot exceed 50% of the farm land.

RESULTS AND DISCUSSION

Figure 2 shows the profitability of each individual activity expressed as gross margins. It shows cotton as the most profitable crop, followed closely by soybean. Wheat performed poorly because it is not irrigated, and its inclusion in the rotation is to provide ground cover. Some of the comments obtained at workshops with growers indicated that "*… these results confirmed why we grow cotton,.. though soybean is a good surprise…*". Further questions were asked giving place to further interaction and engagement with this group of growers i.e. "*… with limited water should we plant smaller area of cotton in a solid configurations or larger areas with skip/2m rows?...*". Participating farmers were also interested in quantifying their *"gut feelings"* in regards to what sort of season is coming up and how they should adjust planting areas and crop densities to suit.

In this paper we provided an example of how a whole farm simulation model can be used with close interaction and participation between farmers and researchers, to test and learn about improved farm business tactics and strategies, before their implementation on farm. The use of the model in collaboration with the farmers permitted better informed discussions, and thus helped both farmers and researchers identify feasible changes in the system towards increases in resilience and capacity to adapt to change i.e. climate, markets, etc. Technologically, APSFarm proved to be a solid performer and a good alternative to static equilibrium models, with the additional benefit of allowing for dynamically integrating the multiple dimensions of highly complicated irrigated farm businesses. Further results and information on this project can be found at http://irrigatedcropping.blogspot.com/

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Acknowledgments

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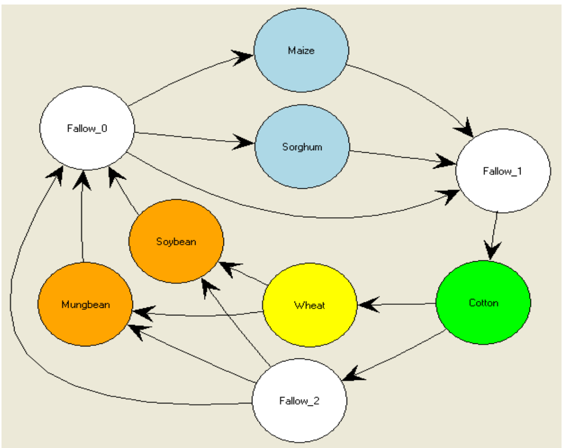

Figure 1: Crop rotation implemented in APSFarm.

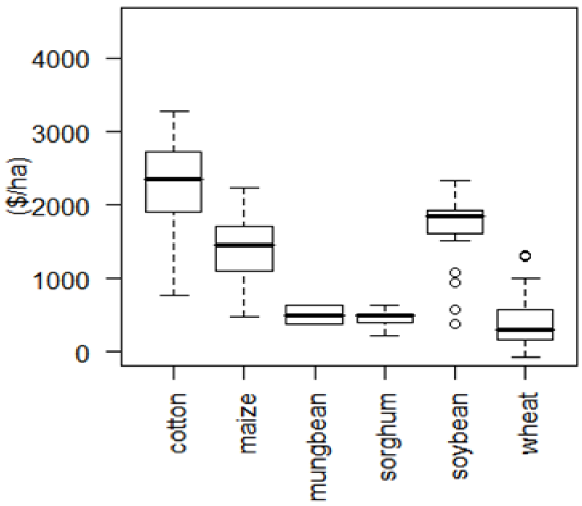

Figure 2: Gross margins ($/ha) for the individual crops

DESIGNING NEW SUSTAINABLE CROPPING SYSTEMS: A METHOD COMBINING THE PARTICIPATION OF VARIOUS STAKEHOLDERS AND THE USE OF ASSESSMENT TOOLS

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INTRODUCTION

Multiple goals are assigned to agriculture nowadays: large food production, ecological services, economic profitability, low use of non renewable resources, etc. And new methods to design innovative cropping systems are needed, particularly to allow the designers to take into account the multiple expectations of the whole society. The involvement of a large variety of stakeholders in the definition and hierarchy of the goals appears as a useful approach to reach these new and multiple goals during the design process.

The aim of this communication is to present and discuss a participative method we are developing to design and assess cropping systems adapted to multi-criteria demands and assessment. Based on the prototyping approach (e.g. Vereijken 1997; Lançon et al. 2007), this method takes advantage of expert knowledge and focuses on the means to collect, gather and transmit the variety of expectations by involving the stakeholders in the process of design. We are building and testing this method in different case studies in France. This communication aims at describing each step of this method, which actors should be involved and which tools we can use to design innovative cropping systems.

MATERIALS AND METHODS

This method is based on four steps.

(1) Firstly, the frame of objectives of the cropping systems must be identified in link with the specificities of the case studies. The objectives and their hierarchy may change depending on the people interested in agricultural decisions at local and global scales: authorities, nature conservation associations, citizens, advisor services, supply firms, etc. These various categories of actors will be then involved. Several meetings will take place successively: firstly by categories and then by gathering some representatives of each category. The characterization of the present cropping systems and their assessment will be used to help people defining their objectives. A qualitative multi-attribute decision model for ex ante assessment of the sustainability of cropping systems (MASC, Sadok et al. 2009) will be also used during the meetings to support the participants.

(2) Secondly, the new cropping systems must be designed. We will pick over some objectives to be reached among the ones defined in the 1st step. This sorting is intended to give some specifications to the designers without being too restrictive not to bridle the inventiveness of the designers. Numerous interactions exist within a cropping system which must be taken into account. Crop models may be useful tools but they often take into account a small number of factors or interactions. We then believe that the use of local expert knowledge may give more realistic results than models. Thus, the actors involved in this 2nd step will be scientists and technical advisors. They will produce candidate cropping systems.

(3) In the third step, we will manage an *ex ante* assessment, to evaluate which of the candidate cropping systems could reach the objectives identified at the 1st step. To manage this sorting, we will combine the local expertise of actors like farmers and technical advisors and the use of e*x ante* assessment tools like MASC (Sadok et al. 2009) or Persyst (Guichard et al. 2004).

(4) In the last step, we will confront the designed cropping systems to the respective propositions of the actors of the 1st and 2nd steps. We will see if the results of the design process

question the conclusions (frame of objectives, candidates of cropping systems) they will have formulated. This step may lead to another loop of design, with a redefined frame of objectives by the stakeholders, new candidates cropping systems and new assessments.

DISCUSSION

For each step of our method, we share questions about the people to involve and the way to involve them.

We believe that each step of the method does not require the same collective as the preceding or the following one. For example, if the 1st step clearly implies the participation of a large range of actors, the 2nd one should focus on the role of the technical advisors who are already in charge of designing cropping systems with farmers. The 3rd step includes an assessment of the feasibility of the cropping systems, that is why farmers may be important to involve.

This position entails that our method gives special attention to the means to lead the different meetings and the participation of the stakeholders (Béguin 2009). We do not search for a consensus among the participants, we want to give them the possibility to express their specificities. We will thus work on the instructions to give, the way of gathering the different categories of actors and the use of the assessment tools.

Finally, we want to focus on the role of the tools of assessment in design processes. The prototyping approach has been combined to the use of crop models to increase the number of tested prototypes of cropping systems. Models are then used in an explorative fashion (Rossing, Meynard, et van Ittersum 1997; Sterk et al. 2007). We propose to use a different type of models: the tools for assessment. Being used by the actors during the work meetings of each step, they are both tools of dialogue and organization and tools of thinking. By giving the participants a possibility to handle and test their propositions, they allow the participants to make their choices and propositions concrete, to give them a reality.

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WHAT MODELLING METHODS ARE USED BY RESEARCHERS IN AGRONOMY?

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INTRODUCTION

Modelling is fast becoming the means to integrate and even produce knowledge in agricultural research. But a quick overview of the scientific publications about modelling shows that the researchers mainly describe their models as a series of equations or as software. They thus focus on the model itself, saying few things about their way of designing the agronomic models. But, it is well known in the field of design that design methods deeply orient the nature as well as the use of a model. Our purpose is to investigate the methods used to design agricultural models and better identify how the agronomic research community exchanges information about modelling methods and develops new ones. More specifically, we are interested in better characterizing the extent to which such methods are use- and users- dependent. In fact some researchers make claims about the potential use of their model, but they rarely explain how they get information about use and users and take it into account in the model itself as pointed out by different authors (e.g.Sinclair et Seligman 1996; Meinke et al. 2001; McCown, Brennan, et Parton 2006).

MATERIALS AND METHODS

To address these questions, we used a bibliometric approach. We chose to search for the papers that focus on the design of new models in the agronomic literature. Eight well-acknowledged journals amongst the agronomic researchers, and available in the ISI WoS data base were chosen to run a search procedure over a ten-year period (Agricultural Systems, Agronomy Journal, Agriculture Ecosystems & Environment, Agronomy for Sustainable Development, Australian Journal of Agricultural Research, Crop Science, European Journal of Agronomy, Field Crops Research). This procedure was built using a list of descriptors to look for in the titles and abstracts of the papers published in these journals. We built a request in which the word “model” and all derived words appear in the same sentence as words belonging to the lexical field of design (like create, build, new, develop, design etc).

All the abstracts of the selected papers were read to check the relevance. We finally obtained a database of about 600 papers on which we then run our analysis. We identified keywords to systematically and automatically glean firstly the objectives the authors give to their models, secondly the designing methods used by these authors. We then analyzed the eventual link between the diversity of objectives and the diversity of designing methods. We finally focused on the role given to the future users in the design process, especially when the authors explicitly define an operational objective and a use for their models by non-researchers.

RESULTS AND DISCUSSION

In our bibliometric search, we did not choose to investigate only so called crop models. Therefore, a first result is a description of the diversity of models which are published in the 8 selected journals.

Secondly, our analysis shows a strong standardization of the modelling steps described by the researchers: description of the objective, definition of input and output variables and the relations that link them, parameterization and evaluation. These steps describe what seems to be an implicit norm about design methods or most probably an implicit norm about the way the design methods have to be described in publications. This standardization contrasts sharply with the diversity of objectives the authors define for their models. More precisely, the lack of in-depth descriptions of these steps does not allow us to link the design methods and the objectives. Parameterization and evaluation are the most discussed steps but from a statistician point of view mostly, which does not help to link design methods and objectives of the models. And yet, various authors working in social sciences showed that design methods should take into account and reflect the given objectives (Bodker et Gronbaek 1991; Akrich 1993, 1995; Béguin 2003; Béguin et Cerf 2004). Moreover the authors mostly describe the standardized steps as separated and not as forming a whole method. Quite often, the different steps are even described in two or more distinct papers. It is a good clue that modelling methods are not handled in publications as a research object per se. Whereas publications about a model are well accepted, it is still not so common to publish by focusing on the design methods of the models.

As well, few authors acknowledge the use of participatory methods while they are numerous to make claims about the use (most often defined vaguely) of their models by non-researchers. Finally, when potential users are involved in the design of agronomic models, it is mainly as sources of information for parameterization or evaluation thanks to the experimental databases they own.

To conclude, we can say that the modelling methods are not much debated in agricultural research whereas the growing development of modelling could justify it. This could partly explain the poor use of agronomic model outside research. From our point of view, this confirms that modelling methods are still to be searched, especially to better link the model content and its future use.

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APPLICATION OF THE HEALTHY FARM INDEX

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INTRODUCTION

Agriculture is dependent on economic, social, and natural capital. A focus on short-term production and maximizing single outputs leads to narrow decisions that risk long-term capital availability. Given the importance of agroecosystems, there is increasing interest in improving less tangible outputs of farm systems, including ecosystem services (Zhang et al., 2008). Many ecosystem services, however, are difficult to value and as a result are not included in farm assessment, design, or decision-making. With human population growth expected to reach 9 billion by 2050, pressure on agroecosystems will continue to increase. The resulting challenge is how to meet production needs while at the same time maintaining social and natural capital. Consequently, new measures of farm success, new means of assessing farm systems, and new decision support tools are needed.

Farmers have a good understanding of how single outputs can be maximized. Balancing multiple outputs, however, requires new assessment and decision making tools that recognize positive consequences of management decisions, address the multiple choices and constraints that farmers face, and recognize and reward farm systems for the ecosystem services they provide (Daily and Matson, 2008). These tools must seek to prevent arbitrary decisions and consider all options available to the farmer. As an integrated assessment and decision-making tool, the Healthy Farm Index (HFI) enables improved decisions by assisting farmers in measuring progress, beyond crop production, toward a diverse set of management goals.

DESCRIPTION OF TOOL

Past research has produced a broad range of applied management suggestions with the potential to improve farm design and enhance ecosystem services. Agroforestry, organic management, reduced tillage, mixed-farming systems, and farming with grass are examples that have been shown to enhance ecosystem services and build capital. In the end, however, what all these practices are measured against is yield and profit. While it is essential that we maintain yield and profit, it is equally important that farm assessment include other indictors of farm health or success. This process needs to occur at the farm level, empowering the individual to understand the full range of outputs or services provided from their land.

Developing an assessment tool requires clear, relevant, and measurable indicators. An index of farm health needs to be adaptable to the location and the resources and labor available. The difficulty in placing an economic value on many parameters of a healthy farm necessitates multiple criteria analysis (Hajkowicz, 2008). The Healthy Farm Index allows economic value to be included as a criterion along with other suitable indicators. To ensure a holistic view of the agroecosystem, we selected indicators from multiple categories of ecosystem services to and from agroecosystems.

A target for each indicator is based on data collected through research, feedback from farmer advisory groups, evidence of the benefits of a practice, and a consideration that a farm needs to remain productive. These indicators fall under four categories – Production, Biodiversity, Quality of Life, and Environment. Ecological, biophysical, and socio-economic data collected during research in Nebraska and Kansas are used as the basis for the index, as it applies in the Great Plains.

Assessment of a farm using the HFI involves the farmer in collection of needed information for the four categories. The amount of food and fiber produced per unit of land is compared to the target of comparable production in the region. Economic resiliency is measured through the number of market opportunities in which the farm participates. Biodiversity estimates are developed from the number of different crops and livestock on the farm, and measures of bird and habitat diversity. Quality of life inputs assess farmer satisfaction with yields and profit and the farm system overall. The environmental measures are derived from functional land use and land cover patterns including; the percent of the farm in non-crop habitat, percent of fields and waterways protected by conservation structures and percent of the year that arable crop fields are protected by vegetation.

Following farm assessment, the HFI can be used to guide the decision making process in such a way that the multiple goals of the farmer and society are included. To meet these goals, farmers are faced with a revolving set of management decisions that are affected by economic and environmental stochasticity. Moreover, the temporal and spatial scales of farm management decisions vary. For example, some decisions are immediate (e.g., cultivation) whereas others require a long-term vision (e.g., windbreaks). Consideration of uncertainty does complicate management goals in managed ecosystems, but complete removal of uncertainty and complexity from farm management is not realistic. The use of structured decision-making (Gregory and Keeney, 2001) as a formal decision-making process, can present new methods, based on the best science, to farmers to address uncertainty and complexity in their farm management. Decisions made with inaccurate or incomplete information may not lead to the most efficient use of limited resources. Without a tool to assess current and future implications of these decisions, a full accounting may not be made.

DISCUSSION

The HFI allows farmers to use their resources efficiently, include and weigh all options in their decision making process, and maintain a healthy farm system that produces food and maintains ecological and socio-economic health. Preliminary assessment with the Healthy Farm Index (Quinn et al., 2009) demonstrates reflectance of sustainable farm design and propensity to reward positive management actions. Representing the overall condition, resiliency, and resistance of the farm, the Healthy Farm Index is a valuable tool for farmers, stakeholders, and policymakers. The current index structure provides a framework in which to add additional indicators developed through future research. Current indicators will continue to be evaluated on participating farms.

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SUSTAINABILITY THROUGH INTEGRATED FARMING SYSTEMS IN SMALL HOLDER FARMS OF TAMILNADU STATE, INDIA

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INTRODUCTION

The three districts identified as disadvantaged by planning commission of India in the state of Tamilnadu *viz*., Cuddalore, Nagapattinam and Villupuram lie on the coast occupying a coastal length of 270 Km and the fourth district Thiruvannamalai lie adjacent to the coast. Monsoon dependent crop seasons, frequent inundations and disasters like cyclones, floods, tsunami besides predominance of clayey soil texture, disputes with adjacent states in sharing of river water, illiteracy, social backwardness and fragmented land holdings (72 per cent of the farming community are small and marginal farmers) have been restricting the adoption of improved farming techniques and crop / farm diversification in these tracts, ultimately reflecting on very poor livelihood status of the farmers. Integrating fish in rice culture is reported to impart sustainability, system bio-diversity, farm diversification, household nutrition, income status of farmers (Njoko and Ejiogu 1999; Rothius *et al.* 1998) and to compliment weed and pest control (Kathiresan, 2007). In rainfed farming conditions, small ruminants especially goats gain importance mainly on account of their short generation intervals, higher rates of prolificacy and the ease in marketing. Goats are observed to be effective in controlling weeds (sedvic *et al.* 1995; Kathiresan, 2007). Integrated Farming System strategies with similar components implemented through World Bank funded National Agricultural Innovation project proved effective in solving the complexities of these tracts through improved generation of employment and revenue, nutritional security and resource conservation. Some of the methodologies used and results obtained are discussed.

MATERIALS AND METHODS

Innovative mode of integrating fish culture and poultry rearing in rice fields involving fish poly culture with Catla, Roghu, Mrigal, Common Carp and Grass Carp in equal proportions of a stocking density of 2000 fingerlings ha^{-1} were taken up in trenches running along the border of rice fields on one side, with a dimension of 1 x 0.5 m, occupying 10 per cent of rice area. Broiler birds @ 1 bird / 10 m^2 of rice area, were housed in cages that would accommodate a maximum of 20 birds (6 x 4′ of floor space and a height of 3′). These cages were installed in the fields using six concrete posts of height 8′, 4′ buried inside the field and 4′ protruding above to lift the cages above crop canopy. The bottom of the cages were made of wire mesh (0.5 sq. inch) so as to leave the broiler waste, straight to the rice field wherein a 5 cm water column was maintained, allowing the poultry waste to get dissolved and to serve both as manure to the field as well as feed for the fishes. This excluded the need for collecting the poultry waste and applying it to the rice field, the task of which is laborious, besides the scope for some wastage. The fishes moved into the rice field to feed on the pests and weeds. This model was evolved through institutional pilot experiments from 1996 to 2005 and on-farm field experiments in three villages during 2005 to 2008. Presently, the model is adopted in 400 small holders' farms spread over four districts of Tamilnadu state. The observations like net return. Organic manure addition and complimentary pest and weed control are discussed.

In the rainfed upland model, farmers were trained to rear the goats, allowing them to graze on the weed vegetation (mostly perennial grasses like *Cynodon dactylon* and sedges like *Cyperus* *rotundus*) that predominate the cropped lands during the off-season. Simultaneously, the goat manure were collected during the off-season and incorporated for the crops (millet / vegetable / flower crop) during the rainfed seasons. Farmers were also instructed to maintain control plots, where in the integration was not practiced and sole crops alone were raised. Observations made like weed bio-mass, net return and soil fertility status are discussed.

RESULTS AND DISCUSSION

Integrated Rice+Fish+Poultry fetched the highest net income of Rs.2,15,447.50(US$4583.98) $ha^{-1}$and a cost: benefit ratio of 1:2.40. The cost of farming was Rs.1,53,817(US$3272.7) ha^{-1} and the gross income was Rs.3,69,265(US$7856.7). This was in comparison to the least net income of Rs.11,150 (US$237.23) ha^{-1} in monoculture of rice. The increase in net income was mainly due to the broiler meat output. The fertility status of the soil was also improved by integrating poultry and fish in lowland rice as indicated by higher post harvest soil available N, P_2O_5 and K_2O by 15kg, 2kg and 17kg ha^{-1} respectively. This is due to higher output of 48.37 to 99.12 kg ha^{-1} of poultry manure everyday ultimately contributing 17.7 t ha^{-1} of manure in a sustained manner. Instead of one stroke application, the organic waste was recycled everyday in smaller quantities. Rice+Fish+Poultry contributed for 30 per cent weed control 20 per cent reduced pest incidence compared to monoculture of rice. The herbivorous feeding habits of grass carp and common carp contributed for weed control impact whereas feeding by other species of fish contributed for reduced pest incidence.

Results of the rainfed upland farming system model revealed that goat integration reduced the population of weeds in maize cultivation by 45 per cent and also increased the grain yield by 7.25 q/ha. The net return was higher by Rs.9,000/ha. (US$188) (Geetha Jebarathnam and Kathiresan, 2005). Goat grazing reduced the weed population by exhausting the food reserves of underground propagules of perennial nut sedge and other weed seed reserves in the soil. The yield increase in maize is attributed to the goat manure addition and reduced weed competition where as the sale of goat meat is responsible for higher net income.

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A methodology for prototyping sustainable cropping systems based on a combination of design process and multicriteria assessment

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INTRODUCTION

A methodological approach of prototyping sustainable cropping systems (CS) inspired from Vereijken (1997) has been developed. We improved the original method by (i) emphasizing the step dedicated to the design of CS through debate within groups composed of experts from various origins, and (ii) using the MASC model (Sadok *et al.*, 2009) derived from DEXi (Bohanec, 2004) to carry out an *ex ante* assessment of the proposed cropping systems.

MATERIALS AND METHODS

The first step of the method consisted in: i) evaluating the sustainability of existing cropping systems to produce guidelines to start the design process; ii) defining the main specifications of the cropping systems to be prototyped as a function of the stakes, goals, and priority settings of stakeholders (e.g., to reduce pesticides in groundwater).

During the second step of the process, innovative cropping systems were designed according to expert knowledge. The group of experts was composed of researchers from different disciplines and farmer advisers. We proposed a three-step approach to design CS prototypes *i)* to focus on a single goal and to decline it into several levels of complexity, starting from the most extreme changes to the lighter ones *ii)* to exchange and share knowledge about alternative techniques, *iii)* to choose and describe each of the CS as prototypes, corresponding to the different "breaking off" levels.

The third step was dedicated to the evaluation of the various prototypes. Each one was characterised using 31 indicators and evaluated using the MASC model allowing a multi-criteria analysis of global sustainability. The MASC model was adapted (Figure) account for some elements of the regional context. The output of the exercice is a ranking of the CS accounting for their multicriteria value, driving the selection of those CS to be tested in field trials in farms or experimental stations.

RESULTS

The case study presented here comes from the region Burgundy a current CS in Burgundy based on an "oil seed rape – winter wheat – winter barley" crop sequence on poor stony soils.

A first version of two prototypes (PEST-1 and PEST-2) describes at plot level and at the level of the surrounding area, and includes an eight-year rotation of six different spring or summer crops. It includes competitive species and pluriannual legumes, the use of lodging-resistant varieties, semi-late sown cereals. Soil tillage with occasional ploughing, mechanical weeding are performed. Uncultivated field borders containing grass and flowers and favouring the establishment of certain auxiliary species or the capture of bio-aggressors are also used.

The MASC model provided an initial classification of the cropping systems for each of the 31 criteria. The integration of these elementary criteria led to an evaluation of the performance of the PEST-1CS, which was considered good for social and environmental sustainability, but poor for economic sustainability. The proposed CS outperformed the reference CS in terms of overall sustainability. However, PEST-2 could not be considered as the best of both innovative systems.

DISCUSSION

The MASC model provides support not only for the development of a framework of objectives, but also for analysing the performances of CS and evaluating them before a new loop of iterative participative improvement. Nonetheless, it is important to develop a computing platform for the rapid characterisation of CS and calculation of the indicators currently included in the MASC model.

The long, diversified rotations including legumes proposed, with a combination of ploughing and reduced tillage and low input crop management, may be considered promising for attempts to address the priority issues in Burgundy. Experimentation in the field is required to assess these systems more thoroughly. Including agricultural advisers in the process proved particularly effective for the design of cropping systems based on diversified rotations in the expert prototyping process.

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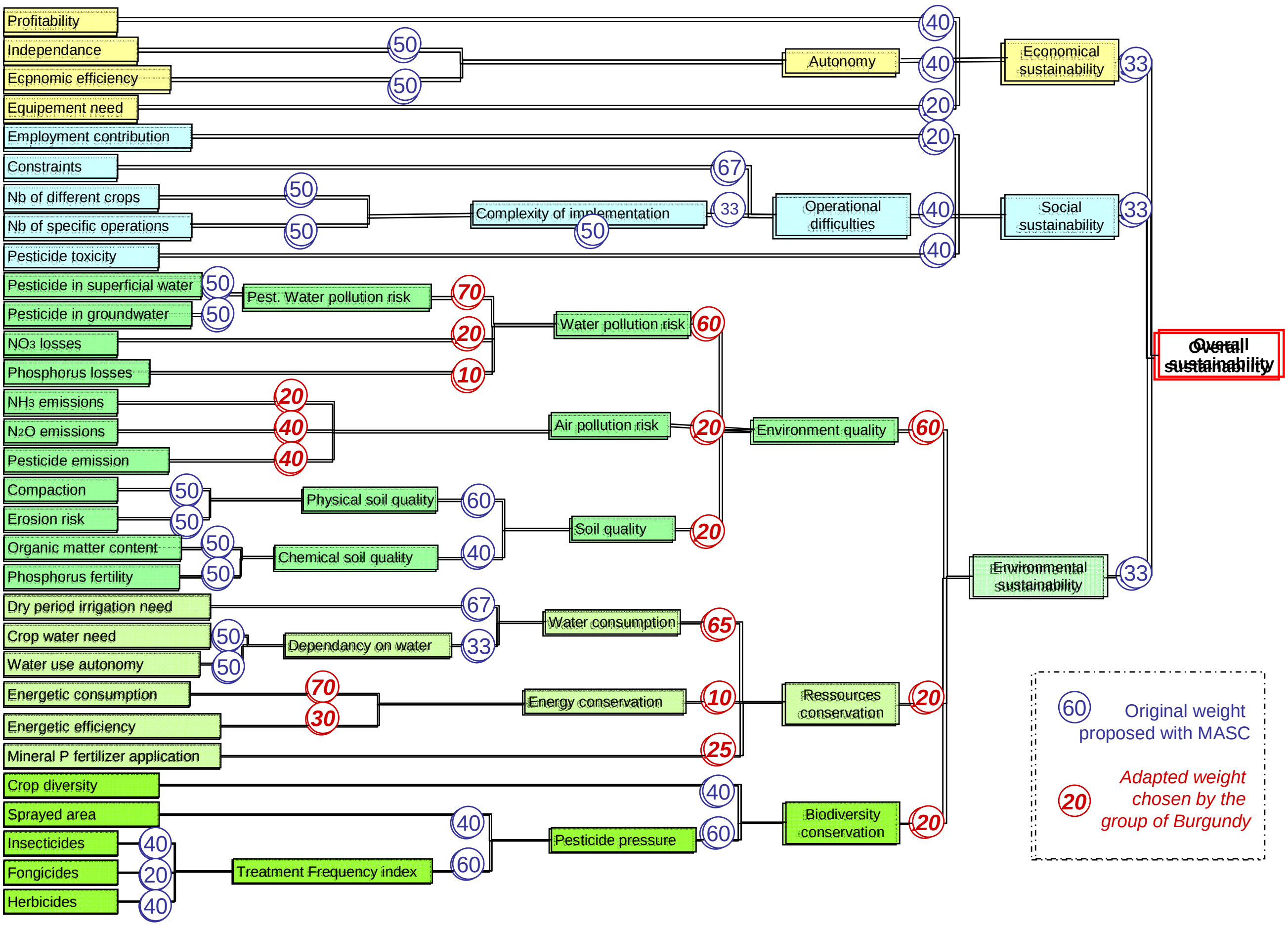

DESIGN OF A GRAPHICAL USER INTERFACE TO DESCRIBE CROPPING SYSTEMS PRACTICES APPLICATION TO THE SIMULATION OF N LOSSES AND N DIAGNOSIS

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INTRODUCTION

The development of sustainable agriculture and of high environmental value farming systems relies on designing innovative systems and diagnosis of systems. Thus, the assessment of sustainability appears a key-point for design (*ex ante* assessment) and for diagnosis (*ex post* assessment).

Indicators and decision support systems (DSS) are relevant and useful assessment tools, but most of the available tools have been designed to assess a single technique, a crop management, a farm, but few are relevant to assess environmental performances at the multiannual cropping systems scale.

Indeed, cropping systems is a very relevant scale to assess nitrogen (N) losses out of the field. But unfortunately, there is no assessment tool available for agricultural advisers and stakeholders to develop the N losses assessment at this scale (Cannavo et al, 2008).

A DSS is currently being developed in the project "Azosystem", in order to help wide spreading the N losses assessment and diagnosis in agricultural systems. This tool will be dedicated to stakeholders or agricultural advisers. The DSS will include a simulator based on a dynamic N model, a graphical interface and databases including default input data and synthetic output data.

We present the design process for the graphical user interface that describes the cropping system practices necessary to run simulations with the dynamic N model.

MATERIALS AND METHODS: ERGONOMICS AND COMPUTING ENGINEERING

In order to estimate, to understand, and to explain N losses as well as to realize diagnosis, or to look after improved cropping systems, it is necessary to facilitate the description of the whole agricultural practices of each crop of the succession, and of the soil and climate characteristics.

The interface specifications for these data were defined from punctual interviews of 27 stakeholders from the French agronomic or agro-environmental N field. Furthermore, a panel of 4 stakeholders was selected out of the 27 (i) to improve our knowledge on agricultural and agro-environmental advisers needs and (ii) to submit to them some concepts or some lay-out of the prototype, as proposed by ergonomists (Béguin, 2003).Therefore the development of this interface was realized in interactions with the potential users of the DSS during the design process.

An UML class diagram describes the useful information about the cropping system, the soil and the climate. They are expressed using attributes, classes and relationships between classes.

RESULTS

Each entry folder is stored with an XML format, and is managed through a tree structure. Each simulation folder describes the cropping system within its context, through the tree structure representation which is localized at top left of the screen, including: (i) the soil description, (ii) the field history, (iii) the crop sequence, (iv) and the crop management (for each crop) described as a series of practical operations (organic fertilisation, mineral fertilisation, tillage, irrigation, grazing, mowing, catch crop) (Figure 1). This tree structure facilitates the multiplication of the simulation, or the copy of elements from one folder to another: a simple copy and paste is needed to introduce twice a crop into a succession, a simple cut and paste is needed to change the place attributed to a crop into a succession. It is allowed by the generic dating of the crop management practices.

The other originality novelty of the prototype is to propose a custom-made product for current crop successions, crop management, and soil characteristics at a regional scale. The aim is to help the user to save time during the data preparation before the simulation; nevertheless each user is invited to enter its own data, or to modify the initial proposed inputs if needed.

DISCUSSION

Improvements of the simulation models are needed in order to be useful for stakeholders as shown by Cox (1996) and Mac Cown (2002). Within this outlook, we have built a DSS joining a practical interface to a dynamic model, proposing default data. This strategy aims at taking into account the fact that few stakeholders nowadays are able to describe a complete cropping system, and at facilitating a diagnosis activity enabling a development of simulation and virtual experimentation.

Designed with a generic approach, the graphic interface could be used for other cropping system assessment tools, or could be integrated in a modelling platform for multicriteria assessment. After the release of the prototype by the end of 2009, we will continue the design of the model, by associating stakeholders in the improvement of the DSS through a learning loop, and we will develop a learning activity with advisers in order to improve the N diagnosis losses assessment with up to date models.

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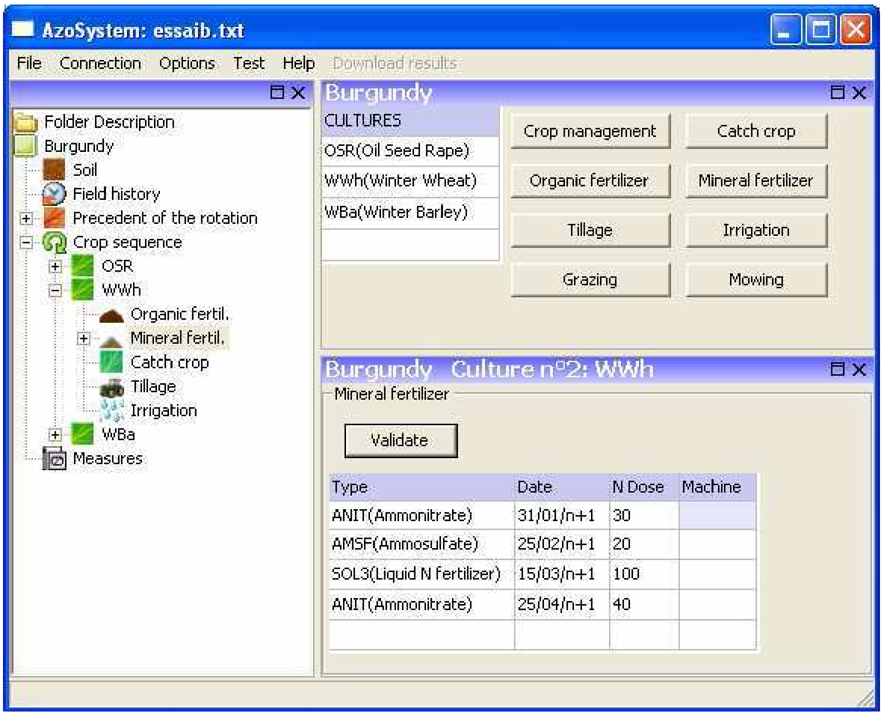

Figure 1: example of a screen shot of the Azosystem graphical interface

Assessing adaptation strategies of European agriculture to changes in climate and market conditions

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INTRODUCTION

Agricultural systems evolve depending on a range of climatic and socio-economic factors. Changes in these factors have been projected for the future, but impacts on agricultural systems including their adaptive capacity remain difficult to assess. Originally, climate impact studies have focused mainly on biophysical relationships explaining the potential impacts of climate change on primary production. In recent years the importance of socio-economic developments is increasingly recognised and integrated in climate impact assessments for agriculture (IPCC, 2007). There is an apparent need for a methodology to assess impacts of climate change on agriculture at the regional and farm levels while simultaneously considering changes in political, socio-economic and market conditions. There is a need to conceptually and technically link biophysical models that enable estimation of climate impacts on e.g. crop yields and land use and associated environmental impacts (e.g. nitrogen leaching, soil carbon content or water use) with farming system and market models, and improve the relevance for stakeholders. Despite the significant progress that has been made in recent years on climate change impact and sustainability assessment, key issues of assessing responses and adaptation at farming system and regional level using a coherent modelling framework remain unresolved.

METHODOLOGY

This study develops a methodology to assess adaptation of agriculture under climatic and socio-economic changes for different agricultural sectors and farm types. The methodology is derived from recent studies that have analyzed and assessed agricultural adaptation across regions in Europe. One study focused on climate-market interactions in order to provide information on the competitiveness of agricultural regions and products throughout Europe (Hermans and Verhagen, 2008). The spatial distribution of wheat, potato and milk production was projected for a base year in 2005 and multiple scenarios in 2020 and 2050. A second study used empirical data to improve understanding of adaptation to climate change and variability at multiple levels of organization. Farm performance data from more than 50000 farms surveyed over a period of 14 years across Europe, were coupled to climate and socio-economic data to identify farm characteristics that influence management and adaptation (Reidsma et al., 2009). These ex-post and preliminary ex-ante assessments will now be extended. In this study we use the SEAMLESS – Integrated Framework (van Ittersum et al., 2008) to assess adaptation strategies in agricultural systems to environmental and market changes at multiple scales (Figure 1). A first application of the methodology is developed for a case study in Flevoland, the Netherlands. To ensure the science-stakeholder and science-policy link, this modelling framework will be complemented with a more applied and semi-quantitative approach, the Agro-Climatic Calender (ACC). Based on literature review, expert knowledge and stakeholder participation, critical climate related risks are identified for major current and alternative crops (e.g. long dry periods in June to August, after stem elongation, can reduce yields of wheat). The frequencies of occurrence of these climate risks are assessed for the current situation (1990) and climate scenarios in 2040. For climate risks with changing frequencies, adaptation strategies are identified. The impact of adaptation strategies at crop, farm and regional level will be assessed with a cropping system model, farming system model and market model as developed in SEAMLESS-IF, and complemented with the ACC information.

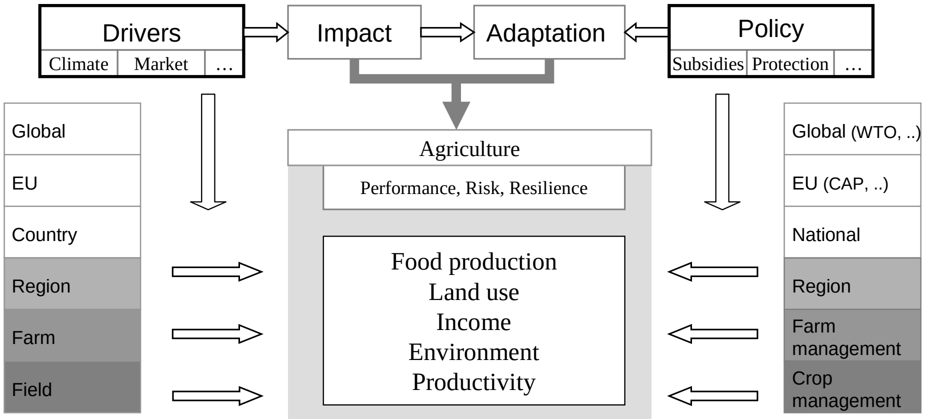

Figure 1. Schematic representation of the scope of the study

RESULTS AND DISCUSSION

Hermans and Verhagen (2008) assessed competitiveness of European agricultural regions in 2020 and 2050 and showed that changes in productivity of wheat, potato and milk differed among regions and were more explained by socio-economic than by climatic changes. Generally, potato and milk production seem to remain competitive in the Netherlands, while wheat production will decrease. This study gave a first overview of competitiveness throughout Europe, but the assumption that small farms will be most vulnerable needs refinement. Reidsma et al. (2009) showed that adaptation is dependent on many other factors besides the economic size of the farms. Adaptation will also be affected by farm intensity, specialization and land use, and the specific regional (climate and socio-economic) conditions. Hazard exposure seems important, as regions with larger climate variability were less vulnerable to yield variability (Reidsma et al., 2009).

In Flevoland, the prevailing climate conditions are suitable for agriculture, but changes in climate have been observed by farmers. The ACC showed that most crops will be able to cope with a change in the frequencies of extreme events. However, risks are projected. For example, long dry periods in June to August are expected to increase, which may reduce yields of wheat. Possible adaptation strategies to reduce the impact of long dry periods are to improve soil water holding capacity (farm level) or developing a heat resistant cultivar (sector level). Also for other crops adaptation strategies were identified at multiple levels. The effectiveness of these types of adaptation strategies will be further explored for different farm types, taking into account the results from earlier studies, which will result in a comprehensive overview of impacts and adaptation to climate change at multiple scales.

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A GENERIC FRAMEWORK FOR THE MODELLING OF LIVESTOCK PRODUCTION SYSTEMS: MELODIE

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INTRODUCTION

Modeling at farm level is considered as relevant for agricultural sustainable development. However, farm scale raises several methodological issues relating to the superficial attention paid to management aspects or to the integration of multidisciplinary knowledge (animal and crop production…). A specific difficulty is raised by *ex ante* simulations, to ensure the consistency of the system simulated, particularly for those that do not exist in reality. Consequently, the modeling of whole farm, even for a very specific purpose, can be in itself a difficult challenge. Besides, resulting models may have poor genericity and evolving abilities. In the scope of the development of a model for dairy and pig farms, initially focusing on nutrient flows (Chardon et al., 2007), a generic framework for the modeling of livestock system has been developed upstream, by using a production system ontology (Martin-Clouaire and Rellier, 2009). The aim was to be able to generate models for contrasted production systems to study nutrient flows from existing knowledge, while leaving opportunities to further extend the model to new processes, decision rules, or criterions (economic, social…) and possibly to other animal species.

MODEL DESCRIPTION

The modelling approach is organized in five layers (figure 1). The base level concerns the structure for an object-oriented modelling of dynamic systems. The second level provides an ontological ground for the domain of agricultural production system, composed of interactive management and biotechnical subsystems (Martin-Clouaire and Rellier, 2009). The next level corresponds to a specialization for livestock farms. Generic entities (applying to every animal farms) were created wherever possible (i.e. "manager", "animal"…). This work benefits from the appraisal of an expert panel from various disciplines (Melodie Project), for example, to carefully design animal feeding. The result could therefore be seen, to a certain extent, as an ontology of animal production systems. More specialised entities were then created for more specific purposes (e.g. "bovine", "pig", "dairy cow"…). Processes associated to these entities and especially involved in nutrient cycling (N, P, C, Cu, Zn) have been implemented (animal excretion, gaseous emissions during manure storage and treatment…). Similarly, published decisional sub-models have been integrated to simulate farmer's decisions from an overall strategy, climatic conditions and the evolution of the system (i.e., cropping and spreading plans generators, herd simulator…). For example, cropping and spreading plans are generated each simulated year to fit objectives such as desired self-sufficiency, with given available stocks (resulting from previous years), and they could be revised in the course of the year if climatic conditions are not compatible. The structure of the model enables to easily substitute or add sub-models. At the last level, a specific pig and dairy farm can be generated, with all required components to simulate nutrient flows for several years, with a daily time step (Chardon et al., 2007).

RESULTS AND DISCUSSION

Each level is a particularization of the conceptual level below, and can therefore be seen in itself as a modeling result. The generic framework for livestock systems has supported the formalisation of two contrasted production systems (pig and dairy) with numerous common concepts. The generic properties of the model help to structure emerging projects for other animal species (poultry, suckler cows) and at other scales (catchment scale). These projects prove the relevance of this conceptual level. The next conceptual level (pig and dairy farms) has been used to generate six dairy farms and five pig farms. The implemented modules in the framework covered contrasted feeding management (with varying areas of pasture and maize) as well as contrasted manure handling schemes (slurry, solid manure, composting…). The simulation of both biological flows and coherent decisions from an overall strategy resulted in complex interactions between animal, manure and crops. For example, gaseous emissions from animals and manure are not only the result of biological processes at animal and manure level, but it also dynamically depends on crop growth and the strategy of the farmer to feed animals or to spread manure. The flexible adaptation of the system to climatic conditions, in a dynamic way, enables to estimate variations of nutrient flows between or within years (Chardon et al., 2007). The variations between years, for a given overall strategy, takes into account stocks evolutions (feed, manure, organic matter in soils…). Moreover, the simulations can be used to perform comprehensive multicriteria assessments (nutrient balances, LCA…). As a conclusion, the existing framework is powerful to simulate *ex ante* nutrient flows in farms with contrasted productions (dairy cows, pigs, and different crops) and farmer strategies. Moreover, the flexibility of the framework enables the further integration of new sub-models and other criterions, and possibly the extension to other production systems.

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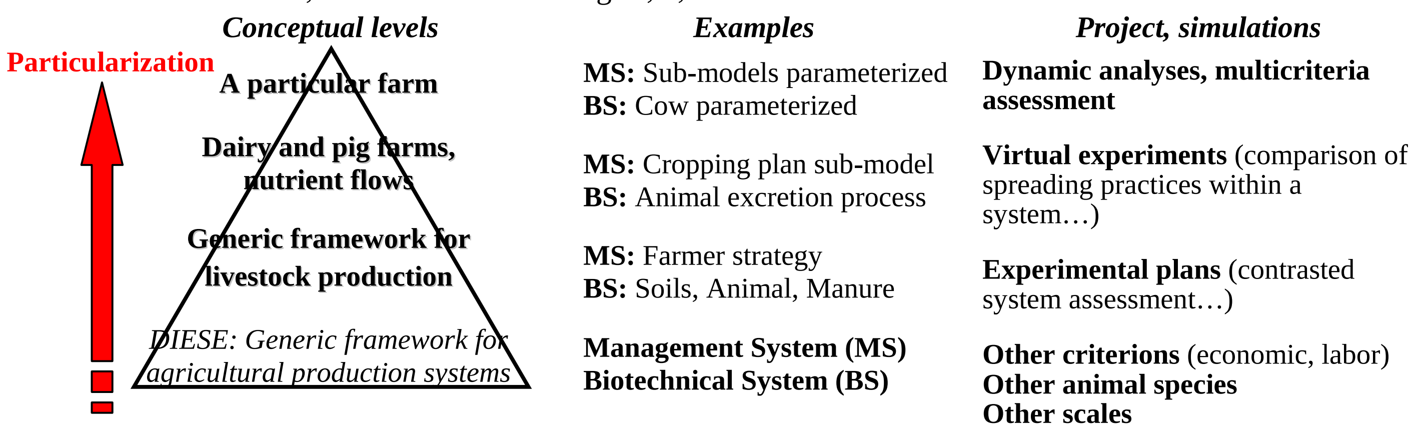

Figure 1: The five levels of the framework, examples and respective implications

MODELING DYNAMICALLY THE MANAGEMENT OF INTERCROPPED VINEYARDS TO CONTROL THE GRAPEVINE WATER STATUS

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INTRODUCTION

In vineyards, introducing a grass cover as intercrop is a common practice around the world. Indeed, it can provide some ecological services such as mitigation of runoff and erosion, and control of grapevine vegetative development (Battany and Grismer, 2000; Smart et al., 1991). Moreover, it can constitute an interesting alternative to the systematic use of herbicides. However, introducing a new crop makes the system more complex, and farmers have to adapt their way to manage them. In Mediterranean vineyards, a major difficulty is to manage correctly the two crops, to satisfy production and environmental objectives with respect to the competition for soil resources and climate variability.

As experiments are time consuming and difficult to carry out in these perennial systems, the use of a modeling approach is more appropriate to test and evaluate different types of intercrop management plans. A recent study showed the difficulty in finding robust management plans over a 30-years period. It can be explained by the fact that they did not manage responsively to observed states of the biophysical system and they did not take into account the high inter- and intra-annual climate variability (Ripoche et al., 2009).

This study analyzes the merit of introducing some flexibility in the management of intercrops in vineyards. The investigation relies on a simulation model that reproduces the interactive dynamics of decision-making and biophysical processes. Simulation is used to support the design of more robust management plans enabling control of the grapevine water status in these cropping systems.

DESCRIPTION OF MODEL

A generic modeling platform, DIESE (Martin-Clouaire and Rellier, 2009), created to simulate a manager interacting with and operating on a biophysical system has been used to write and simulate dynamic models of management that reproduce the chain of decisions and actions that affect the biophysical processes of both grapevine and intercrop. The simulated decisions are informed by climatic and biophysical indicators. This software platform offers a conceptual object-oriented modeling framework under the form of a production system ontology. DIESE relies on three main concepts: entity, process and event, which correspond to the structural, functional and dynamic aspects involved in the dynamic systems to be modelled. In addition, DIESE provides a discrete event simulation engine and a modeling environment tailored to the underlying ontology.

Biophysical system

The biophysical system is represented by different entities related by processes coming from a water balance model adapted to intercropped vineyards (Celette, 2007). For instance, *Field* is an entity composed of 3 other entities: a *Soil Reservoir*, an *Inter-Row* and a *Row*. The last two entities include a *Soil Surface* entity and a specification of the *Vegetation* entity, namely *Grapevine* or *Grass*. As assumed in the water balance model, a *Soil Reservoir* component is also attributed to the Inter-Row to represent the volume of soil explored by the grass. The grapevine can explore the two soil reservoirs.

Management system

As we focuss on the intercrop management, the management system is defined to account for the activities directly related to the grass management (e.g., tillage for preparing seed-bed, sowing, mowing) and also activities related to soil management in case of grass destruction (e.g., tillage or chemical weeding). These activities concern the inter-row and impact the biophysical processes linked to this component as well as processes at field level such as the evolution of the grapevine water status. They are combined to form annual plans themselves aggregated into different pluri-annual strategies for the cropping systems.

Flexibility takes place at different levels. Operational flexibility relates to the feasibility conditions of the activities (e.g., rainfall on the candidate day of sowing or the day before precludes the immediate execution of the activity). Tactical flexibility corresponds to the determination and timing of activities in function of the state of the biophysical system (e.g. performing a mowing at the right moment depending on grass state). Strategic flexibility refers to the context-dependent replacement of parts of the strategy with other activities more suited to the overall objective assigned to the system.

RESULTS AND DISCUSSION

Different strategies were built including different levels of flexibility. The first strategy considered as ‘standard’ consists in maintaining a bare soil in the inter-row. In the second one, a permanent grass cover is installed and sustained over years. In the third one, the intercrop is sown then destroyed every year as a function of the grapevine water status. The so-called ‘mixed strategy’ offers the choice between keeping the intercrop or destroying it, i.e. switching to bare soil management for the rest of the year. The next year, intercrop may be sown again.

These strategies were simulated over 5 years of contrasted climatic data of Montpellier (South of France) and their agronomic performances were compared. Because a flexible strategy responds to climate variability and to changes in the state of the biophysical system, its application results in different calendars of executed actions. For example, the ‘mixed’ strategy resulted in a permanent intercrop in 2004 and 2005 (with different series of dates of mowing). Its destruction was decided in 2006, 2007 and 2008 in relation to a dry spring. This strategy resulted in better agronomic performances than the one with permanent intercropping.

The use of the ontological framework DIESE to build this model is efficient in representing the complexity of a perennial multi-crop system and for helping to design innovative and robust management strategies. The dynamic interactions among the weather, the biophysical and management systems are consistent and realistic. To confirm these results and extend the scope of our study, strategies have to be evaluated under various climates and for longer periods. Moreover, constraints related to time and material resource consumption by all the activities should be taken into account in order to deal with the possible competition between activities at field or farm scales.

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USING FARM-SCALE BIO-ECONOMIC MODELS TO EXPLAIN ADOPTION OF FARM PRACTICES AT THE REGIONAL SCALE

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INTRODUCTION

A range of factors affect the rate and ultimate level of adoption of a particular practice, and these largely come down to factors that encompass actual and perceived "relative economic advantage" of a new practice on-farm. The relative advantage and potential scale of adoption of a new technology or practice developed at a field scale may not be obvious until integrated into a wider farm system. Whole-farm bio-economic models with an objective function for maximising profit can account for enterprise tradeoffs and synergies, allocation of resources (land, labour) and economies of scale and hence can be useful tools in examining systems-level integration. Surveys of actual adoption of practices can be used to ground-truth, inform and challenge output from such bio-economic models.

Two studies in the broadacre cereal-livestock zone of Western Australia compared actual adoption of particular practices at a regional scale with predicted levels of adoption based on profit-maximisation from whole-farm models representative of typical farms found in the region. The aim was to explore the utility of joint use of bio-economic models and farm surveys to gain greater insights to the economic and other drivers for adoption on farm.

METHODS

In the first study, the drivers for fluctuations in the area of broadleaf break crops (canola, lupins, fieldpea, fababean) in cereal-dominant rotations was investigated by combining regional surveys of the area and grain yield of break crops on-farm collected in 2005-2007 seasons with whole-farm bio-economic modelling to determine the upper limit to the area of break crops on representative farms in two agro-climatic regions: low rainfall (80 farms, <350 mm MAR) and medium rainfall (150 farms, 350mm<MAR<450mm).

The second study was based in a catchment threatened by rising saline watertables and where wider plantings of perennial pastures, such as lucerne and kikuyu, within the crop-dominant farming system could address the threat. Target areas for perennial plantings were compared with: potential areas based on biophysical limits, what would be profit-maximising in the short-term, what has actually been adopted and what farmers say that they may plant in the future.

In both studies a linear programming bio-economic model (MIDAS) that represents the biological, physical, technical and managerial relationships of a mixed farm was used to represent the production systems within a defined region. The model allocates available resources to maximise the objective function of whole-farm profit, subject to resource, environmental and managerial constraints, for an "expected" season. The model was run with a range of parameter values (prices, costs, crop yields, pasture growth patterns), to assess the influence on the profit-maximising mix of enterprises and level of farm profit.

RESULTS AND DISCUSSION

In the break crops case study, modelling showed that break crops are an important component of the farming system, even where the optimal area is small. Is it clearly costly to exclude break crops from the farming system. The modelled area of break crops at maximum profit is much higher than that found in farm surveys (Table 1) The fact that many growers do not grow break crops and those that do grow areas well below the economic optimum raises questions about farmer motivations for adoption of break crops and further research into the model and actual farm factors is required to understand the reasons for the discrepancy. Our modelling poses some possibilities. When yields are used in the models that are more representative of values found in farm surveys it is noteworthy that canola drops out of the optimal farm plans and also do legumes, although by not as much. A smaller boost of cereal yield to preceding break crop also could explain lower break crop adoption, as do higher fertiliser costs and reduced grain prices (Table 1). The scope for increased area of break crops beyond 35 to 40% of the farm is limited, even with increases in yield boost to cereals and high break crop prices (Table 1).

In the perennial pastures case study, farm surveys showed that the 18,000 ha of the crop-dominant catchment currently has 2% saline land and 9% coverage with perennials (lucerne, trees, fodder shrubs, perennial grasses). The current levels of adoption agree well with bio-economic modelling, which suggests small areas of lucerne and kikuyu with a combined area of less than 10% are economically-optimal. It would seem that what farmers are currently doing in the catchment is economically-rational, especially considering the declining emphasis on sheep production and also the fact that on-farm stocking rates are in the vicinity of 2 DSE/ha, while modelled stocking rates were 3-4 times higher than this. Under 'low' grain prices (i.e. similar to what was mostly received until about 2005), perennial area would be optimal on 10-40% of the farm. The current area of perennials and likely economically-optimal areas are vastly smaller than the area required to control groundwater rise on the landform patterns underlain by the dominant intermediate groundwater flow systems. This presents a dilemma for future prospects of controlling salinity in the catchment. Farmers recognise the value and efficacy of small areas of perennial in “drying up” localised saline outbreaks, undoubtedly associated with local groundwater flow systems. However, broadscale treatment of the landscape under current economic trends and farming systems orientation is untenable. It appears that increased adoption will only occur with the development of more profitable perennials for the local farming system and compatible with farmer objectives.

In conclusion, these two case studies highlight that the combination of bio-economic models and farm surveys provide insights to drivers of adoption that neither approach alone could give. The models can explore biophysical and economic limits, while surveys quantify actual adoption and the importance of non-bioeconomic drivers in influencing rate and ultimate level of adoption.

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Table 1: Area of break crops on farm (modelled profit-maximising and actual from farm survey) in two climate zones in Western Australia

	Low rainfall	Medium rainfall
Profit maximising farm area (%) with:		
Standard assumptions	23	38
25% reduced yield	8	18
50% reduced yield boost	15	23
Higher fertiliser costs	8	21
Lower grain prices	0	10
50% increased yield boost	27	38
High break crop prices	37	51
Actual percent farms growing break crops	54	75
Actual percent farm area under break crops	8	12

The intrinsic plasticity of farm businesses and their resilience in the face of change

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INTRODUCTION

While farmers continuously adapt their management practises in response to changes in their operational environment, medium and long term farm business planning requires far greater levels of information and support to ensure success. In this paper we postulate that, as in evolutionary ecology, plasticity in decision making and farm business strategy can provide a powerful base for long term adaptation to change; and tested the hypothesis that farm businesses having contrasting levels of "intrinsic plasticity" in their tactical and strategic management, achieve different levels of resilience when exposed to a stressor such as a climate change. We defined plasticity in farm management as the outcome from a set of flexible and opportunistic management rules that moderate potential changes, or allow benefit from opportunities associated with operating in a highly variable environment, i.e. a more environment contingent system. In contrast, a more "rigid" farm management strategy tends to follow a number of fixed management rules or fixed rotation of crops, i.e. a more "calendar" dependent system. To test the hypothesis above, we used the APSFarm whole farm model, and simulated the impacts of a range of expected climate change scenarios on the economic performance of four farm businesses of contrasting levels of plasticity. Results are discussed in terms of their contribution towards the development of the concept of *Adaptation Science*, i.e. the process of identifying and assessing threats, risks and opportunities, and generating the necessary information and knowledge required to produce a change in the system towards a higher state of resilience.

MATERIAL AND METHODS

APSFarm is a multi-paddock dynamic simulation environment that uses the APSIM modelling platform (Keating et al., 2003) to simulate the allocation of land, labour, machinery and finance resources at the whole farm level (Rodriguez et al., 2007). Outputs from APSFarm include, production measures i.e. individual crop yields; economic measures i.e. crop and fallow costs, individual crop gross margin, farm annual operating return, and farm cash flow; efficiency measures i.e. whole farm water use efficiency; and environmental measures i.e. deep drainage, runoff, and erosion. The managers from two farm businesses having contrasting level of plasticity, i.e. at *Capella- plastic*, and *Goondiwindi-rigid*, Queensland, Australia, were interviewed, and a complete description of the tactical and strategic management of their farms was obtained. From discussions with expert agronomists two alternative (hypothetical) farm businesses were also described i.e. *Capella-rigid*, and *Goondiwindi-plastic*. The four farm businesses were then implemented in APSFarm and the model outputs were validated against farmers' knowledge and results from long term rotational trials using the last 20 years of climate records. After validation, the model was run for climatology (1987-2006) i.e. baseline, 380ppm CO_2, and four climate change scenarios downscaled from the Hadley CM3 model, i.e. A2 2030 (451 ppm CO_2) and 2070 (635 ppm CO_2), and A1F 2030 (440ppm CO_2) and 2070 (716 ppm CO_2) (Crimp et al., 2008). Results from the simulations are presented in terms of differences in performance between the present farm business management strategies (i.e. *Capella-plastic* and *Goondiwindi-rigid*), and the two hypothetical cases, (i.e. *Capella-rigid* and *Goodiwindi-plastic*). Performance was evaluated in terms of individual crop yields (median values over the whole farm), cropping intensity, crop mix, farm profits and economic risks.

RESULTS AND DISCUSSION

Downscaled climate change scenarios (Crimp et al., 2008) showed a maximum (A1F 2070) decrease in median annual rainfall of 77mm (from 536 to 459mm), and 80mm (from 541 to 461mm) at Capella and Goondiwindi, respectively. Rainfall reductions occurred mostly during the autumn and winter months in Capella, and during the spring months in Goondiwindi, with no changes or slight increases in summer rainfall. Maximum increases in monthly average temperatures were similar between sites (≈ 3°C warmer), and constant within a year. Both, simulated farm business strategies and climate change scenarios modified the probability distribution functions of crop yields and farm profits, the cropping intensity, and crop mix. At *Capella-plastic*, differences in simulated yields, between the baseline and the A1F 2070 scenario, were positive for wheat (+51%) and chickpea (+41%) and negative for sorghum (-19%) and maize (-13%). At *Goondiwindi-rigid*, differences in simulated yields, between the baseline and the A1F 2070 scenario, were positive for wheat (+4%), and negative for sorghum (-9%) and chickpea (-3%), (maize was not grown at Goondiwindi). At *Capella-plastic*, the cropping intensity changed from 99% (Baseline) to 73% (A1F 2070), and at *Goondiwindi-rigid*, from 81% (Baseline) to 60% (A1F 2070). At *Capella-plastic* the number of summer crops increased by 8%, while the number of winter crops were reduced by 15%; at *Goondiwindi-rigid* the number of summer crops were reduced by 28% while the number of winter crops increased by 13%. Comparing net profits ($/ha.y) between the two real (i.e. *Capella-plastic* and *Goondiwindi-rigid*), and two hypothetical farm businesses (i.e. *Capella-rigid* and *Goondiwindi-plastic*), showed that at both locations the more *plastic* strategy had significantly higher median profits ($p<0.001$, df=99), and similar values of down side risk (30%). These results indicate that *plasticity* in farm businesses is a desirable property for increased resilience when exposed to variable and changing climates, at least for the two environments we investigated. More plastic business designs and decision rules enable farmers to respond better to environmental shifts, thus ensuring the economic viability of the farm business. Even though the presence of variability is necessary for plasticity to be a beneficial attribute in a farm business, the answer to when or whether a more plastic strategy should be favoured over a more rigid one, remains open. Our results on changes in crop yields, cropping intensity and mix, emphasise the importance of studying climate change impacts and adaptation options by simulating changes in the performance of the whole farm compared to individual crops.

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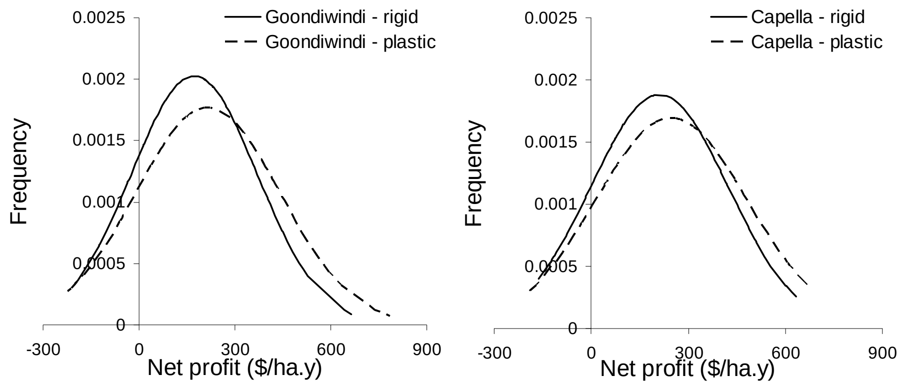

Fig 1. Density functions for net profits ($/ha.y) derived from simulations of two real (*Capella-plastic* and *Goondiwindi-rigid*), and two hypothetical (*Capella-rigid* and *Goondiwindi-plastic*) farm business strategies, using climatology (1987-2006, 380 ppm CO_2), and four climate change scenarios.

FORESIGHT METHODOLOGY TO FINE-TUNE CHANGES IN LOCAL LAND USE POLICY THEREBY MINIMIZING RUNOFF IMPACTS

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INTRODUCTION

In the silt-loam agricultural region of Pays de Caux (Upper Normandy, north-western France), farmers frequently face runoff and erosion problems, often causing off-site damage. The silty soils, having crusting properties, induce a high risk of run off and erosion (Fox et Le Bissonais, 1998). Agricultural land use plays a role as interactions between rainfall, farming operations, and topsoil texture bring about rapid and significant changes in the hydraulic properties of topsoil, restricting its infiltration capacity.

Socio-economic factors are tightly related to agricultural land use and practices (Bordman 2003). For example, market conditions or farming policies at the European level are likely to influence future trends in agricultural land use and therefore runoff in an area such as in Upper Normandy.

Hence, the importance of foreseeing future land use changes in assessing their environmental impacts. We have undertaken to investigate future land use changes in terms of runoff production based on a two step procedure: (1) building scenarios of possible futures within the Seine-Maritime county to shed light on the alternative futures of local agricultural land use, taking the year 2015 as the time horizon; (2) and assessing these different land use change scenarios in terms of consequences on runoff production.

MATERIALS AND METHODS

SYSPAHMM (SYStem, Processes, clusters of Hypotheses, Micro-scenarios, Macro-scenarios) (Sebillotte M., Sebillotte C., 2002, Sebillotte C., Sebillotte M., Ledos F., 2008) is being used to foresee land use changes at the local scale, and a group of local stakeholders is implicated in the investigation. Firstly, we identify factors involved in the functioning of the land use system. They are presented in both a static way, through a graphic representation, and a dynamic way, through processes, which explain the functioning of the land use system and are essential for drawing up a list of hypotheses. Secondly, a set of hypotheses for future evolution is elaborated starting from the processes. Processes designated as the most important ones by the group of stakeholders for the land use future and having a potential impact on runoff are used for hypothesis building. Thirdly, we analyze the influence any one hypothesis has on another one by building a matrix of relationships between hypotheses. Hypotheses, depending on the influence they have on each other, are then grouped together to form clusters, every cluster corresponding to a microscenario family. In our case, three microscenario families have been identified. Finally, from each microscenarios family, individual microscenarios are built by liking hypotheses guided by a leader hypothesis. The last step is the overall scenario building, choosing one microscenario from each family. An overall microscenario has been tested in terms of its consequences on runoff.

The Saussay watershed was selected to carry out the overall scenario assessment. It is located in Pays de Caux, in the French region of Upper Normandy. The Saussay watershed stretches over 522ha. Firstly, runoff impact of the current situation (2007) has been evaluated taking into account farmers’ choices and agricultural practices (i.e., crops areas, return crops period). To create a diversity of watershed layouts according to farmers’ choice we used Landsfacts spatio-temporal allocation of crops to fields software (Castellazzi et al., 2008). Then, at the farm and watershed levels, the impact of current agricultural practices on runoff volume was simulated using the DIAR model (Martin, in press) and the STREAM model (Cerdan et al., 2002) respectively. STREAM model simulates runoff at the watershed level according to soil-surface infiltration capacity, determined by soil-surface characteristics (crusting stage, roughness and crop cover) and for a given rainfall event. DIAR model simulates runoff based on the calculation of curve number values for each stage of the soil-surface-state sequence.

RESULTS AND DISCUSSION

The three microscenario families identified are named as: 1) "Agriculture facing rural development" concerning land urbanisation and environnemental policy; 2) "Will the local supply chain continue to play a role?" concerning crops; and 3) "What does the future hold for cattle breeding?" concerning livestock farming. By choosing one microscenario from each family, we built three overall scenarios which represent strongly contrasting situations for local farming and local territory development.

We are simulating overall scenarios in terms of its consequences on runoff. As an example, we are testing the overall scenario "Territory loses its traditional production in favour of cash crops in a context of rural exodus", local stakeholders labelling it the worst case scenario. In this scenario dairy farming disappears in favour of cash crops farms or suckler farming. As already done for the current situation (2007), the prospective situation (2015) according to the "Territory loses its traditional production in favour of cash crops in a context of rural exodus" scenario is being assessed at the farm and watershed levels using STREAM and DIAR models respectively. We will be comparing the impact of the two scenarios on runoff. In efforts to minimize the environmental impacts of farming, this assessment of the impacts of overall scenarios on runoff should encourage both local policy makers and local actors to actively discuss the future of land use in Upper Normandy.

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SHAPING CO-INNOVATION FOR MORE EFFECTIVE FARMER ENGAGEMENT BY FARMING SYSTEMS SCIENTISTS: AN ILLUSTRATION FROM LATIN AMERICA

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INTRODUCTION

Smallholders in emerging economies such as those in Latin America who are producing for markets are easily caught in a vicious cycle of unsustainability. Decreasing prices of agricultural products and rising prices of inputs caused declines in family income over the past two decades. The typical farmers' response was to increase the intensity of production by increasing input application and share of cash crops, and by taking up farming on marginal parts of their land. This intensification used substantial inputs of labor and capital and often resulted in resource base degradation which in turn negatively impacted on productivity. A major cause of this downward spiral we argue is that the adaptation of farmers to changing conditions is mostly incremental, short-term oriented and only rarely involves strategic re-design of their rural livelihood strategies as a whole. As a result, livelihoods become locked-in on unsustainable development tracks. Alternative developmental tracks are possible when socio-economic improvements are combined with improved natural resource use. Systems thinking provides the means to explore consequences of changes in systems management to reveal conflicts between alternatives and to provide directions for promising development tracks. To date, only few positive experiences have been reported where systems approaches have directly supported strategic farmer decision processes. Economically and agro-ecologically diversified livelihood options do not come as validated technology packages waiting to be adopted by farmers. Researchers can play a role in supporting the innovativeness of resource users. Researchers themselves learn by being able to analyze the many experiments that farm practices represent. This collective learning process, we argue needs to be embedded in project design, and monitoring and evaluation tools should be mobilized and developed to allow continuous adjustments in project activities. (Complex) systems approaches, continuous project monitoring and learning facilitation are the key constituents of a 'co-innovation' approach developed in the European-Latin American Co-innovation of Agricultural Systems (EULACIAS; INCO-CT-2006-032387) project (Fig. 1). Here we describe the approach and its constituents, based on experiences in ongoing case studies in Argentina, Mexico and Uruguay.

MATERIALS AND METHODS

In EULACIAS farms and their institutional context are compared to Complex Adaptive Systems (CAS) *cf.* Axelrod and Cohen (2000). A CAS consists of agents, entities which can make things happen, along with the artefacts and strategies that they use in their interactions with other agents and with artefacts. Evaluation of the results of these interactions leads to selection of strategies or artefacts to copy, or recombine or to invention of new ones. This evolutionary process introduces novelty. Such CAS cannot be managed in a linear way due to many unknown interactions and feedbacks between system components. Management should rely on understanding and stimulating variation in the types of agents, strategies, artefacts and their interactions, the selection processes by which the "fitness" of an agent, strategy or artefact is assessed, and the subsequent processes that allow the fitter to survive and spread (Douthwaite 2001). Conceptualizing innovation as management of CAS requires development projects to adopt methods which take these characteristics into account. In EULACIAS methods are founded in quantitative systems approaches, project theory and learning selection.

RESULTS AND DISCUSSION

Quantitative systems approaches constitute a systems scientist's means of both describing and understanding variation between farms, and judging fitness of current or alternative strategies. Patterns may be summarized in farm typologies and scenarios of possible future contexts (Fig. 2). Outliers are identified, facilitating learning from good examples. In the case studies, whole-farm modelling is used to generate 'bright ideas', entry points for scientists to become involved in action-oriented on-farm research (Dogliotti et al., Cittadini et al. this volume). The *project monitoring* method implemented by EULACIAS allows stakeholders to play an active role in structuring development options and technological innovations. Key elements are an initial Impact Pathway workshop with project implementers, next users, end users and politically important actors and 6-monthly Reflection Workshops to review and adjust planning. Co-innovation also includes fostering *'learning selection'*, which leads to novelties and on-farm testing and re-design. Examples include the use of cover crops to reduce soil erosion (Uruguay), production of maize silage to reduce dependence on external feed sources (Mexico), or diversification of existing production systems (Argentina). Most Significant Change stories are used as a means to identify and share such learning trajectories stimulated through field visits and field days (Table 1). Since the cases represent different development stages in the three components, they offer rich material for strengthening future scientific engagement in farming systems development.

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Table 1. Tools, domains of co-innovation, stakeholders and frequency in the Uruguay case study.

Tools	Domains of co-innovation	Stakeholders involved	Frequency
Reflection Workshop	1. Dynamic monitoring 2. Social learning	Farmers, Researchers, Extension Agents	1x $year^{-1}$
Most Significant Change (MSC) stories	1. Dynamic monitoring 2. Social learning	Farmers, Researchers	1x $year^{-1}$
Monthly meetings of the research team	1. Complex systems app. 2. Social learning 3. Dynamic monitoring	Researchers	1x $month^{-1}$
Training activities of the research team	1. Complex systems app. 2. Social learning	Researchers	3-4x $year^{-1}$
Activities of scaling out and up oriented to farmers, technical advisers and extension organizations	1. Social learning	Farmers, Researchers, Extension Agents	4x $year^{-1}$
Visit of the pilot farms	1. Complex systems app. 2. Social learning	Researchers, Farmers	Fortnightly

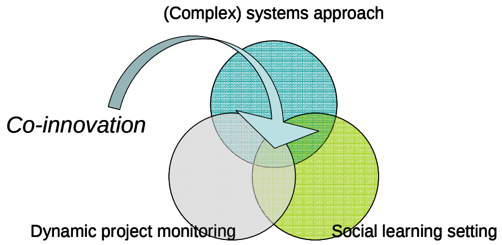

Fig. 1. The three knowledge domains of EULACIAS; co-innovation at the intersection.

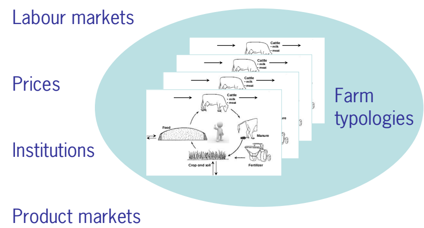

Fig. 2. Components of the complex adaptive farming systems in EULACIAS.

FLEXIBLE RE-USE OF SYSTEM MODULES FOR WHOLE-FARM AND LANDSCAPE ANALYSIS AND DESIGN WITH MODEL EXPLORER

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INTRODUCTION

Integrated modeling environments are currently seen as important means to overcome obstacles in operational flexibility, quality control and cost-effectiveness of case-based approaches and institutions are investing in their development. At the same time, as researchers we may prefer well-known and highly accessible local tools over institution-wide generic applications even when the latter offer superior features. As yet no conclusions are possible on the critical success factors of modeling environments, as experience is still limited. In this paper we present the Model Explorer environment for local flexible model assembly, using the principles of prototyping. Model Explorer was developed to meet the needs of our work at the farm and landscape levels where we are interested in analysis of current and future land use and landscape configurations. Re-use of existing knowledge is essential as are short turn-around cycles with stakeholders, resulting in software prototyping. We illustrate how working in this way, Model Explorer was used to develop two different models: ROTAT and Landscape IMAGES. We end by discussing the merits of local versus 'global' approaches.

MATERIALS AND METHODS

Models in Model Explorer are constructed around 'kernels', software components that determine the flow of the calculations, such as calling of dynamic simulation models or executing an optimization algorithm. The kernels have a number of 'slots' to which one or more primary calculation components of a predefined type can be coupled. The selection of a kernel and the linking of primary components is done by dragging-and-dropping, so that alternative model configurations can be constructed rapidly. The kernels are typically problem-specific; primary components are often re-used among kernels. The relations between software components and input and output files (and queries of parts of these files) are documented. If a component is added to a model, also the relevant files become linked to the model and can be viewed in the Model Explorer.

ROTAT is a procedure developed to generate crop rotations from a list of candidate crops for the purpose of strategic studies (Dogliotti et al. 2003). It uses agronomic filters to eliminate crop rotations which are infeasible or undesirable. The filters concern the crop level, with checks such as the period since last occurrence and the acceptability of the crop succession, as well as the rotation level with checks such as crop and crop group frequencies. The ROTAT rotations are input for evaluation procedures to assess their performance in terms of e.g. yield, organic matter and erosion. ROTAT was re-programmed in Model Explorer as ROTAT+, resulting in a kernel with crop and rotation filters, and with evaluation modules for crop yield, soil organic matter and erosion as the primary components. A project with vegetable growers necessitated a tool, which would take into account the simultaneous feasibility of the cropping plan (i.e. the crops occurring simultaneously on a farm) and the crop sequence over a period of 1-4 years to assist in the complex planning of production on 10 fields and more. The new questions about feasibility of crop occurrences in time and space led to abandonment of the concept of rotation in favor of crop sequences and a rolling planning horizon. A new kernel was developed largely based on the ROTAT+ kernel, denoted as Farm STEPS. The software components describing the crop level filters and the evaluation modules were re-used. New primary components were developed to account for agronomic constraints across the cropping plan, such as maximum and minimum areas for each crop in relation to market opportunities.

Landscape IMAGES (Groot et al. 2007) was developed in Model Explorer to allow a spatially explicit assessment of indicators at field, farm and landscape levels. The approach was developed in prototyping cycles with an NGO. The first kernel combined multi-objective optimization based on Evolutionary Strategies with spatially explicit analysis and representation. Indicators were developed for agronomic (production levels at field scale), economic (field, farm ad regional gross margins) and environmental (botanic biodiversity) performance. The result was presented to the NGO in several workshops. The interaction prompted a re-orientation of the choice of indicators as the NGO's practice was more focused on the landscape level and less on agricultural aspects. Due to the agreement of the type of analysis that needed to be done, the kernel could be retained and attention was focused on development of indicators that described landscape quality and ecological performance.

RESULTS AND DISCUSSION

Fig. 1 summarizes the construction of models in the two projects, indicating reuse of previously developed components. Experience in the projects demonstrated the need to minimize the duration of a software-development - user-validation cycle to allow multiple cycles during the project to maintain user interest and output salience. Software development necessitated labor division between agronomists and software engineers. However, the local implementation of Model Explorer ensured a common focus, allowed both disciplines to become part of the team and to respond flexibly to changing project objectives. The relative isolation of a local modeling environment can be overcome by creating primary components such that exchange with other environments is possible. We argue that attention for the aspect of exchangeability will provide synergy to local innovativeness and global re-use.

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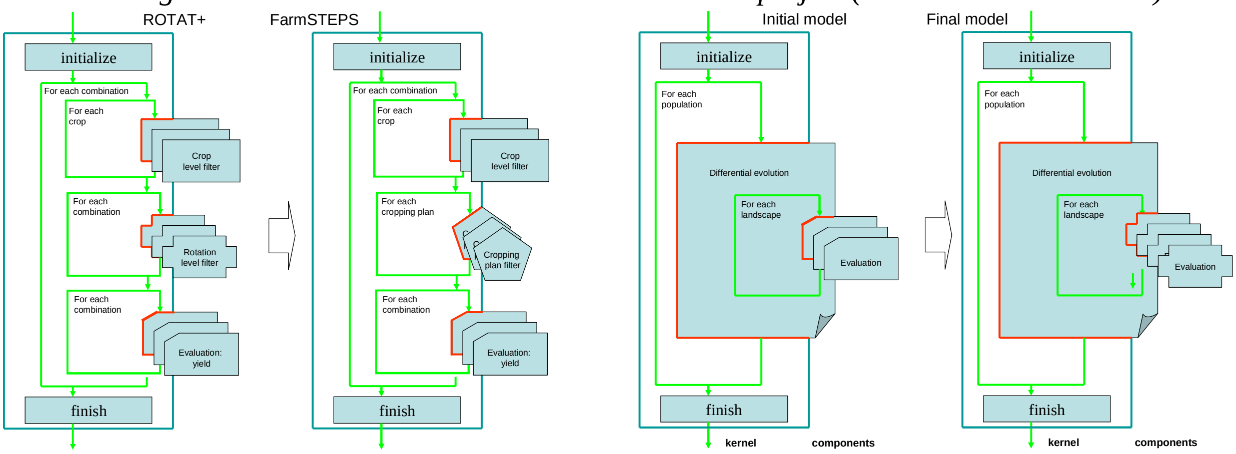

a. **b.**

Fig. 1. Illustration of development and re-use of primary components (a and b) and kernels (b) in Model Explorer. a. From ROTAT+ to FarmSTEPS. b. From one set of objectives to the next in Landscape IMAGES.

CHANGES IN *HELIANTHUS TUBEROSUS* PHENOLOGY AND PLANT ARCHITECTURE FOR THE SUSTAINABLE INTEGRATION OF BIOENERGY CROPS IN CURRENT FARMING SYSTEMS IN CENTRAL ITALY

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The inclusion of energy crops in farming systems of Central Italy and elsewhere is an opportunity for farmers to increase the efficiency of agricultural inputs, and reduce emissions of potential greenhouse gases. *H. tuberosus* L. (*Ht*) is being explored in different part of Europe and Central Italy regions as an alternative to maize or sugar-beet cropping systems in either the crop rotation with winter cereals or in their continuous cropping system, aiming at sustainable transition from first to second generation biofuel technologies. The efficiency of stalk and tuber biomass production depends, among other factors, on plant density and water resources supply. Plant density is related to the clone genotype for plant architecture (PA), and the use efficiency of water resources supply is connected to the rainfall pattern during critical *Ht* crop phenological phases (PP) during the cropping season. *Ht* clones expressing new PA and PP patterns were selected to explore a range of farm production environments in the Latium region, differing mainly air temperature-rainfall regime.

METHODOLOGY

In 2008, four new *Ht* clones selected from ortet rose from half-sib progenies obtained after open pollination of the parental clones K8, D19, Violetto di Rennes and Clone Ungheria (CU3B). The clones were: K8HS142 (C_1), D19HS2 (C_2), VR1 (C_3) and CU3B (C_4). They were planted in the farm of University of Tuscia, Viterbo, according to a randomized block field design with 3 replicates. The traits recorded at the proper growing stage were: stalk height; PA "columnar or monostalk" (M) and "branched or multistalk" (B); date of beginning of tuber-forming phase (btf); date of tuber physiological maturity (tpm); plant dry matter; tuber Harvest Index (HI_t); stalks Harvest Index (HI_s). Btf and tpm were used to obtain the phenological heuristic measurements of the Growing degree days (GDD-btf and GDD-tpm with T_{base} set to 10 °C). Using survey data, the farm of the Latium region were grouped according to four edaphic-rainfall pattern combinations: (A) light soil and no limitation to water supply from rainfall; (B) heavy soil and no limitation of water supply from rainfall; (C) light soil with limitation of water supply from rainfall; and (D) heavy soil and limitation of water supply from rainfall. Thermo-pluviometric and soil patterns registered for 38, 60 and 27 years, respectively, in farms at Todi (lat 12°24'N, lon 42°46'E, alt 630 m asl), Viterbo (lat 12°6'N, lon 42°25'E, alt. 350 m asl) and Maccarese lithoral area (lat 12°12'N, lon 41°52'E, alt. 4 m asl), embody three of the four listed edaphic-rainfall configurations. Water requirement (ΣETc) for each *Ht* clones grown at Viterbo was estimated according to Allen *et al.* (1998). The estimated water requirement was used to detect the water balance that should have occurred for each *Ht* clone if the rainfall pattern fitted the multiyear rainfall averages detected at the three mentioned localities during the periods corresponding to "planting to btf" (M_b) and "planting to tpm" (M_t).

RESULTS AND DISCUSSION

The clones C_1 and C_2, both displayed "columnar" PA and late (the former) or medium-late (the second) btf. C_3 exhibited "branched" PA and earlier btf which is apt for stem biomass production. C_4 showed a "branched" PA and mild-late btf and tpm. C_1 clone produced the highest quantity of dry matter per plant, 68% of which was accounted by the tuber component (Table 1), but required about 1305 GDD for btf and 1907 for tpm. C_3 has also an high proportion of dry matter partitioned to the tubers but require less GDD and water up to btf. The lowest total dry matter per plant of C_2 and C_4 is related to their lower GDD requirement up to btf, and about 40% of their plant dry matter is partitioned to the stalks. Over 90% of the total *Ht* water requirement from "planting to tpm" should have been replenished, for at least 30 out of 38 years, if the rainfall pattern was as in Todi (Table 2). In 40 out of 60 years the restoration of water requirement by rainfall should have been balanced for 80-90% during "planting to btf" at Viterbo, and clones for stalk dry matter production, such as C_4 and C_2, should have been favoured, although C_2 would perform better at high plant density due to its "columnar" PA. These two clones are the most suitable for stalk dry matter production under Viterbo and Maccarese water regime if 15% to 40%, respectively, of the water requirement can be replenished by irrigation. In the absence of irrigating facilities, C_1 for high tuber dry matter should be favoured under the Todi's rainfall pattern where 92% of the water requirement in the period "planting to tpm" is restorable by rainfall. The water requirement of C_3, whose attitude is for tuber dry matter production, could be fulfilled for 80% only in the highest rainfall area of Todi.

CONCLUSIONS

The clones C_1 and C_2, both displaying "columnar" PA, have different biomass partitioning feature: 68% tuber and 21% stalks, the former, and 47% tubers and 41% stalks, the latter. C_1 is suitable under rainfed condition such as those in Todi, while in the other areas supplemental irrigation water is necessary. In the same water regimes C_2 is expected to perform well for stalk dry matter production at higher planting densities. However, at low planting densities C_4 is expected to give the highest stalk dry matter production. C_3 has attitude to store 62% dry matter in tubers but in the examined environments it should be preferred to C_1 when earlier tuber harvest is desired.

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TABLE 1. Main agro-ecological characteristics measured for the four *Ht* clones analysed.

Clone	PA	Stalk height (cm)	Plant dry matter (g)	HI_s	HI_t	GDD btf (°C)	GDD tpm (°C)	ΣETc btf (mm)	ΣETc tpm (mm)
C_1	M	250.0ns	605.1c	0.41a	0.47b	870.4	1751.9	231.0	559.7
C_2	M	214.0ns	1596.5a	0.21c	0.68a	1305.5	1907.2	312.5	545.8
C_3	B	236.5ns	966.0bc	0.31b	0.62a	393.2	1890.0	137.1	691.9
C_4	B	241.5ns	1067.3b	0.40a	0.47b	605.1	1888.6	178.2	647.8

In each of the first four column the multiple mean comparison based on LSD is reported; means followed by the same letter are not significantly different at P=0.05; ns: not significant.

TABLE 2. Percentage and standard error for the water requirement balanced by rainfall (WRbr) until btf (Mb) or tpm (Mt), and years with full WRbr until btf (Y_b) or tpm (Y_t), if the four *Ht* clones were grown in Todi, Viterbo and Maccarese.

Site	Todi (38 years)				Viterbo (60 years)				Maccarese (27 years)			
Clone	M_b (%)	Y_b (n.)	M_t (%)	Y_t (n.)	M_b (%)	Y_b (n.)	M_t (%)	Y_t (n.)	M_b (%)	Y_b (n.)	M_t (%)	Y_t (n.)
C_1	93±2.0	24	82±2.6	14	84±2.8	28	66±3.2	11	61±4.7	2	41±3.9	0
C_2	89±2.4	21	92±2.8	21	78±3.0	15	77±3.2	21	49±5.2	0	52±3.5	1
C_3	98±1.1	35	81±2.1	11	90±2.5	40	64±3.3	6	73±3.9	9	40±4.5	0
C_4	97±1.3	31	89±3.0	14	90±2.4	41	82±2.2	16	70±4.6	8	79±3.4	7

A FRAMEWORK FOR EVALUATING FARM WATER USE EFFICIENCY IN RAINFED GRAIN AND MIXED FARMING SYSTEMS

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INTRODUCTION

The performance of rainfed agricultural production systems in arid and semi-arid zones is regularly limited by water supply. A fundamental objective in these systems is to maximise the efficiency with which rainfall is captured and then used by plants to produce biomass, harvestable plant and animal products and, in market-based systems, economic profit. Indices of water use efficiency (WUE) are useful to help characterise and benchmark the performance of production systems and identify opportunities for improvement. A number of WUE (or rainfall/precipitation use efficiency) indices have been proposed at crop (French & Schultz 1984, Rodriguez & Sadras 2007) and cropping system scales (Farahani et al., 1998, Routley, 2007). The use of many of these indicators can be limited by onerous data collection requirements, the spatial and temporal scales over which they apply and a lack of context-specific benchmarks for assessing performance. There has been little attempt to develop indices that cater for systems that include fodder and animal production components. An understanding of the processes involved in the transformation of rainfall to production system outputs will aid the development of useful indices and appropriate intervention to improve performance.

WUE FRAMEWORK

We propose a simple conceptual framework (Fig 1) to describe the flows of water, biomass, (including harvestable product, surface and soil biomass and greenhouse gasses), and money in grain and mixed grain and livestock production systems. The framework identifies the key transformations (solid arrows) and inefficiencies or losses (dashed arrows) that occur in the pathway between rainfall, primary productivity and profit. The losses may have negative (eg runoff, drainage), neutral (eg soil evaporation) or positive (eg surface biomass, soil carbon) implications for other aspects of systems performance, nevertheless they each represent a reduction in productivity measured in terms of output of plant or animal product, or profit.

Conversion or efficiency factors can be derived as ratios between various components of the framework. Key first order efficiency factors are highlighted in Fig 1 (eg *f* : shoot biomass transpiration efficiency, *f4*: rain harvest index) and higher order efficiency factors can be calculated to suit the requirements of particular analyses. The framework presented is applicable at a range of temporal (single crop to multiple year crop sequences) and spatial (point to whole farm) scales.

INDICATORS AND APPLICATION OF THE FRAMEWORK

We conducted a simulation experiment using the APSIM cropping systems simulation modelling platform (Keating et al., 2003) to illustrate the application of the framework and the derivation of WUE indicators. Factorial combinations of two cropping intensities (implemented as different stored soil water planting thresholds), two cropping sequences (continuous sorghum and a flexible wheat/sorghum rotation) and two soil types (black vertosol, low and high plant available water capacity) were simulated over 100 years of climate records for an opportunity cropping system at Emerald in north eastern Australia. Grain yield and water balance outputs were used to calculate the water use efficiency indices Proportion of Rainfall Transpired and Grain Rainfall Use Efficiency (quotient of total grain yield and rainfall) over the period simulated. Typical crop and input prices were applied to calculate gross margins for each treatment and a $ Rainfall Use Efficiency index was calculated as the quotient of total gross margin and total rainfall. All indices of WUE were higher for higher cropping intensity, high PAWC soils and more diverse crop sequences (Table 1). Modelled Grain Rainfall Use Efficiencies are consistent with values measured on well managed farming enterprises in the same region (3.6 – 4.8 kg/ha/mm rainfall) (Routley, 2007). The close linear relationship between the indices (Fig 2) suggests that both the biophysical and economic performance of rainfed cropping systems is dependant on maximising the proportion of rainfall used for plant transpiration, as suggested by Farahani et al., (1998).

CONCLUSION

The WUE framework presented helps identify the key transformations and sources of inefficiency inherent in the capture and utilisation of the most limiting resource in rainfed grain and mixed farming systems. An understanding of these processes and their interaction with environmental, management and genetic variables will help in the design of more efficient production systems.

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Table 1. Effect of soil properties and management practices on WUE indices at Emerald, Australia

Cropping Intensity	PAWC	Rotation	Proportion of Rainfall Transpired	Grain Rainfall use efficiency	$ Rainfall use efficiency
			%	kg/ha/mm	$GM/ha/mm
High	120	S	0.16	3.03	0.18
		WS	0.22	3.54	0.31
	180	S	0.29	5.81	0.68
		WS	0.33	6.35	0.83
Low	120	S	0.10	1.97	0.02
		WS	0.16	2.50	0.16
	180	S	0.26	5.42	0.66
		WS	0.28	5.17	0.72

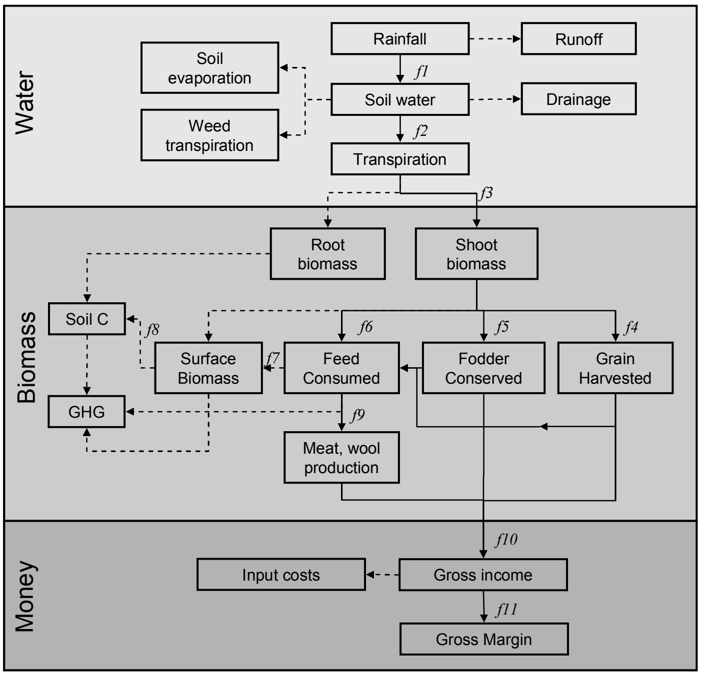

Figure 1. Conceptual framework for WUE

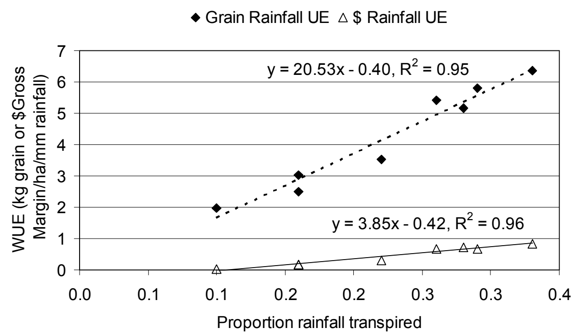

Fig 2. Relationship between WUE indicators

EFFECT OF HIGH TEMPERATURE STRESS IN DIFFERENT PERIODS OF THE GROWING SEASON ON POTATO PLANT DEVELOPMENT AND YIELD

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INTRODUCTION

The potato has specific temperature requirements and develops best at a temperature of about 20°C. Experiments in growth chambers have revealed that haulm growth is fastest at a temperature of about 25°C, whereas the optimal for tuberization and tuber growth is 15-20°C (Bodlaender, 1963). In connection with global warming projections, the problem of tolerance of potato cultivars to high-temperature and drought stresses during the growing season has increased in recent times (Rykaczewska, 2004d; Haverkort, 2008). Research on this topic has already been carried out in Poland, but only two cultivars were implemented (Rykaczewska, 2004 a,b,c). It was found that the stress of high temperature during the post-tuberization period, affecting the plants under favorable conditions of soil humidity, caused an acceleration of maturation of the plants, but after the end of the thermal stress – their secondary growth. Both types of stresses, high temperature and drought, operating simultaneously, were the cause of yield reduction by about half and numerous physiological defects of tubers, particularly their germination in the soil. Seemingly the mildest, because of causing only a 25% decrease in yield, high-temperature stress acting on the plant under favorable humidity conditions was practically the most harmful, because of the extent of the physiological defects in tubers of up to 60% of the total harvest. High temperature stress during the growing season was also the cause of the deterioration in seed value (Rykaczewska, 2004c).

The purpose of the subsequent studies presented here in part is to determine the response of selected potato cultivars to high temperature stress at different times during the growing season, in drought conditions and at the right soil humidity.

MATERIALS AND METHODS

The pot experiment in the growth chamber and in the greenhouse was carried out in 2008 and is continued in 2009 in the Plant Breeding and Acclimatization Institute, in the Department of Potato Agronomy.

The following factors are tested:

1. Cultivars: five Polish (Iris - very early, Cyprian - early, Adam, Irga, Zebra - early middle) and one American (Katahdin - one of the most tolerant to environmental stresses)
2. Three periods of high temperature stress: June 16-30, July 1-15 and July 16-30
3. Two kinds of high temperature stress (day/night 30/25°C): under drought conditions and at favorable humidity of the soil.

The control plants were growing under conditions close to optimal.

The response of the selected potato cultivars to the high temperature stress at different times of the growing season was evaluated on the basis of the ability of plants to regeneration, the possibility of further growth and tuberization, the presence of physiological defects in the final yield and the changes in the yield structure. The response of plants to regeneration was assessed *in vivo*, using chlorophyll-*a* fluorescence technique with Fluorimeter Pocket-PEA Hansatech Instruments Company (UK) for the purpose of determining the maximum quantum efficiency (Fv / Fm) of photosystem II and the vitality index (PI) (Strasser et al., 2001).

RESULTS AND DISCUSSION

After the first year of the study, it was found that the choice of the Polish cultivars was appropriate, and the inclusion of the American cultivar Katahdin fully justified. In a European database, which includes 3,711 cultivars of potato from 48 countries, there is little data on the physiological characteristics of the cultivars and their response to environmental stresses, but the American variety Katahdin is described as a genotype with a very high adaptability to the environment (Anonymus, 2007). The final yield of the tested cultivars in the control combination was high and averaged 1,594 g / plant, with the cultivar Irga characterized by the highest yield (1,715 g / plant). The date of high-temperature stress was highly important for further development and yielding of potato plants. The most damaging was the stress occurring early, in the second half of June. The decrease in yield in this period amounted to 40% when heat stress was combined with drought stress. As time passed, the negative effect of high temperature decreased. The impact of high temperature under favorable soil moisture conditions manifested itself in the formation of tubers that were chronologically and physiologically younger, which means that at the time of the final harvest they were immature. The tested cultivars showed a varied response. The highest tolerance to heat stress was clearly exhibited by the American cv. Katahdin and the Polish cv. Zebra. The assessment of the usefulness of chlorophyll-*a* fluorescence techniques for evaluating the cultivars in terms of the variations in tolerance to environmental stress will be made after the completion of the second year of studies.

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INTEGRATED ASSESSMENT OF THE POTATO FARMING SYSTEM IN POLAND

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INTRODUCTION

Some models of crop growth indicate that calculated productivity levels are strongly correlated with a few environmental factors representing local weather and soil conditions. However, statistical relationships are not very useful when dealing with changes in agricultural management practices or changes in climate. Nor are they of much use when there have been fundamental transformations in the economic and political systems of a state. It is precisely such changes that potato production in Poland has been subject to. After the Second World War, the largest total land area under potato cultivation was recorded in the years 1960-1969. In the 1980s, the total land area under potato cultivation in Poland was still more than 2 million hectares, representing about 16% of total sown area. Potato production was then on a level of 36 million tons annually. The transition from the centrally-controlled to a market-driven economy in 1989 resulted in major changes in Polish agriculture. The land area under potato cultivation started to decrease steadily (CSO, 2007). After accession to the European Union in 2004, most other crop plants have been covered with a wider scope of financial support than the potato. Consequently, this has contributed to a further reduction in potato cultivation area in favor of cereals, legumes and oilseed plants. According to the latest figures, the area of land under potato cultivation in Poland is only 549 thousand hectares and its share in the structure of sown area has decreased to 4.7% (CSO, 2007). Potato production in 2008 reached 10.4 million tons and still exceeds the market capacity and consumption needs (Potato Market, 2008). However, the potato still remains a strategic crop plant in Polish agriculture, because of its nutritional value, its usefulness as a raw material for food processing, and due to the important role that it plays in crop rotation.

The purpose of the work, besides the assessment of actual potato farming system in Poland, is to use results of modeling study for innovation in design and construction of potato crop production systems.

MATERIALS AND METHODS

The study in the field of modeling for innovation of potato crop production system, conducted in Plant Breeding and Acclimatization Institute, in Jadwisin, are presented on the basis of selected publications (Mazurczyk et al. 2007; Heidmann et al. 2008). Polish scientists have been involved in creating a model for a potato crop growth using information from across Europe (Heidmann et al. 2008). In the FertOrgaNic EU project, 3 years of field experiments with drip irrigation and fertigation were carried out during 2003-2005, involving seven different varieties of potato. The Daisy model, which simulates plant growth together with water and nitrogen dynamics, was used. An initial potato parameterization was generated from an independent dataset and was used for site-specific calibration.

RESULTS AND DISCUSSION

The information from the site-specific calibration was combined into a common parameterization of potato growth. This common parameterization serves as a platform for adaptation of the Daisy model to new potato varieties or for improvement of the existing parameter set (Heidmann et al. 2008). The Daisy model was also used in other work which covered three potato cultivation systems: conventional, pro-ecological and integrated ((Mazurczyk et al. 2007). The results show that manure with proper irrigation ensured the highest potato tuber yields in all system tested. The irrigation method used (simple balance and decision support system: DSS) eliminated water stress during the potato vegetation period with total application of about 110 mm of irrigation water. The Daisy model with the 'Triada Potato' calibration facilitated the simulation of potato yields for the conventional cultivation system of this crop in Plant Breeding and Acclimatization Institute in Jadwisin.

This work in progress requires further improvement as the implementation of the model in Poland is complicated by the fragmentation of agricultural farms, including potato farms (Tab.1, Fig.1) (CSO, 2007; Potato Market, 2008). The number of farms in Poland is about 2 476 thousand, which represents 17.1% of all the farms across the European Union (27). Most of them are farms on less than 5 ha of land, of which the potato field usually occupies less than 1 ha. The current state policy aims at consolidation the area of agricultural holdings, but this is expected to be a long-term process.

The modeling effort can contribute to positive changes in the potato farming system in Poland.

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Table 1.

Farms by area groups of agricultural land in European Union and in Poland

Countries	Total in thousand	Farms by area groups in %			
		< 5 ha	5 - 20	20 -50	> 50 ha
EU (15)	5 843	54,6	23,6	11,3	10,5
EU (27)	14 479	71,5	18,0	5,7	4,8
Poland	2 476	70,7	24,6	3,9	0,8

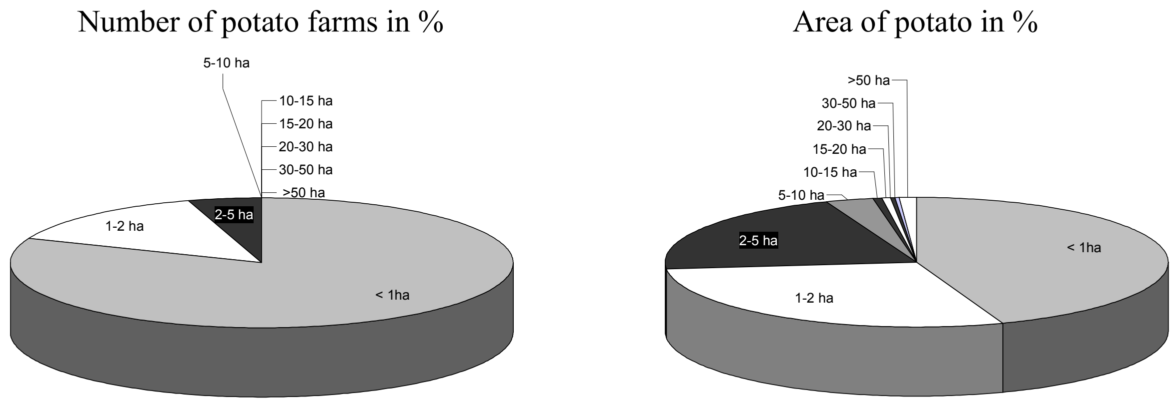

Fig.1. Potato farms in Poland depending on the area.

EXPLORING AGRICULTURAL PRODUCTION SYSTEMS AND THEIR FUNDAMENTAL COMPONENTS WITH DYNAMIC MODELING

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INTRODUCTION

Agricultural production systems are undergoing rapid changes in response to changes in production expenses, consumer demands, and increasing concerns for food safety, security, and environmental impact. Future production systems and management practices need to be designed taking these concerns into account (Hanson *et al.*, 2008).

The Integrated Agricultural Systems Workgroup is examining the US agricultural production system in detail. Key drivers impacting production systems can be delineated into four areas: economic; social/political, environmental and technological. These key drivers interact to form production systems with unique regional characteristics, and have resulted in the development of four predominant production systems in the US today (Hendrickson *et al.*, 2008).

Here, we use qualitative and quantitative indices of three predominant production systems (row crops, extensive livestock, and integrated crop/livestock) to explore the relative sustainability of the production systems. Using a dynamic modeling environment, we explore whether integrated systems are more sustainable than conventional systems. Our measures of sustainability are indices of economy, environment, and social welfare.

MATERIALS AND METHODS

A model was developed in STELLA (isee systems, Lebanon, NH). The model has six sectors: crop production, herd size, animal diet, economics, environmental quality, and social quality. Interaction between the crop and animal production components was realized through grazing of forage, which reduced the need for supplemental animal feed, and use of manure for crop fertilization, which reduced fertilizer requirements and improved soil quality. Indicators are used to determine the relative output of the model. Wealth is used as the economic indicator and is calculated as net return on investment, less all costs of production. This is also an important social indicator, as production must return sufficient income to support the farming enterprise and the farm family. Social quality is defined as the leisure time appropriated to the producer. Increasing labor reduces the flexibility of the farmer to spend time on leisure pursuits. External social quality is determined as net protein produced per acre, representing societal concern for adequate food quantity and quality. Environmental indices include SCI (Soil Conditioning Index); N and P indices, representing excess fertilization; and manure, which is animal waste produced in excess of that which can be used on-farm.

The model was initially parameterized with information from the upper Midwest, for three crops (corn, soybeans and wheat) and one animal system (cow/calf). Simulations were run for a farm of 1200 acres. For crop only, the acreage was evenly divided between corn, soybeans and spring wheat. Extensive livestock had 1200 ac grazing land for the cattle herd. For the integrated crop/livestock simulation, 600 acres was dedicated to grazing lands, and the remaining 600 was equally divided between the three crops. The model simulates production over 100 years. Each simulation was performed 100 times, and the output averaged. For stocks that accumulated (wealth and manure), the yearly production was averaged. The average values for each index were then normalized for comparison.

RESULTS AND DISCUSSION

Economic return is one of the key drivers impacting agricultural production. The production system with the highest return was the integrated system with both crop and livestock (Figure 1). This system also had the lowest labor index, though was intermediate in protein production. Because of the large amount of grazing acreage devoted to livestock, the net protein production on an acre basis decreased with increasing animal production. The animal system had the most negative environmental index, primarily due to the production of manure. The integrated system had a slightly improved environmental index due to improved SCI.

The model gives us the opportunity to explore interactions within various production systems, and determine the relative impact of management inputs on indices. This information can be used to develop more economically, environmentally and socially acceptable production systems. As measured by the indices used here, integrated crop-livestock systems are more sustainable than single enterprise systems consisting of crops alone or livestock alone. Examination of production systems for other regions of the US will be performed to compare relative economic, environmental, and social impacts of management decisions and degree of integration.

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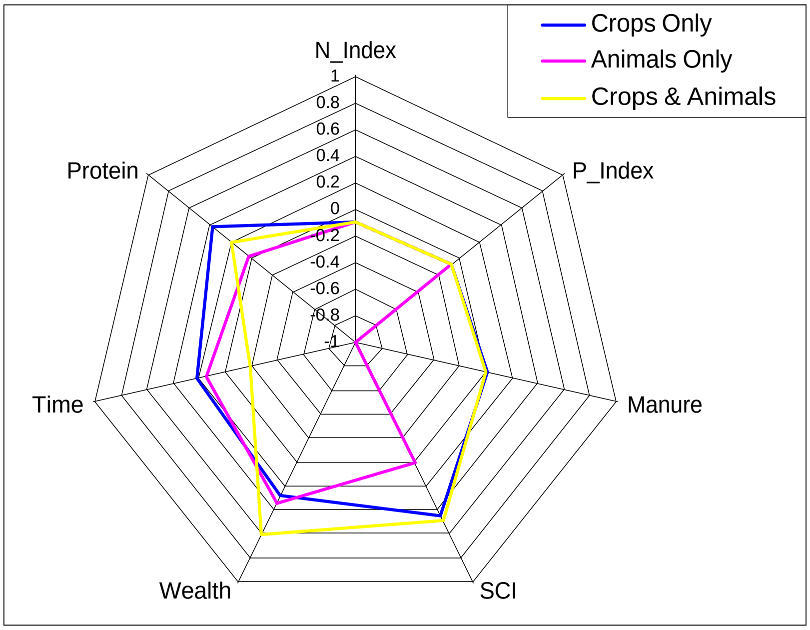
Figure 1. Radial plot of indices calculated from three production systems. Each index is the normalized average of 100 years from 100 independent simulations.



DIVERSITY OF FARMERS' ADAPTATION TO A NEW CONTEXT OF IRRIGATION RESTRICTIONS: CONSEQUENCES ON GRASSLAND AREAS DEVELOPMENT

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INTRODUCTION

The French region "Niort Plain" has recently undergone several periods of drought. This situation has led both arable and cattle farmers to develop irrigation, especially when growing corn (Lemaire and Pflimlin, 2007). Corn yields are indeed very likely to be high for both grain and forage and yet they strongly decrease under water stress. Thus, due to recurrent droughts and the shallow soils prevalent in this region, irrigation is a necessity for farmers choosing corn. This extension of irrigation has resulted in a decrease in grassland areas, contributing to a decline in patrimonial birds populations. Since 2000, local authorities have tried to limit agricultural irrigation and to preserve water resources for other purposes. In this paper, we focus on the adaptations that the farmers have developed to cope with this new context. We also analyse the impacts of these adaptations on the extent of grassland areas, considering all farming systems, whatever function these grassland areas may have on the farm (mainly set aside area for arable farms and forage for livestock farms).

MATERIALS AND METHODS

The study was carried out between 2005 and 2007, which corresponds to the setting up of the new European Common Agricultural Policy (CAP) (Le Gall *et al.*, 2005). Over this period, we investigated the different farming systems that we had identified with the help of the national agricultural census. A total of 83 interviews were conducted in the region in order to collect information about structural and operating components of farming systems: soil characteristics, cropping systems and grassland areas, livestock, labor force, farm buildings and agricultural machinery. We also took the farm history and its socio-economical context into account. All this collected data was then organised according to a scheme based on the farmer's global project (Capillon, 1993). In addition, we paid particular attention to the different farm type adaptations to drought constraints, and the impacts of these adaptations on the use of grassland areas and their extent on farms.

RESULTS AND DISCUSSION

Our results led to a typology based on both the adaptation of the local farm systems to drought and changes in grass areas. We distinguished 5 types of arable farms, 4 types of dairy cattle farms (Havet *et al.*, 2007), 3 types of goat farms and 6 types of beef farms. In this paper, we focus on the arable and dairy farms which grow one common crop: corn (*Zea mays*). The forage system in dairy farms is indeed based mainly on corn silage in this region, while corn is also grown for grain on arable farms. Confronting the same issue, the farms differed extensively in their forms of adaptation.

Results showed that: 1) the largest arable farms, with usable farm area (UFA) above 250 ha specialized in irrigated corn for grain, maintained irrigation by developing artificial ponds with expensive plastic sheeting systems. Since these ponds are filled in winter and not connected to ground water or rivers, they do not suffer irrigation shortage due to administrative restrictions. The smallest fields of these arable farms have all been dedicated to set aside (according to CAP requirements) with long term grass areas, which also reduces work constraints during the irrigation period. 2) Smaller arable farms (UFA<150 ha) have no access to the costly pond systems. When faced by irrigation bans they thus reduced their irrigated corn areas. To guarantee their income, most farmers have cultivated set aside areas with oil seed rape dedicated to bio-fuel. Very few set aside areas have been left covered with grass. 3) Dairy farms with deeper soils have restricted their corn production to dry corn silage, abandoned irrigated grain corn and kept grassland areas unchanged. They may have partially increased when farmers replaced intercropping grass areas (sown after summer harvests and harvested before spring sowings) by temporary grasslands. 4) Dairy farms with previously irrigated shallow soils have dropped irrigated silage corn areas and have partly developed new irrigated grassland areas: the amount of water and the early period when they can use it are more profitable for grassland compared to corn (a water deficiency during flowering period results in a decrease of 50% or more in the final corn yield). 5) Dairy farms with shallow soils and no irrigation devices made no changes to their systems due to drought and irrigation bans. They continued growing more corn silage than the minimum necessary for cows on average years to secure the herd's forage needs. Grasslands remained unchanged.

Droughts had no real consequences for the larger arable farms (1) equipped with artificial ponds for irrigation. Grass areas on set aside fields remained the same. On the contrary, smaller irrigated farms with no access to ponds developed industrial set asides (oil seed rape dedicated to bio-fuel) replacing long term grass covers (2). For dairy farms with irrigation or large proportions of deep soils, the general trends after droughts showed a limitation of corn areas (3, 4) and a maintenance (3) or even extension (4) of grassland areas. Dairy farms with no irrigation and shallow soils (5) have continued growing corn without any consequences to grassland areas. After the last severe drought in 2005, the increase in agricultural prices (2007-2008) was crucial for farmers' choices. On the one hand, those who decided to keep a system based on water demanding crops bet that there would be no more irrigation ban. As no drought has occurred since 2005, these farmers won their bet and grassland areas stopped their increase in this case. On the other hand, some dairy farms chose a strategy of limited feed purchase (even if it may lead to a decrease in milk production per cow) which resulted in an increase in grassland areas. In 2009, agricultural prices dramatically decreased (by 30%), due partly to the worldwide economic crisis. At the same time, the European commission decided to cancel the set aside obligation for farmers. As a consequence, these new elements may lead to another decrease in grassland areas in the Niort Plain. Further research would be needed to assess this potential reduction of grasslands, representing a real threat for local biodiversity protection.

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MAPPING FARMERS' DIVERSITY OF GRASSLAND MANAGEMENT FOR BIODIVERSITY PRESERVATION AT THE REGIONAL SCALE

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INTRODUCTION

The negative environmental impacts of agriculture have been increasingly brought under question over the past 20 years (water pollution, landscape standardization, biodiversity crisis, etc.). All over Europe, many bird species have indeed regressed in agricultural landscapes. In the southern west French region "Niort Plain", Bretagnolle (2004) showed that the intensification in cereal cropping at the expense of extensive grassland areas has resulted in a severe decline in patrimonial bird populations explained by a reduction in habitat heterogeneity (Benton *et al.*, 2003). The link between grassland extension in cereal areas and biodiversity preservation has thus been generally accepted, which has contributed to the setting up of environmental public policies promoting grasslands (specific individual contracts in the Niort Plain or national support for grazier breeding and pastures since winter 2009). While grasslands are mostly associated with livestock farms as pastures or harvested forages, they also exist in arable farms as set-aside areas. At the same time, the CAP has recently ended the obligation of 10% set-aside on farms. Hence, it seems possible that this measure would cause a drop in grass set-aside and in grasslands.

In order to consider the potentially contrasted effects of these environmental policies, one needs to investigate the different grassland uses on arable and mixed crop-livestock farms and their spatial variability. We propose here to map the variability of grassland uses at the regional scale of the Niort Plain and to study specifically the contribution of grass set-aside in total grasslands. We finish by discussing the possible consequences it will have on future grassland extension.

MATERIALS AND METHODS

We chose the region "Niort Plain" since it represents crucial area for both biodiversity ("Natura 2000" zone for specific protection) and agricultural dynamics: previous studies based on farmer interviews and CAP data-base exploration (PACAGE 2003 with animal data) have shown that farms are specializing in crops, which is leading to a decline in breeding activities (cattle and goat production) and a drop in grassland areas (Bretagnolle, 2004).

To study the extension of grasslands and the variability of their uses, we used here the anonymous and spatially explicit CAP data-base (RPG 2007). It contains different types of land-use information, but no animal data, which makes it impossible to identify farming systems inside the data-base. At plot scale, it provides information about crop (commercial crops, pastures, grass and industrial set-aside areas, etc.), crop area and the farm and village to which it belongs. However, when several crops are grown in the same plot, the limit between crops is not spatially explicit. At farm scale, RPG gives information about area and territory but no information about the farmstead.

Once we had selected all the villages with more than 80% of agricultural area in our study area, we calculated the village cropping plan, the proportion of grasslands in the village agricultural area and the contribution of grass set-aside in the village total grasslands before studying their spatial repartition at the regional level. Using crop proportions instead of crop areas made it possible to avoid the problem of lack of crop localisation in plots while using a village approach facilitated the identification of contrasted zones of grassland management at the regional level.

RESULTS AND DISCUSSION

Comparing maps 1 and 2 (ArcGIS® 9, based on RPG), we observe that the contribution of grass set-aside in total grasslands tends to be low (from 6 to 31%) in villages with a high proportion of total grasslands (up to 38%). Grasslands in such villages (A, B) are mainly used for pastures and forage which lead us to believe that they are breeding zones. This result is consistent with the confrontation to PACAGE data-base showing the contribution of different farming systems in village total grasslands. It indeed portrays that the grasslands in village A are mainly due to dairy cattle farms vs. beef cattle farms in village B. On the opposite, maps 1 and 2 show rather high proportions of grass set-aside in total grasslands (up to 69%) in villages with few total grasslands (7 to 15%, especially in the South West). It clearly suggests that grasslands in this second type of village (C) are not related to pastures or forage, but more likely to the former set-aside obligation. PACAGE data-base confirms this assumption by displaying that the grasslands in villages C are mostly associated with arable farms having different uses of their set-aside areas (grass or biofuels).

On the basis of these results, it now appears that the end of set-aside could cause a drop in grass set-aside in villages type C (inside the Natura 2000 zone) and a consequently significant drop in total grasslands, which could jeopardize patrimonial birds. If these villages are mainly occupied by arable farms, there would indeed be no reason for farmers to keep grass set-aside, perhaps except if the farm area were very high or if grass set-aside valorised non arable areas or low potential soils.

In light of this discussion, we conclude that farming system repartition and grassland management in arable farms seem to play a significant role in grassland extension and biodiversity preservation at the regional scale. As a result, the effects of different environmental measures will be highly contrasted when comparing villages to one another, due to the spatial heterogeneity of farming system repartition and the associated grassland uses. There appear to be two possible ways of supporting grasslands in addition to those in livestock farms: either maintaining grass set-aside on arable farms, or promoting pasture areas on arable farms for more efficient and environmental-friendly complementarities between farming systems at the regional scale (Lemaire, 2007).

In further research, we will need to build a spatially explicit typology of farming systems to study the links between farming system repartition, farm area, land-use choices and grassland management in greater depth. Such research would necessitate identifying farming systems inside RPG beforehand: either on the basis of farmer interviews-based criteria or by combining different data-bases like PACAGE and RPG. Due to an important heterogeneity in data, this perspective will be very challenging from a methodological point of view.

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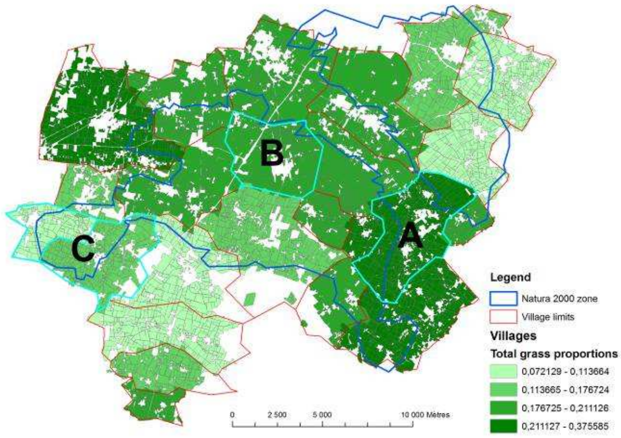
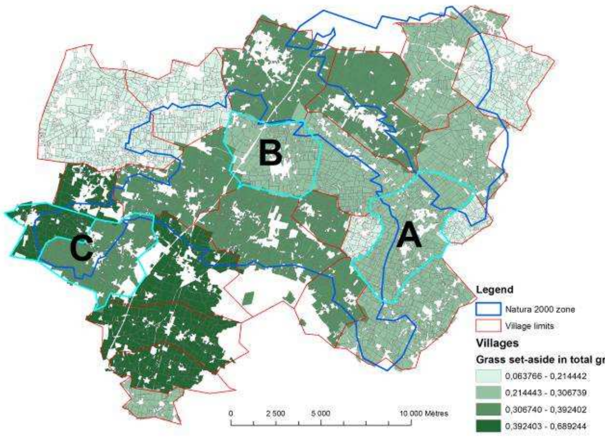
FIGURES AND TABLES



Map 1: Total grass proportion in the village area



Map 2: Proportion of grass set-aside in total village grasslands

DO'S AND DON'TS OF LONG-TERM CROPPING SYSTEMS EXPERIMENTS

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INTRODUCTION

Many lessons in long-term cropping systems research are learned from experience rather than in a university classroom. Even with careful planning, scientists often cannot foresee future opportunities and problems that may arise due to design limitations of their experiments. I have led large-scale, long-term, multidisciplinary cropping systems experiments at university research stations and in farmers' fields for 20 years. Several practical lessons that I have learned through the years are outlined below.

LESSONS LEARNED

1. Form a farmer advisory group of individuals who have a strong vested interest in the research. Allow the farmers and active role in designing cropping systems combinations. Allow farmers to feel ownership in the project and they will likely remain strong supporters throughout the life of the project.
2. Set term limits for farmer advisors (e.g., 3-5 years). Some advisors will make numerous valuable contributions and maintain a high level of interest whereas others will not. Your most valuable advisors will likely agree to serve an additional term(s). Term limits provide a diplomatic means to end the service of the less valuable or less energetic advisors.
3. Your collaborating scientists will largely determine the success of the project. Put a great deal of thought into what academic disciplines will best contribute to the cropping systems team. I am a research agronomist and generally collaborate closely with an agricultural economist, soil microbiologist, and plant pathologist. Look closely at the publication record of experienced scientists. If they have an excellent track record, they will likely continue to publish regularly. Certainly include enthusiastic, young, new career scientists. Avoid experienced scientists with undistinguished publication records, - they are unlikely to change.
4. Involve a statistician from the very first to ensure that the experimental design is valid (Cady, 1991).
5. Plan to conduct the cropping system experiment for at least six years or through two completed cycles of the crop rotations.
6. For valid statistical interpretation of results, all cropping systems treatment combinations must have a common denominator. For example, if you have 2-year, 3-year, and 4-year cropping systems, the experiment needs to be conducted for 12 years.
7. If at all possible, conduct long-term experiments at a university or ARS research station where land and facilities are guaranteed to be available for the long term (Drinkwater, 2002). Mistakes are less likely to happen at a research station than in a cooperating farmer's field. Labor and equipment resources are most efficiently utilized when travel is kept to a minimum. Travel time is down time. In addition, personnel at research stations are available to check the experiment daily, if needed. It costs much less to conduct a cropping systems experiment at a research station versus in a farmer's field.

8. Don't expect a cooperating farmer to use and operate his own equipment to conduct field operations (e.g., planting, harvesting, herbicide application) for long-term experiments. This may be feasible for the first few years, but the farmer needs to conduct his own field operations during the same time period and the experiment will likely be a lower priority for him. Plan to provide your own personnel and preferably your own equipment to ensure that field operations are conducted in a proper and timely manner.
9. Become a trusted friend of your cooperating farmer. Don't become a burden. Pay an annual plot hectarage rental fee. List the cooperating farmer as a co-author on all popular and extension publications from the experiment.
10. If you plan to use commercial size farm equipment, plot length should be a minimum of 100 m.
11. Small-plot field equipment may need to be customized for cropping systems experiments. For example, many experiments involve conservation-till or no-till management. A small-plot combine is accurate for grain yield determination, but most machines lack proper chaff and residue spreading capability. Residue and chaff spreaders can be fabricated for small-plot combines (Schillinger et al., 2008).
12. Be sure to include all phases of all crop rotations every year.
13. Many cropping systems experiments do not contain enough treatments and/or replicates to provide adequate degrees of freedom for error to detect statistically different treatment differences (Cady, 1991). Remember: (t-1) (r-1) = df error.
14. Funding for long-term cropping systems research is often difficult to obtain (and maintain) because answers cannot be obtained within the typical 3-year grant cycle (Soane and Ball, 1998). Even modest set-aside funds from the university experiment station can go a long way in sustaining long-term experiments.
15. Long-term no-till cropping systems experiments provide critically important data on soil quality, carbon sequestration, and nutrient cycling (Richter et al., 2007) that is of interest to a worldwide audience.
16. Publish results in peer-reviewed journals at regular intervals. Decide beforehand which scientist(s) will take the lead on articles and the time frame in which the articles will be written.
17. Be open to new ideas. Although you need to "lock in" and stay with the crops and crop rotations throughout the experiment, there is often opportunity to superimpose new experiments, especially with large-scale cropping systems plots.
18. Long-term experiments are often the building block for long-term friendships among scientists, technicians, graduate students, and farmers.

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CORRELATION OF A MORPHOLOGICAL LEAF MODEL WITH 3D SHEET-OF-LIGHT DATA OF REAL PLANTS

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INTRODUCTION

For the successful breeding of useful plants monitoring of plant growth especially at early growth stages can be an important tool to ensure optimal growth. A 3D-scanning system (Fraunhofer 2007) for field use allows a non-destructive, high-resolution scan of the plant's surface. The measured data can be used to directly derive basic morphological parameters like leaf count and leaf area.

This paper presents an approach to transform 3D-measurement data into a smaller set of easily interpretable parameters of a morphological plant model for plants in early growth stages. The model parameters are determined automatically from a measured plant's data.

DATA ACQUISITION AND PREPROCESSING

In order to acquire the morphological features of a plant, a sheet-of-light (SOL) based approach was used to scan the plant and reconstruct a three-dimensional representation of the scanned surface of the plant. The SOL principle has a limitation though, as parts of the plant that are obscured for any reason can not be scanned. By using an additional camera this effect can be effectively eliminated by fusing the data from the two views. In order to be able to perform the fusion a calibration of the SOL setup must be performed, yielding calibrated coordinate data from each camera which allows a simple merge operation of the height images of all cameras. By adding a color camera and performing an additional calibration, it is possible to reproject the color data algorithmically onto the surface data, yielding a 3D-color representation of the plant. This measurement setup was installed in a portable scanner for use in the field.

MORPHOLOGICAL MODELLING

In order to be able to assess complex plant parameters, a model is required that provides all required information to the evaluation process while at the same time keeping the model as simple as possible. One approach is to utilize knowledge of the typical morphology of a plant. The model plant representation is decomposed into single leaves, each of which is modelled individually. The leaf model is not meant to result in photographic quality image data, but to provide only the information required for health diagnostics. If future diagnostic algorithms required an extension of the plant model, this will certainly be possible.

Each leaf is modelled from B-splines or Bezier curves to generate the surface model. While all of the parameters of each curve have an influence on the geometry of the resulting leaf, they are all dependent on each other. So the parameters of the curves were separated into two categories, primary and secondary parameters. Primary parameters p have a major influence on the leaf's shape, while secondary parameters s only have a minor influence.

CORRELATION OF DATA

A two-stage process was implemented to automatically calculate model parameters from scan data. First, a good initial approximation of the parameter vectors p and s must be determined. Then the parameters are optimized in an iterative process using a distance function. The iterative algorithm minimizes the distance function between model and scan data, yielding a useful approximation of the primary and secondary parameters required to generate surface data similar to the scanned leaf (see Figure 1).

The key to the optimisation is the distance function. Two different distance functions were used alternating in the optimisation. One distance function calculates the difference around the perimeter of the leaf, while the other distance function calculates the distance of the leaf areas.

RESULTS AND DISCUSSION

To verify the modelling process, various primary parameters were observed over a period of 30 days from seeding. The plant was scanned several times over this period of time, and the model parameters were calculated for each scan. The parameter graphs showed the expected properties, e.g. the lamina length parameter showed a steady growth through the period of the experiment.

The morphological modelling of plants from scanned data is a promising approach to objective plant diagnostics. Be it for breeding optimisations or health diagnosis, the possibility to derive key values for important plant features can be a powerful tool. Future work will focus on the inclusion of additional modalities like color, spectroscopic data or X-rays and include the classification of parameter vectors to determine e.g. various plant diseases.

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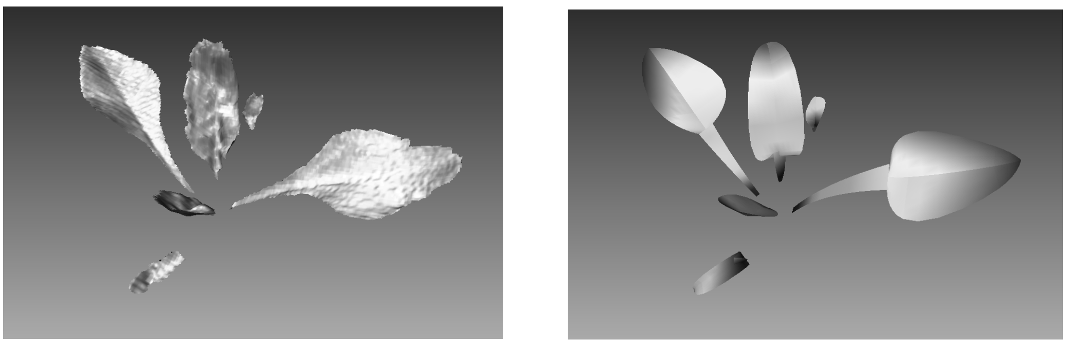

Figure 1: Reconstructed 3D data from scan (left) and model generated from automatically calculated parameters (right)

A NETWORK OF FACT FARMS IS NEEDED TO PROVIDE CREDIBLE EVIDENCE OF SUSTAINABLE AND PROFITABLE FARMING SYSTEMS

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INTRODUCTION

The quest for sustainable and profitable food and fiber production has been an elusive goal for mankind as evidenced by a number of ‘collapses’ of civilizations to date (Diamond, 2005). The consequences of farming system innovations are unlikely to be fully understood without long-term, whole-farm investigations of the interactions of those systems with the environment over time and space. Innovations such as zero tillage, grazing management, agroforestry, managing soil acidity and dryland salinity, etc. require experimentation across a range of agricultural ecosystems and lengthy climatic sequences in order for the general principles to become well understood.

Credible objective evidence of the sustainability of farming systems is needed not only by farmers and modelers but also by consumers who need to be made aware of their role in supporting the sustainability of managed ecosystems upon which food and fiber production depends.

PROBLEM DESCRIPTION

In spite of the ever burgeoning scientific literature there remains a ‘chasm’ between farming practices and research findings. Farming systems research is often conducted by testing relatively simple scenarios that can inadequately represent the complex interactions faced by farmers managing whole farms. As noted by Scott (2003), livestock managers need to cope with as many as 36 factors governing their agricultural ecosystem. Also, the short-term nature of funding for most research projects provides little opportunity for long-term results to be accumulated. For example, a field experiment which aimed to quantify the sustainability of grazed pasture systems (Scott et al., 2000) was conducted on a small area (6 ha) over a period of just 3 years.

A farmer-led research and adoption project, the Cicerone Project (http://www.cicerone.org.au/), attempted to overcome some of the constraints noted above by carrying out a whole-farmlet study of three different management systems on 150 ha of the Northern Tablelands of NSW over a period of 6 years (Scott et al., 2006). This project involved 120 farmer members, staff of several research and extension agencies and four postgraduate students. Experimental measurements were made of a wide array of climate, soil, plant, animal, economic and environmental factors and modeling was carried out in order to examine risk management and optimization strategies. Unfortunately, the results of this project were limited in their applicability as the trial experienced below median soil moisture conditions over all 6 years of the investigation.

PROPOSED SOLUTION: A NETWORK OF FACT FARMS

There is a need to better inform policy makers and consumers of the tension between food production and the maintenance of environmental services (Tilman et al., 2002) over the inter-generational timeframe necessary for assessing sustainability.

Participatory approaches which invite real ‘ownership’ of research investigations result in farmers, researchers and extension specialists developing much greater levels of interest and mutual trust than projects conducted with little farmer contact.

It is proposed that farming systems experiments be conducted as part of a network of long-term ‘fact farms’ located across a range of agroecological regions in order to distil key principles governing the systems. There is a need for common approaches to measuring farm performance and environmental impact (van der Werf and Petit, 2002) and so the use of common experimental protocols is to be encouraged. Modern database and Internet technologies now present an opportunity for databases of experimental findings to be shared within and between nations (Scott, 2008). Benchmarks of the economic, biophysical and environmental performance of the different 'fact farms' could be developed and also be made available via the Internet. Farmers could enter their own benchmark data to compare with relevant 'fact farms' and hence facilitate adoption.

Some suggestions of criteria that might be used when establishing 'fact farms' include:

- Sites representative of agroecological regions, soil types and enterprises.
- Comparisons of system treatments on contiguous land with common soil types.
- Sufficient size of farming system for credibility of results in the eyes of farmers.
- 'Ownership' and engagement by the regional farming community.
- Relevant to all stakeholders (farmers, scientists, extension workers, policy makers, community, etc.).
- All partners require funding support if real participation is to be achieved.
- Recycle income earned from the farming systems trials to provide partial self-funding and allow continuation between funded projects.
- Secure land tenure to allow experimentation to continue over an indefinite period.
- Measurement of sufficient key components of climate, soil, crop/pasture/livestock, financial and environment (e.g. hydrology, greenhouse gases and carbon sequestration) over long time scales.

The great promise offered by increasingly sophisticated models of farming systems will only be met if they are supported by the ongoing accumulation of credible datasets from different agricultural ecosystems across both temporal and spatial scales.

There is a clear need for better integrated knowledge of complex farming system interactions as well as greater adoption of improved practices. Both of these needs can be better met if researchers work more closely with farmers and engage with them to refine questions and test solutions within credible whole-farm investigations conducted as part of a network of 'fact farms'.

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A REVIEW OF THE GRAIN YIELD RESPONSE OF WHEAT FOLLOWING LUPIN, FIELD PEA, CANOLA AND OATS IN WESTERN AUSTRALIA

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INTRODUCTION

Crop production in Western Australia is dominated by wheat. Most farmers devote 30% to 60% of their farm to wheat in any one year. Break crops and pastures have long been a major tool for managing weed and disease build-up in these wheat systems. This study quantifies the benefit break crops provide to wheat and discusses if modern production systems are changing their impact.

MATERIALS AND METHODS

Data was collected from 167 crop sequence experiments located at 61 locations throughout the Western Australian wheatbelt during the period 1974 to 2007 in low (annual < 350 mm), medium (350-500 mm) and high (> 500 mm) rainfall zones. Wheat after lupin was compared to wheat after wheat in 88 experiments (167 trial x year combinations), wheat after field pea in 32 experiments (63 trial x year combinations), wheat after canola in 16 experiments (19 trial x year combinations) and wheat after oats in 10 experiments (13 trial x year combinations). The majority of experiments included nitrogen treatments (1-52 kg N/ha, mean 29 kg N/ha) in the wheat phase. Data was analysed using Genstat for Windows V 10.0 (2008) to perform restricted maximum likelihood analysis (REML) on treatment mean grain yield data with all models using Trial.Year as the random effect.

RESULTS AND DISCUSSION

In 90% of instances wheat sown after lupin produced higher yields than wheat after wheat (Figure 1a). The average response to lupin was 600 kg/ha. Most large responses to lupin (responses above the 1:2 ratio line) occurred when wheat after wheat yields were below 1.5 t/ha. This indicated that wheat-on-wheat yields were constrained and that the inclusion of lupin in the crop sequence removed these constraints. Invariably these constraints have been identified in individual trials as the disease Take-all (*Gaeumannomyces graminis* (Sacc.) v. Arx and Olivier var. *tritici* Walker) or competition from annual ryegrass or brome grass (MacNish 1980; Rowland 1987; Rowland 1996).

Wheat sown after field pea produced on average 450 kg/ha more grain than wheat sown after wheat (data not shown). Responses were consistent so that so that in 89% of instances wheat sown after field pea produced the same or higher yields than wheat sown after wheat. Responses to canola were variable. The average response was 411 kg/ha but in 48% of instances the response was less than 250 kg/ha and in 16% of instances wheat after canola yielded less than wheat after wheat. Whilst there appeared to be a relatively large number of instances where canola provided little or no benefit, in some situations canola provided large increases in the yield of the following wheat crop. In particular, yield increases following canola averaged 1,100 kg/ha at southern regions sites such as Esperance, Mt Barker and Katanning. Wheat sown after oats produced on average 350 kg/ha more grain than wheat sown after wheat. The largest responses occurred when the yield of wheat sown after wheat was below 700 kg/ha. In the majority of instances this was attributed to the presence of Take-all.

The average response to including lupins in wheat rotations appears to have changed over time. From 1974 to 1990 there was a gradual rising trend in the response of wheat to lupins. It then drops off again after 1993 (Figure 1b). To separate the effect of rainfall from management we compared the water use efficiency (WUE) of the two sequences with similar locations (1983-1995). This showed that the difference between the WUE of wheat after lupin and wheat after wheat was for the first time consistently above 3 kg/ha/mm from 1990, despite no real changes in available water (growing season rainfall + stored water). Around 1990 there was a shift to no-till machinery and more effective herbicides became available that enabled selective control of weeds in lupin crops. Rotations also shifted to more continuous cropping as sheep numbers declined throughout WA. Observations from trials in the period 1990-95 indicated that the lupin plots were generally free from weeds whilst there were difficulties controlling grass weeds in the continuous cereal rotations. Furthermore, prior to 1990, as the rate of nitrogen increased, the difference in yield between wheat after lupin and wheat after wheat decreased (data not shown). However since 1990, nitrogen had no effect ($P > 0.05$) on the difference in yield. We suggest the widespread use of effective grass herbicides, which occurred at this time in Western Australia, made it possible to grow a grass-free lupin crop thereby reducing the incidence of cereal root diseases. Wheat grown after lupin was healthier and therefore more able to respond to nitrogenous fertiliser.

In summary, wheat sown after either lupin or field pea has been consistently higher yielding than wheat sown after wheat in WA. Canola and oats only provided a useful break compared to wheat after wheat in high rainfall areas with high root disease pressure. Crop production methods will change over time which, in turn, affects the benefits break crops provide in crop sequences.

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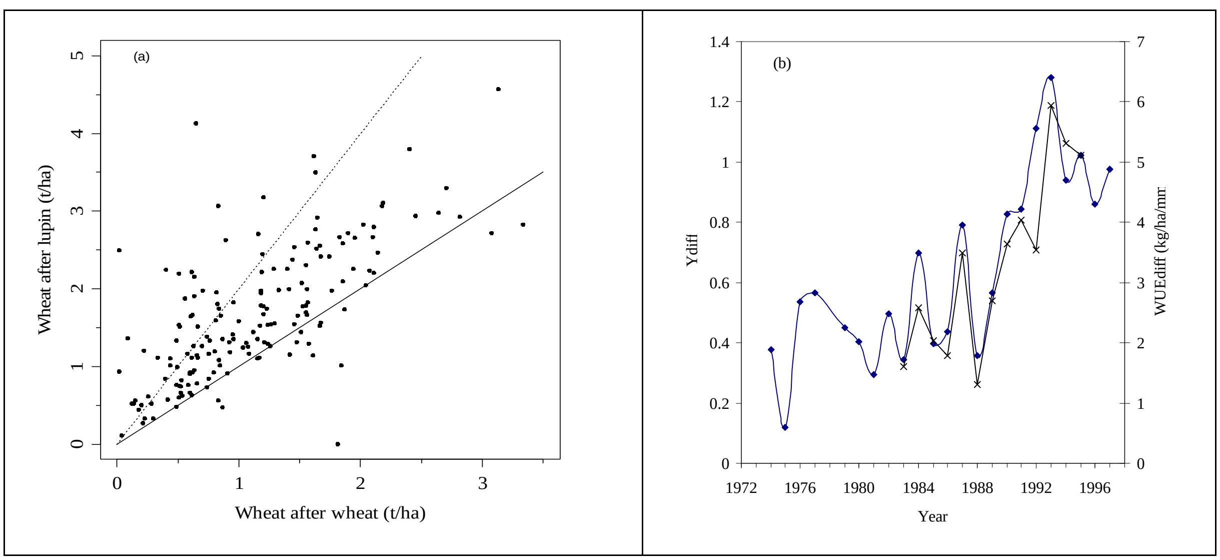

Figure 1 **Break effect of lupin.** (a) Grain yield response of mean data. Solid line indicates the 1:1 ratio and the dotted line the 1:2 ratio; (b) Yield difference (Ydiff, ♦, t/ha) and water use efficiency difference (WUEdiff, ×, kg/ha/mm) between wheat after lupin and wheat after wheat over time**.**

Impacts of Maize intercropping with soybean and groundnut on environment

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1.INTRODUCTION

Phytoremediation is the use of plants to directly or indirectly degrade or remove contam -inants from soil and water (Cunningham et al., 1996). It may be used to manage the N pollution problem since previous studies (Youngsoo et al.,2008; Andrew et al.,2007) found it suitable for remediating contamination in soils. And few papers which was using phytoremediation to reduce the nitrogen pollution on farms and to use Life Cycle Assessment to assess the effects of different planting patterns on environment were documented. The objectives of this study were to (1) analyse the effects of different maize planting patterns on environment,and (2) to select more suitable measures to reduce nitrogen pollution.

2.MATERIALS AND METHODS

Field experiments were conducted on a calcareous alluvial soil at Shangzhuang experiment station (39.9°N,116.3°E) in suburb of Beijing，China.The treatments were as follows:maize soled only (C -K),maize+soyabean(CST),maize+groundnut(CGT). The experiment plots ($24m^2$,4.8×5m) were arranged in a randomized complete block designed with 3 replicates. Maize were planted with wide-narrow pattern, the wide line and the narrow line were 80 cm,40 cm, respectively. Soyabean and groundnut were planted in middle of the maizes' wide lines, and placing of 29 cm within lines and the density was 63,000 seedings ha^{-1}. Planting and harvesting date were 20^{th} May and 20^{th} September 2008 , respectively.Life cycle assessment (LCA) is a methodology to assess all the environmental impacts associated with a product, process or activity by identifying, quantifying and evaluating all the resources consumed, and all emissions as well as wastes released into the environment(Rebitazer et al.,2004). The study depends on the 4 steps and assesses the 3 different planting patterns. The function unit would be the bio-prudctivity yield so as to compare the different systems' effects on environment. Therefore, this study relates all resouce consumpts and emissions to 1 ton of dry-biomass.

3.RESULTS AND DISCUSSIONS

3.1DEPLETION OF ABIOTIC RESOURCES, GLOBAL WARMING, EUTOPHICATION, AND ACIDIFICATION OF DIFFERENT TREATMENTS Resource consumption includes renewable resource and unrenewable resource, in this study, we considered the unrenewable resource only. According to table 1, it could be seen that CST treatment consumpted energy was the lowest than the other 2 treatments, and CK treatment was the most. The values of CK, CGT and CST treatment were 9147.8,8915.2 and 5908.5 MJ per ton,respectively. Table 2 revealed that The global warming indices of CGT and CST systems were all lower than CK system according to upper table values.According to fig.1,The impact category eutrophication values of CK treatment are higher than the other two treatments. Fig.2 showed that the acidification potential values of 3 treatments were clearly difference, and the value of CK treatment was lower than the CGT or CST treatment.

3.2NORMALIZATION AND WEIGHTING OF DIFFERENT TREATMENTS The aim of the normaliz-ation of indicator and weighting results was to better understand the magnitude for each indicator results of the product system under study. Table 3 indicated that the aggregated environmental indicator values of CK, CGT and CST were 0.1295,0.1229 and 0.0945, respectively.

4.CONCLUSIONS

The comprehensive index of environmental impacts varied in the order, maize sole＞maize plus groundnut＞maize plus soyabean,with intercropping corresponding values of 0.1295,0.1229 and 0.0945,respectivly. The results showed that intercropping maize with suitable plants(groundnut and soyabean) could reduce the adverse effects on environment owing to overapplicate nitrogen fertiliser. And the study also indicated that, it is a convinent,excellent and effective way to use phytoremdation to reduce the negative effects of nitrogen pollution on environment.It is more convient for the researchers to use LCA method to assess the effects of different planting patterns.

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Table 1 Life cycle energy depletion potential of different planting patterns（$MJ \cdot t^{-1}$）

Treatment	Energy depletion	Value to ck
C K	9147.8	/
CGT	8915.2	-232.6
CST	5908.5	-3239.3

Table 2Global warming($kgCO_2 \cdot t^{-1}$ bioproductivity) of different planting patterns

	CK	CGT	CST
CO	3.3	3.2	2.1
CH_4	11.3	11.0	7.3
N_2O	75.4	73.5	48.7
CO_2	682.2	664.9	440.6

Table 3 Aggregated environmental indicator values(EcoX)per ton of bioproductivity

treatment	total values
C K	0.1295
CGT	0.1229
CST	0.0945

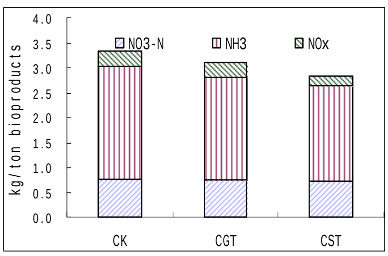

Fig.1.Eutrophication ($kgPO_4 \cdot t^{-1}$ bioproductivity) of different planting patterns

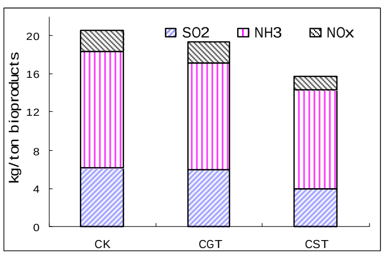

Fig.2.Acidification ($kgSO_2 \cdot t^{-1}$ bioproductivity) of different planting patterns

Effects of condensed tannins on pastoral systems

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INTRODUCTION

Incorporation of moderate concentrations of condensed tannins (CT) into pasture species is likely to improve ruminant health and production but little is understood about the direct and indirect effects of CT on the plant-soil system. Direct effects of CT in the ruminant diet include: increased animal production per unit of dry matter (DM) intake (Min et al., 2003); a change in the dung-urine partitioning of excreted nitrogen in favor of more dung (Barry et al., 1986); and reduced mineralization rates in the soil organic matter (Swain, 1979). There are many indirect effects likely to arise from those direct effects including; reduced leaching, volatilization and denitrification; increased soil organic matter; increased N stress in the pasture; increased legume proportion and N fixation in the pasture. This paper uses an agro-ecosystem model (EcoMod) to examine the direct and indirect effects of CT on a pastoral system examining both the production and environmental consequences.

DESCRIPTION OF MODEL

The modeling described was done using EcoMod (v4.7.7), a biophysical simulation model (Johnson et al., 2008) with an option that allows heterogeneous urine return (Snow et al., 2009) within a single paddock of a farm. Here EcoMod was set up following the methodology in (Snow et al., 2009) to simulate a paddock in a climate typical of the dry east coast (rainfall of 600 mm /yr) of the South Island of New Zealand with typically light soil, 100 mm of total plant-available water, growing a ryegrass-white clover pasture. Two farm systems, dryland with no fertilizer and irrigated with 180 kg N fertilizer /ha /yr, were simulated with steers grazing the pasture. Both systems were simulated at a low and moderate level of fertility and each of the four systems without and with the direct effects of tannins in the plants. The direct tannin effects were included by: increasing N removed in animal production per unit of DM intake by 20%; changing the excreted dung:urine ratio in favor of 15% more dung; and reducing organic matter mineralization rates by 30%. All indirect effects were simulated only as those arising from the direct effects listed above.

RESULTS AND DISCUSSION

Annual average pasture growth rate decreased by up to 17% (Fig. 1a) when tannins were introduced into the system with smaller decreases in the higher fertility and irrigated-fertilized systems. The primary cause of the decreased growth was probably increased N stress: there was up to 8% more N stress in the pasture with the pattern mirroring the change in growth rate. Nitrogen fixation increased in the dryland systems but there was little effect observed in the irrigated systems. The spring pasture production peaks were relatively more severe in the with-tannin simulations and, in irrigated systems without N fertilizer, spring growth was significantly delayed due to N stress. Tannins had a positive environmental effect with decreases in relative (Fig. 1b) and absolute N leaching (Fig. 1c) and increases in the accumulation of N in the soil organic matter (Fig. 1d). All these effects were influenced by farm system (Fig. 1). Nitrogen retention efficiency (amount of N retained in the plant-soil system as a percentage of N ingested) increased from 1 to 18% (data not shown) with the greatest effects observed in the irrigated higher fertility systems.

These simulations indicate probable reduced pasture production with the introduction tannin, but the increase in animal production per unit of DM (Min et al., 2003) will likely result in a benefit at the whole farm level. This, combined with the positive environmental effects, suggests that tannins will lead to higher production with improved environmental performance. However because the tannins changed the pattern of pasture production with month, the whole farm system implications should be examined using a model that can represent greater detail in farm management decisions.

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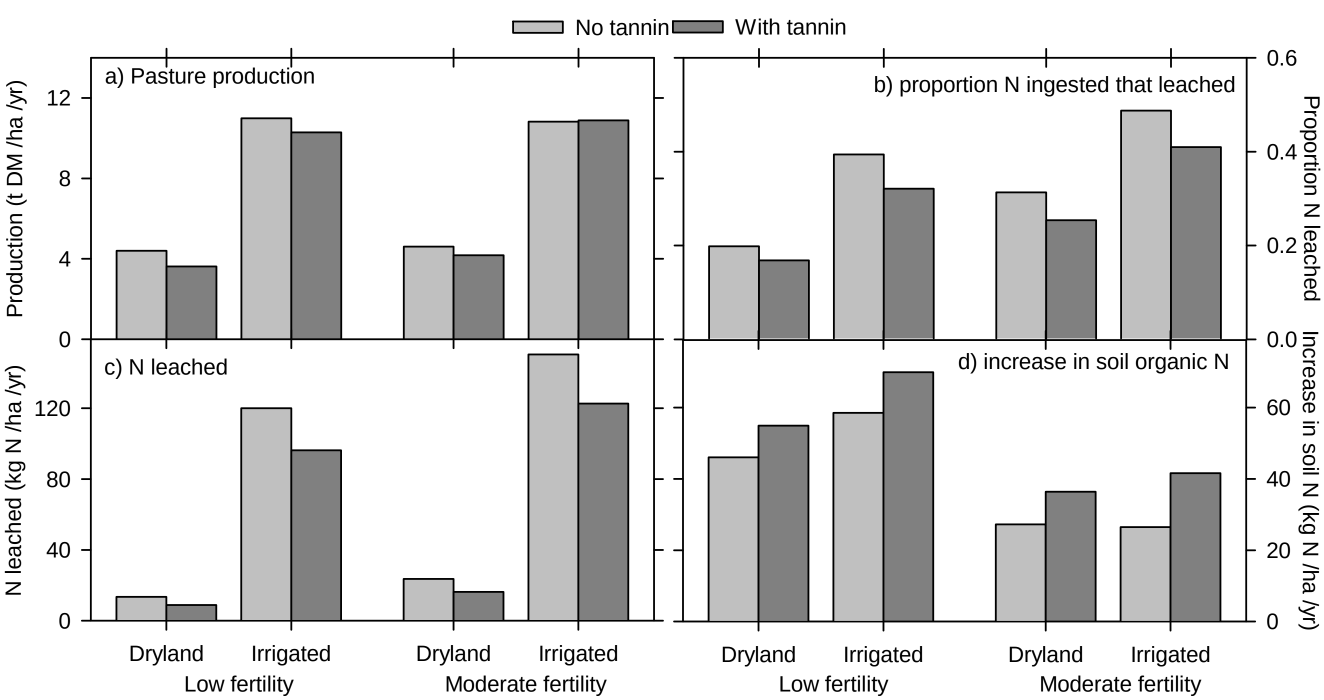

Fig. 1. Effect of tannin in the pasture on DM intake, N leaching, the proportion of ingested N that leaches and the change in soil organic matter for the four farm systems simulated.

PERFORMANCE OF RICE ON A COARSE SANDY LOAM SOIL IN RESPONSE TO WATER-SAVING IRRIGATION PRACTICES IN LOWLAND EASTERN INDONESIA

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INTRODUCTION

Rapid increase in world population and a corresponding increase in demand for water and land from industrial and municipal have forced the agricultural sector to use marginal land and irrigation water more efficiently by using less water to produce more food. Coarse-textured and porous soils of the tropical regions are increasingly used for growing both upland and lowland rice. In porous soils under rice, continuous flooding cannot be maintained due to high water percolation rates. Development of appropriate planning and management strategy to improve available water resources for the agricultural sector is a high national and global priority. Increased efficiency in water use is essential for future food security in Asia where rice production needs to increase by 70% over the current production by the year 2025 (Tuong and Bhuiyan 1999). However, experimental evidence for the hydrological and environmental conditions of coarse soils under which current rice-based cropping systems are practiced is limited. Such studies will become more important as porous soils are increasingly used for irrigated rice-based cropping systems. In this paper, we evaluate the effectiveness of alternately submerged and non-submerged (ASNS) over continuously submerged (CS) irrigation practices using three years of field experimental data on a coarse soil in the tropical region of eastern Indonesia.

MATERIALS AND METHODS

The experiment was based on a split-plot design consisting of three replications of two irrigation treatments (CS and ASNS) as main plots and three rates of N fertilization of 0 (F0), 69 kg N ha^{-1} (F1) and 138 kg N ha^{-1} (F2) as subplots within each main plot at an experimental station of BPTP NTB Indonesia (08°35' N, 116°13' E and 150 m elevation). Phosphorus and potassium fertilizers were applied at rates of 100 kg TSP ha^{-1} and 50 kg KCl ha^{-1} before transplanting of rice. All N-fertilizer applications were split into 20% at 7 days after transplanting (DAT), 30% at 29 DAT, and 50% at panicle initiation (45-50 DAT). For both CS and ASNS irrigation treatments, ponded water depth in the field was maintained between 0-20 mm during the first 7 DAT and was drained at 10 days before harvesting. For the CS treatment, ponded water depth was allowed to fluctuate between 0-100 mm throughout the growth period. Plots under ASNS treatment remained without submergence for around 5–7 days depending on rainfall conditions. Daily weather data were collected from a weather station at the experimental site. Crops were sampled for yield, biomass and N uptake at harvesting and analysed using Genstat Software (Version 9.2.0.153, VSN International Ltd, Oxford).

RESULTS AND DISCUSSION

Daily rainfall and ponded water depth (D) in the field for CS and ASNS treatments are shown in Figure 1 for 2007-09 rice growing seasons. Values of D were within the range of 0 to 99 mm and -79 to 59 mm for CS and ASNS, respectively. Negative value indicates water depth below soil surface. Percentage of days without ponding in ASNS was 23%. Total amount of irrigation water applied over three years to CS and ASNS during rice growing season was 1080-1820 mm and 664-1104 mm, respectively. Amount of water saved during rice growth with ASNS compared to CS irrigation was 36-46% during 2007-09. Rainfall during rice growth was 1029, 233 and 897 mm for 2007, 2008 and 2009, respectively. Mean percolation rate over three years for the experimental site was10.1 mm per day.

This study indicates that the ASNS treatment on coarse soil did not lead to very dry soil conditions during the nonsubmergence periods although there was water saving of 36-46% compared with CS treatment, biomass, yield and components of yield did not significantly differ between ASNS and CS (Fig. 2). Significant differences in yield and yield components with N rates but not with water regimes, is consistent with previous studies (Bouman and Tuong, 2001; Belder et al., 2004; Qi Jing et al., 2007). Success with alternate submergence and non-submergence conditions in ASNS treatment was due to soil remaining close to saturation in which water depth did not drop to 10 cm below the soil surface (Fig. 1). Similar results have been reported by Belder et al. (2004) for a clay soil with a shallow water table and percolation rates of 1-4.5 mm per day.

Absence of any significant reduction in yield and biomass due to the direct effects of irrigation treatments and lack of significant interactive effects with N-treatments suggest that these results appear to be typical for well-drained, irrigated lowlands in eastern Indonesia and ASNS practices can results in considerable water-saving without adversely affecting yield.

ACKNOWLEDGMENTS

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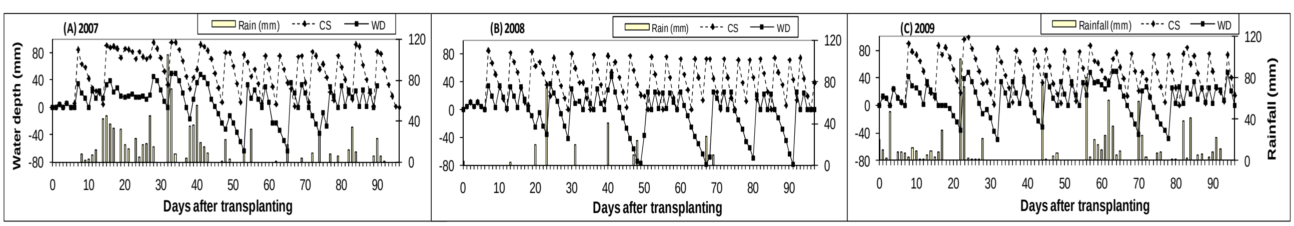

Figure 1. Water depth and rainfall in CS and ASNS water regimes during rice growing seasons in 2007 (A), 2008 (B) and 2009 (C).

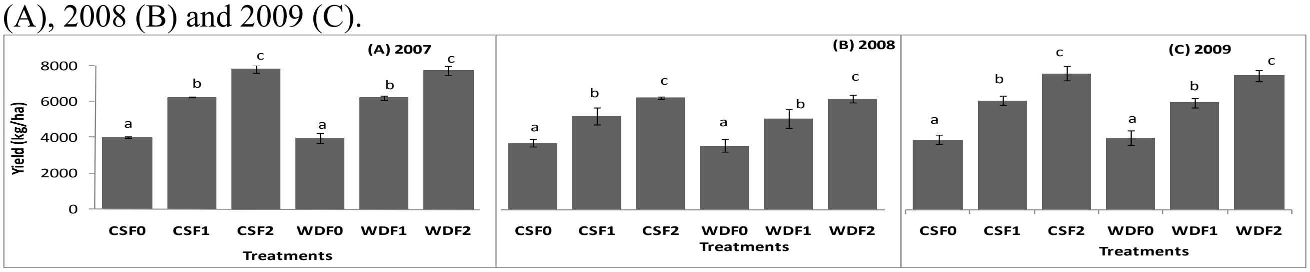

Figure 2. Effect of water regimes (CS and ASNS) and N fertiliser (F0, F1 and F2) on grain rice yield.

CAPABILITY OF APSIM-ORYZA TO SIMULATE LOWLAND RICE-BASED FARMING SYSTEMS UNDER NITROGEN TREATMENTS IN A TROPICAL CLIMATE

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INTRODUCTION

Rice is the most important crop in Asia and the staple food for most of the world's population. Due to the overwhelming importance of this crop, modelling rice-based farming systems will provide valuable help to compare experimental research findings across regions, extrapolate field experimental data to wider environments, develop management recommendations and decision-support systems, explore effects of climate change and adaptation options, and prediction of crop yield. There is an increasing demand for the capability to simulate rice-based cropping systems, especially in Asia. Such a system capability will allow expanded investigation of nitrogen dynamics, crop sequencing, intercropping, crop residue management and soil and water management. Incorporation of the ORYZA2000 rice model (Bouman and van Laar, 2006) into APSIM (Agricultural Production Systems Simulator (APSIM-Oryza) together with recent work on carbon and nitrogen dynamics in transitional flooded/non-flooded systems (Gaydon et al., 2009) has facilitated long-term simulation of lowland rice-based farming systems scenarios. However, the capability of APSIM-Oryza to simulate rice-based crop sequences involving other crops has undergone limited testing to this point and under a variety of crop management practices and cropping systems. In this paper, we detail testing of the APSIM-Oryza simulation model against an experimental dataset involving lowland rice-rice-soybean crop rotation in West Nusa Tenggara Province (NTB) Indonesia.

DESCRIPTION OF MODEL

The APSIM farming systems simulation framework is described in detail by Keating et al. (2003), and the key processes of ORYZA2000 have been well documented (Bouman and van Laar, 2006). Simulation of the transitional (flooded-non-flooded) soil environment and pond processes within the APSIM framework has also been recently described (Gaydon et al., 2009).

RESULTS AND DISCUSSION

The performance of APSIM-ORYZA with and without nitrogen limitation was evaluated using rice-rice-soybean crop sequence data from a field experiment conducted at the Assessment Institute for Agricultural Technology (BPTP) NTB Indonesia in 2007-2008. Three rates of N fertiliser were applied to rice; 0 kg N ha^{-1} (F0), 70 kg N ha^{-1} (F1) and 140 kg N ha^{-1} (F2) and three rates for soybean; 0 kg N ha^{-1}(S0), 12 kg N ha^{-1} (S1) and 24 kg N ha^{-1} (S2). In general, the model satisfactorily simulated the dynamics of crop variables measured (phenological stages, yield and biomass), soil and water variables (ponded water depth, pH, temperature and daily infiltration rate). Simulated biomass matched the pattern of rice growth when nitrogen was not limiting factor (F2), with slight over-prediction under both F1 and F0 treatments for both the first (wet) and second (dry) rice seasons (Fig. 1). A similar pattern was also found with the grain yield of rice (Table 1). The simulated yield of rice has achieved closer agreement with the measured data as N-fertiliser application increased. This is probably due to inadequate simulation of nitrogen immobilisation during residue decomposition following the first rice crop. Simulated biomass of soybean correlated well with the measured data better than rice for both nitrogen limited treatments (S0 and S1) and non-nitrogen limited treatments (S2). The model satisfactorily simulated the dynamics and magnitude of ponded water during rice growth (Fig. 2).

This validation exercise highlighted some areas where improvements might be possible; however we conclude that APSIM-ORYZA would perform sufficiently well to extrapolate our experimental results to different management practices within the study area for longer-term simulation of rice-based farming systems.

Acknowledgments
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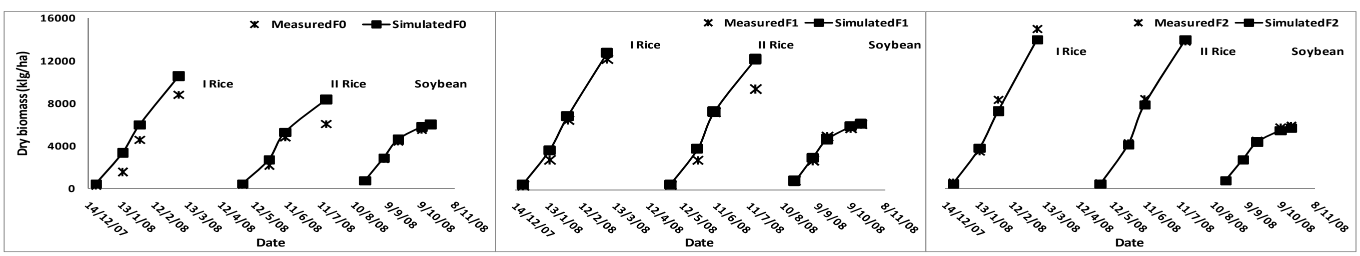

Figure 1. Temporal variation in rice and soybean dry biomass within a one year crop sequence.

Table 1. Measured (m) and simulated (s) yield of rice I and II and soybean within a crop sequence.

Treatment	I Rice (23 Nov 07 - 05 Mar 08)			II Rice (02 Apr - 16 Jul 08)			Soybean (19 Jul - 18 Oct 08)		
	measured	simulated	% (m-s)	measured	simulated	% (m-s)	measured	Simulated	% (m-s)
F0	4025	4968	-23	3683	3448	6	2233	2140	4
F1	6267	6470	-3	5175	5510	-6	2361	2192	7
F2	7842	7368	6	6208	6715	-8	2211	2043	8

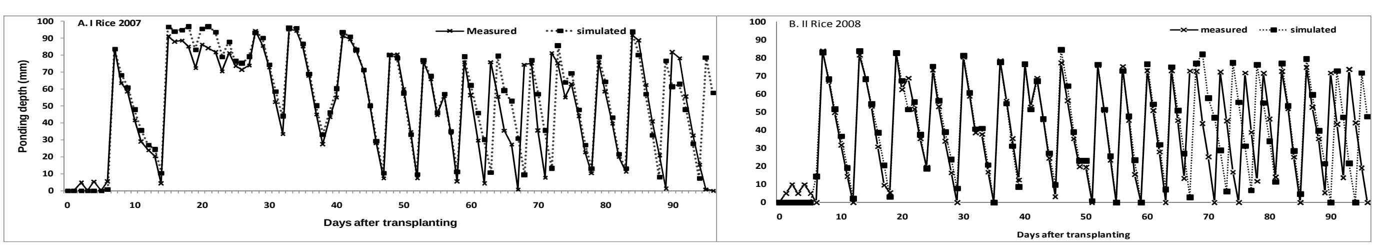

Figure 2. Measured and simluated ponding depth in rice I and II crops during the cropping seasons.

Nitrate leaching potential of biomethane waste applied to maize – a model based evaluation

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INTRODUCTION

The production of methane from anaerobic digestion of slurry and/or biomass has greatly expanded in Germany due to substantial subsidization (> 4000 plants in 2009). While initially regarded favourable, criticism has been voiced recently due to fuel-food competition and potential environmental impact. Biomethane waste, which is produced in large amounts, should be used in a sustainable way. The objective of this study was to assess the nitrate leaching potential of biomethane waste applied to maize compared to animal manure and mineral fertilizer.

MATERIALS AND METHODS

A study was conducted through a 2-year field experiment (2007-2008) at the Karkendamm experimental station (longtime average: 844 mm; 8,6 °C) of the Christian-Albrechts-University in Kiel, Northern Germany. Maize was grown in monoculture on a sandy aquod soil and N fertilizer applied as either mineral, cattle slurry, pig slurry, or biomethane waste from mono- or cofermentation, in levels varying from 0 to 360 kg N ha^{-1}. The leachate was sampled weekly with ceramic suction cups (P80) 60 cm below ground surface, while the soil moisture content was determined by TDR-probes (Time Domain Reflectometry). Soil water balance and plant growth were calculated using the object oriented model library HUME within the Delphi/C++ © Builder programming environment (Kage 1999), and nitrate load in the leachate obtained from the measured nitrate concentrations and simulated leachate amount. The model uses the Penman—Monteith equation for calculating the potential evapotranspiration. Plant growth was simulated by fitting simple functions to crop height and leave area index (LAI). Calculations of the soil water movement were based on soil water potential. Relationships between soil water diffusivity and the volumetric water content were described using the functions of van Genuchten in the revised form of Woesten and Van Genuchten (1988). The needed parameters (Tab. 1) were calculated using the RETC code based on field measurements (top soil) and using empirical data from the Ad-hoc-Boden database in the deeper layers (van Genuchten, 1991; Ad-hoc-AG Boden, 2007). The statistical analysis was conducted, assuming a quadratic relationship (without linear term) between the mineral share of the N input and the nitrate-N load. The intercept of the function was derived from the nitrate-N load of the control plots. The function parameters were estimated separately for the different N fertilizer types and each year, and were compared by means of t-tests with subsequent Bonferroni-Holm correction.

RESULTS AND DISCUSSION

It is generally assumed that the use of residues from biogas production in crop production would increase the yield and, consequently, decrease the N- leaching losses because of its higher NH_4-N content compared to animal slurries. To test this hypothesis we compared the N-load in the leachate after application of biogas residues with application of mineral fertilizer, cattle slurry and pig slurry. The model calibration for the water balance resulted in a satisfactory agreement between observed and calculated soil water contents (R^2 0.30-0.70; RMSE 0.05-0.06 $cm^3\ cm^{-3}$), which allowed to calculate the nitrate-N loads. The statistical analysis refers only to periods, where measurements of nitrate-N concentration in the leachate were available for all treatments.The relation between the mineral input of N fraction and the nitrate output could be quantified by a quadratic function (Fig. 1). No significant effect was detected of the type of tested fertilizers (mineral, cattle, BG-mix) on the slope of the function when relating the nitrate-N load to the mineral share of the N input. In the next step the N-balance will be simulated to allow N loss calculations over the whole 2-year period.

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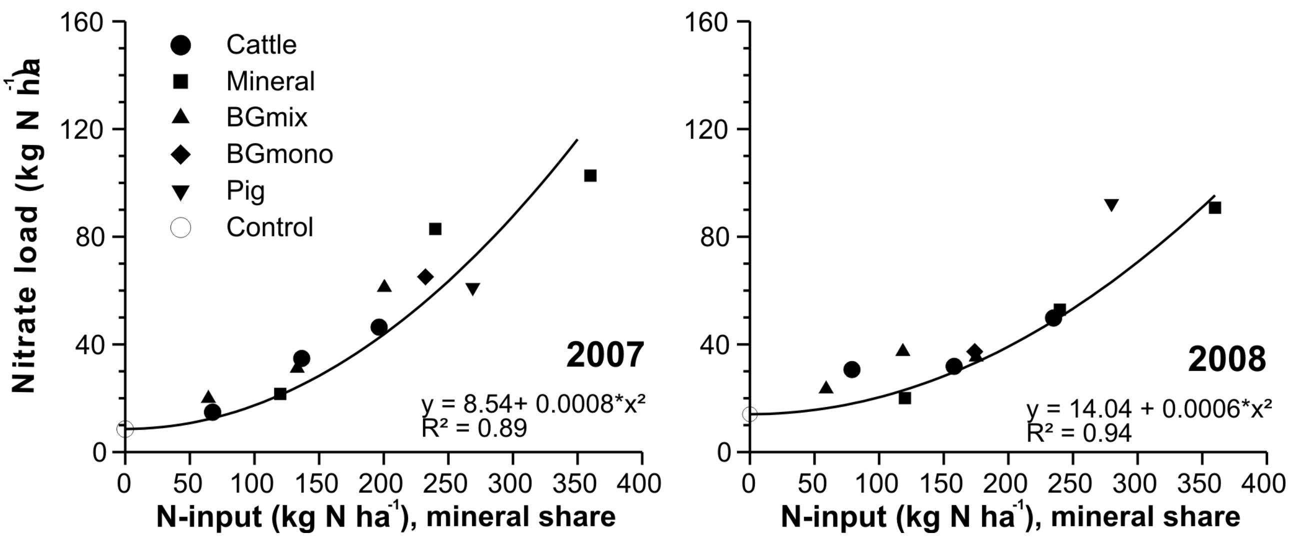

Fig. 1. Relationship between NO_3 load in leachate (kg N ha^{-1}) and N input (mineral share, kg N ha^{-1}) for maize grown at Karkendamm. Calculations for 2007 include 20 weeks, and 35 weeks for 2008. BGmix: biogas residue from cofermentation, BGmono: biogas residue from monofermentation.

Tab. 1: Parameters used with the van Genuchten equations

Soil	Depth (cm)	θr ($cm^3\ cm^{-3}$)	θs ($cm^3\ cm^{-3}$)	α (cm^{-1})	n	Ks (cm day^{-1})
Sandy sand	0-30	0.12	0.43	0.04	1.66	45
	30-40	0.08	0.37	0.03	2.48	107
	40-50	0.14	0.4	0.04	1.62	89
	50-200	0.04	0.33	0.01	2.43	151

LONG-TERM ASSESSMENT OF THE PRODUCTIVITY, PROFITABILITY, AND ENVIRONMENTAL IMPACT OF TWO MID-ATLANTIC NO-TILLAGE CROPPING SYSTEMS

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INTRODUCTION

Future farming systems need to simultaneously 1) meet the demand for feeding a growing world population, 2) adjust to the developing scarcity of energy, nutrients, and water resources, and 3) mitigate environmental hazards. Development of cropping systems that maximize ecological processes for providing crop growth resources and minimize the use of external inputs can contribute to the success of future farming systems. However, most ecologically based cropping systems require the diversion of additional land or time within a rotation to grow soil-building species rather than growing food crops. Thus, a tradeoff may develop between farming systems that rely on intensive production of food crops to feed a growing population and farming systems that rely on ecological principles of building soil fertility and pest management through rotational diversification. Results from the Sustainable Agriculture Demonstration Project (SADP) at Beltsville, Maryland, USA, provide an instructive example of this tradeoff.

MATERIALS AND METHODS

This experiment compared corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], and wheat (*Triticum aestivum* L.) production on a 6-ha site with 2 to 15% slope to evaluate the efficacy of reduced-tillage systems suitable for erodible land typical of the mid-Atlantic area. Two of the systems in this experiment are discussed in this paper. The first was a standard mid-Atlantic no-tillage system (NT) with recommended herbicide and fertilizer inputs that represented an intensive production approach with grain crops grown through as much of the rotational cycle as possible (corn in the first year followed by winter wheat and double-crop soybeans in the second year). The second was a cover crop based no-tillage system (CC) including hairy vetch (*Vicia villosa* Roth) before corn and rye (*Secale cereale* L.) before soybean where the cover crops were intended to reduce N inputs and to suppress weeds thereby reducing herbicide inputs. Three general approaches were taken for evaluating these systems. First, various metrics of system performance were measured directly during the 9-year system comparison from 1994 through 2002 (Teasdale et al. 2000, Teasdale et al. 2007). Second, a 60-year projection of the long-term agronomic, economic, and environmental performance of these systems was simulated using the EPIC model (Watkins et al. 2002). Third, following the 9-year systems comparison, a uniformity trial was conducted from 2003 through 2005 wherein all plots were planted to corn according to the NT system (Teasdale et al. 2007).

RESULTS AND DISCUSSION

The NT system represented an intensive approach whereby grain crops were grown for 19 months out of this 24 month rotation (Table 1). This system produced more total grain per unit area per year than the CC system, an output achieved by application of herbicides to control unproductive vegetation (weeds) and fertilizers to provide nutrients. Although this no-tillage system reduced simulated erosion below tolerance levels on this sloping land, simulated atrazine leaching, nitrogen runoff, and phosphorus runoff were above water contamination limits (Watkins et al. 2002).

The CC system substituted cover crop vegetation for a portion of nitrogen requirements (vetch before corn) and herbicide requirements (weed suppression by cover crop residue), which required that wheat as a cash crop be eliminated and full-season soybean be implemented as the sole second season crop. Thus, cover crops were grown for more months of the rotation than cash crops (Table 1). This eliminated one nitrogen-requiring crop in favor of a non-nitrogen-requiring crop and an overall reduction of inputs, which is reflected in the lower variable costs of CC than NT. Soil C in the surface 15 cm was higher at the end of nine years in CC than in NT (Teasdale et al. 2007) and simulated erosion, herbicide leaching, and phosphorus runoff were substantially below tolerance limits leading to a lower environmental hazard index in CC than NT (Table 1). However, simulated nitrogen in runoff was similar in CC and NT suggesting that N mineralized from legume cover crop and crop residue was potentially as prone to movement off-field as fertilizer N. As a result of requiring more rotational time for cover crops, the total rotational grain production and gross returns per unit area per year were lower in CC than NT. But, because of the lower variable costs, system gross margin was similar in CC and NT (Table 1, Watkins et al. 2002).

This project focused on the efficacy of including ecologically based management approaches within an intensive grain cropping system where at least one grain crop is grown every year. The substitution of cover crops for grain and fallow rotational time in this mid-Atlantic CC system resulted in lower total production but with the benefit of reducing inputs and overall environmental hazard while increasing soil C. In addition, if variable costs can be considered an overall reflection of the energy and resource requirements for production, then the efficiency of production as measured by the ratio of grain yield per variable cost was higher in the CC than NT system (10.8 versus 10.1 kg/$, respectively). More research is required to refine production systems to balance the need for productivity with the efficient use of resources and the minimization of environmental hazard.

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Table 1. Comparison of two no-tillage cropping systems from the Beltsville SADP.

System	Months of a two-year rotation in: Crop	Cover crop	Fallow	Soil C to 15 cm	Grain yield†: Nine year actual	Simu-lated	Simulated Environ-mental Hazard Index‡	Simulated returns: Gross return	Variable costs	Gross margin
				$g\ kg^{-1}$	$kg\ ha^{-1}\ y^{-1}$			$\$\ ha^{-1}\ y^{-1}$		
NT	19	0	5	13.3	6101	6230	1.858	900	616	283
CC	10	14	0	14.9	5130	5200	0.989	775	483	292

† Total grain production of all crops in the rotation divided by years in rotation.
‡ Environmental hazard index was determined by dividing the simulated output for erosion, herbicide leaching, N runoff, and P runoff by their respective loading tolerance and averaging these four values.

DESIGN OF A PARTICIPATORY RESEARCH TO STUDY THE CONTRIBUTIVE FACTORS IN THE BUILDING OF WINES FAME

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INTRODUCTION

Terroir is increasingly important today in wine markets (Casabianca, Sylvander et al., 2005). In a large wine production area such as the Loire Valley, several territories can be distinguished according to different geological, soil, climatic and landscape features. They differ also one from the other by their fame and business success. Farm scale surveys about winegrowers' practices, local knowledge and the quality of the social links in small territories have led to the hypothesis that these differences can be due to different combinations of environmental factors, vineyard production systems and the social links developed by the farmers (Doorman, 1990). Using a combination of technical and sociological survey in Loire Valley vineyards can yield essential information on the hows and whys of winegrowers decision making. The final purpose of the Vineyard Loire Valley Observatory (VLVO) is to produce and combine a knowledge database.

The purpose of this poster is to present intermediary results of the first year of a participatory method developed in order to study the impacts of these combinations of factors on wine quality in the VLVO. VLVO will be a dynamical process and also a result as maps, tables and indicators.

MATERIALS AND METHODS

The "Chambres d'agriculture" which are Research Development and Extension (RDE) agencies decided to join together to analyse the wine production systems in a participatory workshop process. The method attempts to target more effectively RDE dedicated work programmes by involving winegrowers and RDE actors from the beginning of the process which is not very common (Dore, Clermont-Dauphin et al., 2008). In our project, the association of social and technical analyses is needed in order to understand the adoption of decision-making processes by the winemakers (Sarrazin, 2008). It is as well very important to convince real-word RDE managers to negotiate and to participate with searchers potential mutual benefits of the VLVO (Akinola, 1986; McCown, 2002). It will be very interesting to work at the field and at the territory scales. At field scale, the objective will be to optimize vine production systems to produce famous wines. At the territorial scale, the objective will be to combine the field and its environmental factors as climate or slope length for example (Dore, Clermont-Dauphin et al., 2008). The adoption of this method will attempt to 1) exchange technical and social references among the territories 2) provide the growers with reliable and easily accessible information 3) transfer the results of research to the potential users 4) develop new RDE projects according to farmers needs.

RESULTS AND DISCUSSION

3 meetings have been organized in March 2009 with winegrowers' advisers and RDE agents of Loire Valley Vineyards. Two targets: (i) identify the potential reasons why people do not

agree in working together in the VLVO; (ii) identify which subjects these people want to see in the VLVO. Main reasons of the point (i) are not only financial reasons but also databases property. RDE agents want to have a VLVO which give rapid answers to diseases and economical sustainability of farms.

Next months, it will be the end of the first step of the participatory research method: validate the problems pointed out by RDE agents and what the VLVO will contain. These decisions have to be taken with winegrowers, RDE agents and experts. It will be then possible to start the second step of the participatory research method: surveys and databases.

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FARMING SYSTEMS TO REDUCE ENVIRONMENTAL IMPACTS OF SUGARCANE PRODUCTION

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INTRODUCTION

In response to concerns about the health of the Great Barrier Reef (GBR), governments in Australia have developed and are implementing policies to significantly reduce discharge of pollutants from industries located in catchments draining into the GBR lagoon. Agriculture is an important land use in GBR catchments and has been identified as an important source of diffuse pollution. Thus agricultural industries and local catchment authorities are challenged with developing plans (Water Quality Improvement Plans, WQIPs) that specify both management practices to reduce pollutant loads to acceptable levels, and targets for adoption of these practices. Agricultural industries in these catchments, especially crop production, do not have a long history of research into environmental impacts of different farming systems. Thus modeling and systems analysis have an important role to play in identifying both management practices and the extent of adoption needed to meet water quality objectives.

This paper describes the process used to characterize the water quality impact of different cultural practices for sugarcane production in the lower Burdekin catchment, and reach agreement amongst stakeholders for different levels of adoption of the various practices to meet water quality targets. This participative process involved staff from agricultural advisory agencies, farmers and systems analysts, to define adoptable management practices for the local Water Quality Improvement Plan.

MANAGEMENT PRACTICES TO REDUCE NITROGEN LOADS

Nitrogen (N) had been identified as the main pollutant from sugarcane production in the Burdekin region (Brodie and Bainbridge 2008), so this study focuses on characterizing loss of N via runoff and deep drainage. Details of the range of farming operations (e.g. tillage practices, irrigation management, N fertilizer management, etc) potentially used in sugarcane production were collated (Thorburn et al. 2007) and then simulations undertaken to define the operations that effected long-term N losses. Various operations were grouped into five classes, termed E to A (from ‘bad’ to ‘good’), combining decreasing tillage intensity, reducing N application rate and improved irrigation scheduling. Classes E to C represented practices currently common in the region; Class B was similar to the currently promoted ‘best practice’; with Class A being a possible future best practice that is currently under experimental investigation. The long-term annual N losses (Figure 1) and productivity of these management classes were simulated with APSIM-Sugarcane for the dominant soil types in the four main districts (Delta fine textured, Delta coarse textured, Mona Park and Mulgrave) in the region, based on experimental studies of water quality in sugarcane production in these districts.

Extension officers were interviewed to estimate the proportion of farmers currently practicing these classes in each of the four districts. The majority (50-60 %) of farmers were practicing Class D, with fewer practicing Classes E and C. From these adoption estimates and the areas of the districts, the regional average N fertiliser use (211 kg ha^{-1}) was determined. This N use compared well with data on actual use in the past five years (217 kg ha^{-1}), suggesting that the distribution of management practices were plausible. The water quality impacts of the adoption estimates and N loss predictions was also plausible. Recent N load estimations in the region (3000-4500 t yr^{-1}, Brodie and Bainbridge 2008) compare favorably with predicted long term N loads (5500 t yr^{-1}) that are based on under current conditions, rather than historical (and variable) N usage and areas under sugarcane.

SETTING MANAGEMENT ACTION TARGETS

The hydraulic connections in the region are simple: Transport of water and chemicals to creeks and the river is rapid so processes such as in-stream denitrification are negligible. Reflecting this simplicity, a simple regional 'calculator' was constructed based on mass conservation to allow exploration of the relationship between different patterns of practice Class adoption and regional N loads (Figure 2). The exploration was undertaken in participation with local farmers and catchment managers in a facilitated workshop to determine the adoption needed of different practice Classes to meet regional water quality objectives. These objectives included a reduction in N loads of 20% by 2013, and they would be met by having a net shift of 10% of farmers from Class E to Class B practices.

DISCUSSION

The analyses undertaken, and the process used has provided the local catchment management authority with quantitative and agreed targets for the adoption of management practices for sugarcane production in the lower Burdekin catchment (Dight 2009). This will underpin government funding of incentive schemes to facilitate practice change, the means of assessing the effectiveness of those funds, and the water quality improvement resultant from them. This provides a sound basis for implementing the local Water Quality Improvement Plan.

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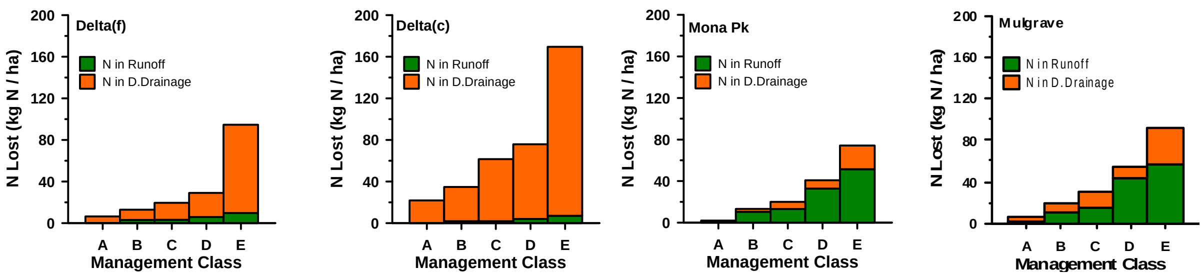
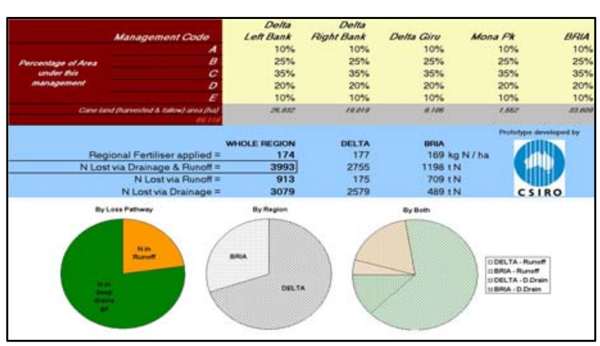


Figure 1. Predicted long-term annual losses of N via runoff and deep drainage at the four sites under five classes of management practices designed to meet water quality targets.

Figure 2. Screen from the regional nitrogen load calculator used participatively with stakeholders to assess the water quality benefits from adoption of various management practices



ORGANIC FARMING AND SUSTAINABILITY ASSESSMENT OF ORGANIC ARABLE FARMS IN THE CZECH REPUBLIC

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INTRODUCTION

The current demand for produce from sustainable farming systems provides great opportunity for organic farming development. Organic farming in the Czech Republic (CR) started as late as in 1988-89 when the political situation changed, and at the end of 2008 there were already more than 341,632 ha under organic farming (8 % of agricultural land). However the era of socialism and collectivized agriculture has influenced agricultural production and thinking of farmers, and their attitude to change. In this article we want to assess the sustainability of organic farming as practiced in the CR, using the example of 3 case study farms.

MATERIALS AND METHODS

We used official statistics (Ministry of Agriculture of the Czech Republic) to find data about the current state and historical development of organic farming in the CR.

Basic indicators (balances of N, P, K, organic matter and energy) were used to assess sustainability of farms. The indicator values were calculated using the Repro software method (Diepenbrock and Hülsbergen 1997). Calculations were based on agronomic records of 3 organic farms. Farm 1 is located in 250 – 400 m above sea-level, with an average temperature of 8.5 °C. It is part of mixed conventional farm which includes fields in a water source protection zone. On the acreage of 156 ha rye, spelt, buckwheat, clover and leguminous mixtures are grown. Farm 2 is located at an altitude of 305 – 605 m and an average temperature is 7.6 °C. It is a mixed farm with 432 ha arable land, some grassland and 550 head of cattle. Field crop species include rye, spelt, wheat, triticale, fodder mixtures, spices and clover. Farm 3 is located at an altitude of 500 – 550 m and an average temperature is 6.5 °C. It is also a mixed farm with 293 ha arable land and some grassland, cattle and pigs. Field crop species include buckwheat, spelt, potatoes, onion and fodder mixtures (legumes and cereals).

RESULTS AND DISCUSSION

In the CR the distribution of organic farms appears to depend on production conditions and the activity of advisory services. The highest numbers of organic farms are in hilly, less productive areas where farming is naturally more extensive and most are in regions close to active advisory services. In the structure of organic land grassland with beef cattle breeding strongly prevails accounting for 82 % of area. Arable land accounts for only 10 % of the organically farmed area, partly because of the location of farms in hilly extensive areas but also because a lot of farms switched from milk to beef cattle when converting to organic farming.

The number of organic farms has been growing since 1989, with the exception of the period from 1993-1997 when there were no subsidies for organic farming. In these 5 years only 70 new farms were registered, while in the 5 years after re-imposition of subsidies in 1998 numbers increased by 443.

The case study farms showed some weak points when subjected to the sustainability assessment. In most cases the N balance (Table 1) on the whole farm level was only slightly higher than the limit set to +/-25 kg N $.ha^{-1}$. However, great variability occurred at the level of single fields. The occurrence of quite high local N surpluses can indicate potential N leaching, especially in the case of farm 2.

Data for the P and K balances are shown in Table 2. Farm P balances were reasonable, with only farm 1 (where farmyard manure was not used) lower than the limit of +/- 7 kg P .ha^{-1} in all 3 years.. The K balance seems to be more problematic because it was lower than the set limit (+/-20 kg K .ha^{-1}) on all farms in 2 years of 3.

In comparison with results from these farms, field trials conducted by FiBL (2000) showed negative balances of P and K but also negative balance of N.

Organic farming had relatively lower energy inputs when practiced as a more extensive system (Delgaard 2003), but also lower energy outputs (yield). On the sample farms we observed differences in yield levels between farms but also quite high yield fluctuations within each farm. Energy use efficiency (output/input ratio) ranged from 6.6 to 16.2 (both farm 2).

The results show the extent of variability between existing organic farms. The most balanced nutrient management was achieved on farm 3 but the highest energy efficiency averaged over 3 years was on farm 1 due to the low level of inputs used.

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Table 1 Nitrogen balance (kg.ha^{-1})

	Farm 1	Farm 2	Farm 3
2004 – whole farm balance	2.73	30.33	18.56
min and max single field balance	-2.32 ; 19.01	-135.33 ; 234.00	-47.24 ; 118.17
2005 – whole farm balance	6.57	85.33	21.23
min and max single field balance	-11.55 ; 79.28	-87.57 ; 285.80	-53.18 ; 153.78
2006 – whole farm balance	8.43	1.86	5.58
min and max single field balance	-14.48 ; 86.21	-251.02 ; 245.83	-37.11 ; 87.18

Table 2 Phosphorus and Potassium balance (kg.ha^{-1})

	P balance			K balance		
	Farm 1	Farm 2	Farm 3	Farm 1	Farm 2	Farm 3
2004	-9.62	-0.23	1.42	-10.98	-42.16	14.89
2005	-9.72	14.46	-0.05	-46.38	63.37	-23.28
2006	-9.4	12.76	-6.29	-31.11	-26.19	-29.24

DELINEATION AND HYDRAULIC CHARACTERIZATION OF MANAGEMENT ZONES AT FARMER SCALE FOR OPTIMIZING THE IRRIGATION SCHEDULING

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INTRODUCTION

The goal of Precision Agriculture is to optimize the use of soil and water resources and chemical inputs on the basis of spatial patterns in soil properties. It then becomes very critical to characterize soil variation with precision, both quantitatively and spatially in order to identify management zones (MZ), defined as homogeneous subfield regions that can be uniformly managed.

Numerical models are increasingly being used to simulate water and solute movement in the soil for a variety of applications in research and soil/water management. SWAP(Soil Water Atmosphere Plant; van Dam et al. 1997) is one of the physically-based models, available at present, that describes the soil water/solute flux through the application of Richards'equation.

The objectives of this paper are: (i) to study the scale-dependent correlation structure of some soil variables and then delineate the management zones within an agricultural field and (ii) to characterize the MZ from a hydrological point of view and to apply the SWAP model to simulate the soil water balance for a typical cultivation in Southern Italy.

MATERIALS AND METHODS

The present study was conducted on a 12 ha field cropped with scarola (*Cichorium endivia* var. *latifolium* Hegi cv Growers Giant) in a private farm located in the coastal area of the Puglia region in Southern Italy. The soil samples were taken up to 0.30-m depth in 50 georeferecend locations, so that they were distributed on the nodes of a 10-m mesh grid. In this paper we used the following parameters: coarse and fine sand contents (%), clay contents (%), field capacity (%) (FC) and wilting point (%) (WP).

The multivariate spatial data were analyzed by cokriging and Factor Kriging Analysis (FKA,) which is a geostatistical method developed by Matheron. The three basic steps of FKA are the following: (1) modeling the joint spatial dependence (coregionalization) of the set of variables; (2) analyzing the correlation structure between the variables, by applying Principal Component Analysis (PCA) at each spatial scale; (3) using a set of cokriging specific factors at each characteristic scale and mapping them.

These three MZ have been characterized from a hydrological point of view utilizing the model ROSETTA in order to derive the three couple Mualem-van Genuchten functions starting from average values of textural data, field capacity and wilting point. With such hydraulic parameters, three different continuous simulation runs of SWAP were carried out over a ten year period for each MZ adopting the automatic irrigation option with crop parameters (for simple growth module) collected in the same farm.

RESULTS AND DISCUSSION

The resultant MZ map depicted three MZ of ~3.9 to 4.3 ha each, characterized by different properties: the southern zone, finer textured and richer in OM (high); the central zone, coarser textured (low), and the northern part, with intermediate properties and larger heterogeneity (medium). The hydraulic retention and conductivity functions for the low and medium MZ resulted in comparable and typical results for sandy soils, with high values for parameters n (1.45 and 1.39), α (0.06 and 0.05 cm^{-1}) and saturated hydraulic conductivity, Ks (301 and 242 cm d^{-1}) and low values of saturated (0.44) and residual (0.03) water content (θs and θr, respectively). The hydraulic function of the third MZ was significantly different with lower parameters, especially for n (1.33), α (0.03 cm^{-1}) and Ks (102 cm d^{-1}). At the contrary, θs (0.45) and θr (0.04) were considered similar to those of the other MZ. The resulting soil water retention for a profile of 70 cm calculated as difference between field capacity (h=-300 cm) and wilting point (h=-15000 cm) was 63, 65 and 99 mm, for low, medium and high MZ, respectively.

Significant difference was found between the high MZ and the other ones with particular reference to irrigation management (depth and time of irrigation) as shown in Fig. 1 of one year in the simulation. The average irrigation depths were 77, 89 and 136 mm for low, medium and high MZ, respectively.

In conclusion the resulting management zones can be used to characterize spatial variability in physical and hydraulic properties, which may potentially have an impact on crop yield and soil management, optimizing the irrigation practice in terms of depth and time, and consequently saving irrigation water and/or increasing the water use efficiency.

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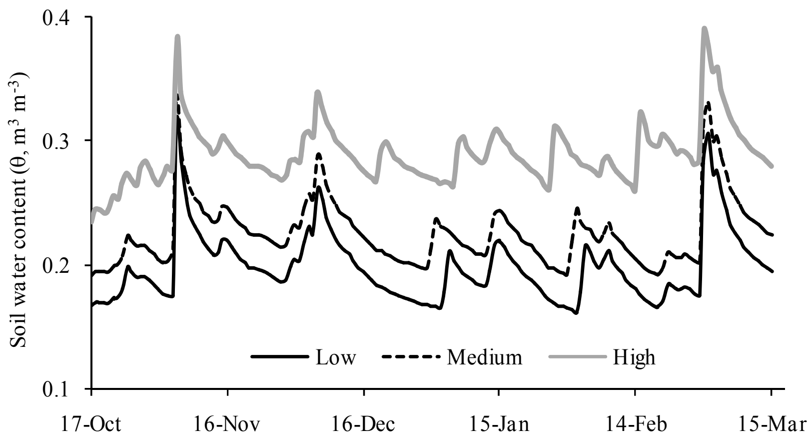

Fig. 1 – Temporal pattern of soil water content for MZs in the 1986-87.

COSMOS, A SPATIALLY EXPLICIT MODEL TO SIMULATE THE EPIDEMIOLOGY OF *COSMOPOLITES SORDIDUS* IN BANANA FIELDS

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INTRODUCTION

Understanding the epidemiology of pests is of special importance for better management (Madden, 2006). The spatial component of epidemiology is a crucial element in the spread of damages from a localised inoculum or when pest dispersal is limited (Winkler and Heinken, 2007). In some cases, individual behaviour of pest leads to the emergence of population-level properties, and the individual-based modelling (IBM) is an interesting approach for understanding emerging properties of a system.

In this study, we use an individual based model (IBM) for studying the epidemiology of *Cosmopolites sordidus* (Coleoptera: curculionidae) (Germar, 1825) (Vinatier et al., 2009). *C. sordidus* is a major pest of banana cropping system. This IBM called COSMOS was designed using bibliographical data on the pest and was validated at field scale. COSMOS is used to answer the question: How agricultural practises affect epidemiology of a pest? We focus on spatial arrangement of plantation and spatial organisation of trapping.

DESCRIPTION OF THE MODEL

COSMOS is based on simple rules of local movement of adults, egg-laying of females, development and mortality, and infestation of larvae inside the banana plants. Model is validated on a dataset of infested plots during two consecutive cropping cycles. Sensitivity of the model to each biological trait is analysed using the Morris method. A module allows the simulation of pheromone trapping of *C. sordidus*. Each trap is spatially located and has a finite attractivity that decreases with the distance to the trap. The trapping module was calibrated using data from Tinzaara et al. (2005).

In a first step, we simulate three spatial arrangements of plantation based on farmer practises: regular (Pattern 1), in double rows (Pattern 2) and in patches (Pattern 3). We hypothesise that spatial arrangement of a plot affects colonisation process of the pest and we calculate the time necessary to colonise the whole plot and the level of damage during three cropping cycles. In a second step, we simulate an increasing density of regular trapping in a field to evaluate the maximal trapping density beyond which there is no more effect on intensity of damages in the field.

RESULTS AND DISCUSSION

Our simulations on the effect of different spatial arrangements of banana plants on the epidemiology of *C. sordidus* show that planting in patches with a large distance between patches should limit the time necessary for the pest to colonise a new field. In contrast, the simulations indicate that the severity of attacks may increase when banana plants are planted in patches. Our simulations on the effect of trapping density on attacks show that control of damages is not improved beyond 16 traps/ha. However, intensity of attacks increases in all cases and interest of mass trapping in those conditions is discussed.

COSMOS helps to understand links between population structure of pests and management practises of farmers, such as planting and use of pheromone trapping. Further improvements of COSMOS would consist in integrating effects of management practises at farm scale on dispersal abilities of *C. sordidus*, as presence of residues or old banana plant. Management practises at landscape scale should consist in studying effects of fallow as source of contamination for neighbouring plots.

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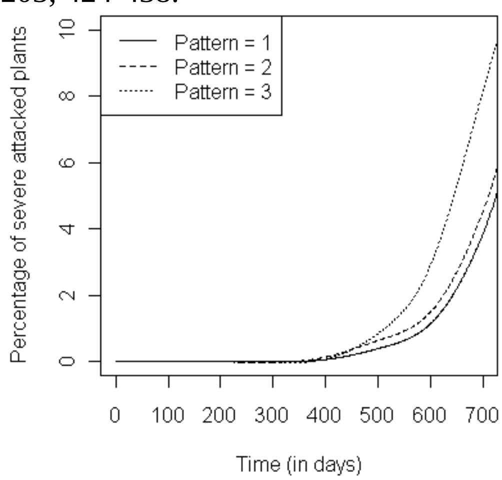

Figure 1 Simulation with COSMOS model of three spatial arrangements of plantation

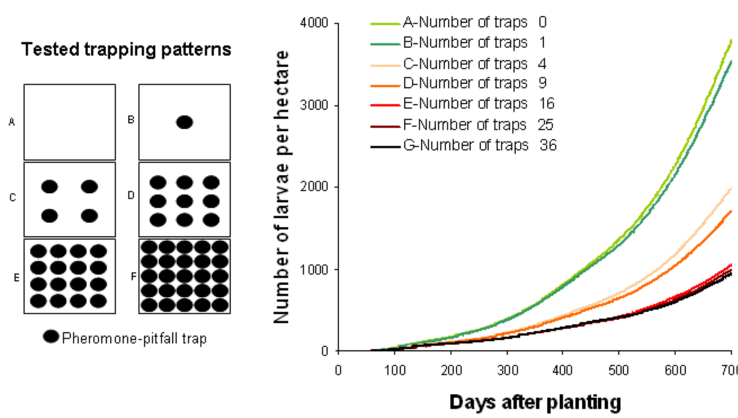

Figure 2 Simulation with COSMOS model of an increasing density of traps.

CONCEPTUAL MODELLING OF A CULTIVATED FIELD: A GENERIC METHODOLOGY AND ITS USE IN AGRONOMY

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INTRODUCTION

Modelling is playing an increasing role in agronomic research, teaching and extension services. However, the conceptual representation underlying the modelling tools is still poorly developed, inadequately shared among modellers and weakly disseminated to the users. A methodology has been developed to translate a problem, defined by a biophysical object and a specific question, into a conceptual model giving an explicit representation of the cultivated field, its components (soil layers, plants, roots, pest and disease...) and its dynamic functioning. This model can be co-developed and shared by scientists of different disciplines, who have a partial knowledge of the system's functioning, as well as with experts (farmers, advisors...) having a practical kwowledge of the system or of one of its components.

METHODOLOGY TO BUILD A CONCEPTUAL MODEL

As described in Figure 1, the approach enables to go from the *definition of the problem*, i.e. a specific question on a specific object (e.g. a given type of crop) to its systemic representation; boundaries, environment, components, input, output, relationships and key variables. Phase 1 is the *structural analysis* of the system identifying the active environment (i.e. the biophysical and technical systems acting on the cultivated field), the components of the system and the products and services it provides to its passive environment. A *functional analysis* is then applied in phase 2 to identify actions, flows and state variables which are needed to derive the outputs of the system from the input and their effects on the components, using knowledge on biophysical processes. The third phase is a *dynamic analysis* defining how the status and structure of the system are modified at key stages of the crop development. These steps are conducted during individual interviews or workshops with scientist of various disciplines and experts with a practical knowledge of the crop. A first version of the model allows the identification of fundamental hypothesis of the model and key relationships which can be further analyzed with literature or additional interviews. Hierarchy, parsimony and transparency of the components, variables and hypotheses are key principles in the development of the model. In a fourth phase a *consistency check* between problem and model is conducted to eventually adjust both.

RESULTS AND DISCUSSION

This approach has been tested in a large range of projects differing by (i) the object : e.g. an individual vineyard plant (Delmotte et al., 2009), a grassland field (Merot et al., 2008), an agroforestry field (Lamanda et al., 2009), (ii) the problem to address: integration of interdisciplinary knowledge to define an experiment (Delmotte et al., 2009), formulation of hypothesis and data analysis in an agronomic diagnosis (Rapidel et al., 2006), definition of the system to be simulated by a numerical model (Merot et al., 2009), definition of the system and its adjustment in a prototyping program (Blazy et al., 2009) and (iii) the actors using the model (researchers, engineers, students).

This method of conceptual modelling proved to be generic enough to be applied to this range of objects and objectives provided the three key principles are followed : (i)*Hierarchy*: sufficient knowledge on the crop is needed to identify the major components, drivers and functions for the problem to be adressed, (ii) *Parsimony*: the model should remain as simple as possible to be further used for the definition of an experiment, of a survey or for its translation into equations (iii) *Transparency*: in order to be shared with scientists for its evaluation or to be trusted by users, the model should make explicit the basic hypothesis underlying its structure and functions ("what is in and what has been considered as less important"). The representation of such type of model on a graphical mode is not easy, especially for the functional and dynamic dimensions, and we are currently looking for tools more adapted than the animated power point presentations which were developed for the above-mentioned projects.

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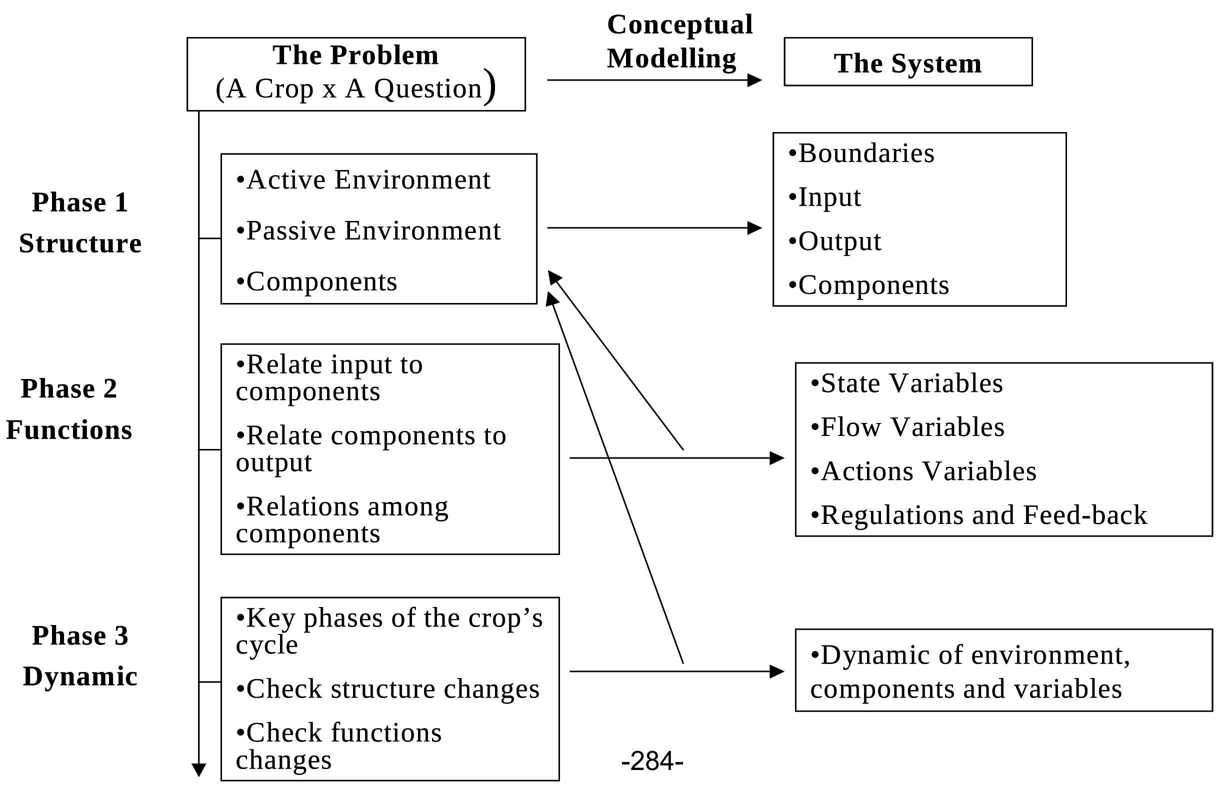
Figure 1 : Conceptual modelling allows to translate a problem in a system with a structural, functional and dynamic analysis of a cultivated field.



MODEL BASED ASSESSMENT OF SILAGE MAIZE YIELD POTENTIAL WITH SPECIAL REFERENCE TO WATER USE

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INTRODUCTION

A strong promotion of renewable energy production by the European and German energy policy led to a substantial increase of crops grown for biogas production in Germany. An economical and ecological sustainable expansion of biogas production requires high biomass yields and low losses of nitrogen and carbon along the whole line of production. To investigate nitrogen and carbon flows in the system of “soil-plant-fermenter” as well as yield potentials and corresponding limiting factors in different biomass cropping systems, within the joint project (BIOGAS-EXPERT) a multi-factorial (location, crop rotation, nitrogen-amount, nitrogen-form) field experiment was established. For a better understanding of the matter flows within biogas production systems and later on for a regionalization of the results out of the field experiment system orientated models are appropriate tools. Modular structured and programmable models are necessary to integrate fragmented research efforts to a linked model describing the whole system “soil-plant-fermenter”.

Due to its high yield potential, silage maize is dominating energy cropping in many regions of Germany. The introduction of late maize hybrids is currently considered as an option to increase biomass yield of energy cropping systems. With respect to this strategy, however, water availability may limit yield potential since prolonged leaf area duration may lead to a higher water demand. To investigate the water balance and water use efficiency of different maize hybrids a system orientated crop growth model for maize was developed and parameterized.

DESCRIPTION OF MODEL

An empirical dynamic crop growth model for maize was developed and implemented using the object orientated component library HUME (Kage and Stützel, 1999). Plant development is calculated according to Yang et al. (2004). Dry matter production is based on a light use efficiency (LUE) approach, thereby LUE is assumed to be a negative linear function of the radiation intensity. Leaf area expansion is calculated by leaf dry matter fraction and specific leaf area (SLA), which is assumed to depend on the leaf area index. Root depth growth is supposed to be linear with temperature sum and root length density decreases exponentially with soil depth. The soil water balance is calculated by a potential based soil layer module. The potential evapotranspiration is calculated according to Penman-Monteith. The crop response to water limitation is calculated by using a reduction factor (SWDF) of plant dry matter production. SWDF is calculated as a non-linear function of the ratio between actual and potential plant transpiration, assuming that also for maize a small reduction of transpiration affects dry matter production less than a higher reduction of transpiration (Stöckle et al., 2008).

Model parameterization was principally done by deriving parameter values directly from experimental data. Some parameters were estimated within the model using the Levenberg-Marquard-Algorithm. Three different data sets were used for parameterization. Parameters of rooting depth and root length density were parameterized using a data set including 3 different hybrids and 2 years (1987-88). Parameters for plant dry matter production, dry matter partitioning and leaf expansion have been obtained from data out of the “BIOGAS-EXPERT-project” from 2 sites (KD and HS) out of 2 years

(2007-08). Some relevant parameters for calculating water consumption pathways, e.g. the canopy resistance factor (rc0), were estimated using a 3 year (2005-07) data set consisting of 3 maize cultivars differing in maturity group (mid early, mid late and late) grown under 2 water supply levels (irrigated: soil water held >50% plant available water capacity by artificial irrigation / rain fed: with "emergency" irrigation). SWDF was optimized using the data sets from HS and KD as well as the data set from the irrigation trial (BS). Crop phenology has been parameterized hybrid specific, and soil parameters are site specific.

RESULTS AND DISCUSSION

Model parameterization led to a satisfactory model performance at least for the simulation of drought stress impact on dry matter yield (Fig. 1). In 2006, which was supposed to be a very dry year, the residuals of the rain fed treatments were not higher than those of the irrigated ones. Comparing 2007 and 2008 for the sites HS and KD reveals a better model performance for the dryer year 2008. Nonetheless, some treatments were not very well simulated by the model and a RMSE of 237 g m^{-2} is still quite big. Further investigations are necessary to get an appropriate model performance and therefore a satisfying model validation as well.

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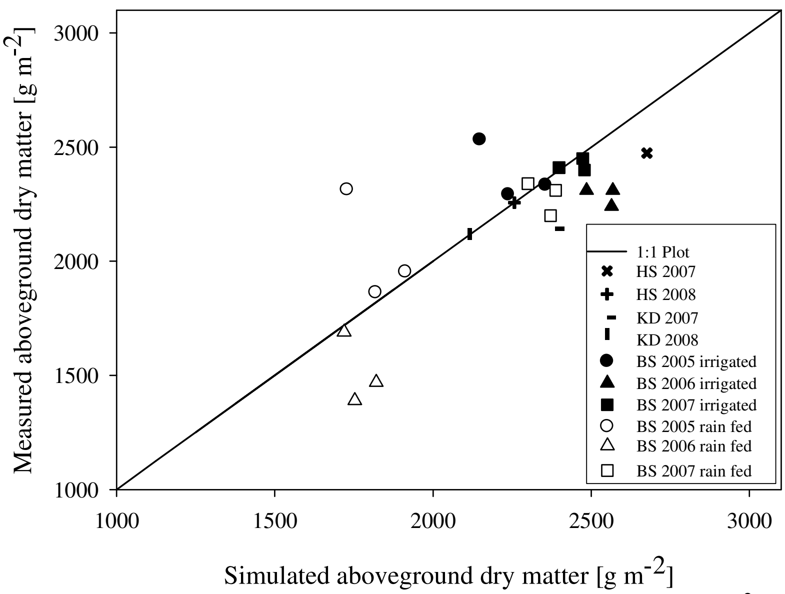

Fig. 1: 1:1 plot of measured and simulated aboveground dry matter yield [g m^{-2}]. Data set of 3 different sites (HS, KD and BS) out of 4 years (2005-08). For BS irrigated and rain fed variants are shown, same symbols hide different hybrids. RMSE: 237 g m^{-2}.