Farming Systems Design 2007
An International Symposium on Methodologies on Integrated Analysis on Farm Production Systems

Farm-regional scale design and improvement

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LA GOLIARDICA PAVESE
Foreword

The Farming Systems Design Workshop is the result of a joint effort among the American Society of Agronomy (ASA), the European Society of Agronomy (ESA), and the International Environmental Modeling and Software Society (IEMSS). This meeting is a result of the joint efforts between ASA and ESA to promote more interaction between the agronomic societies and we are fortunate to have the interest of IEMSS as a partner in this effort on Methodologies for Integrated Analysis of Farm Production Systems in this inaugural effort. We are deeply appreciative of the offer from the University of Catania, Faculty of Agriculture, and the Società Italiana di Agronomia to provide the venue for this meeting.

There is a growing interest in agricultural systems that serve multiple purposes, in the context of driving factors such as climate change, liberalization, environmental concerns, and changing agricultural institutions. Farming systems are continuously being pressured to innovate and change to meet a variety of ecosystem services. The drivers strongly affect agricultural and environmental policies, as these must support the sustainability of agricultural systems and their contribution to sustainable development in general. This places a demand on research approaches that enable analysis of current farming systems, exploration and design of alternative ones as well as new co-learning and dissemination strategies. These research approaches must provide capabilities for assessing the economic, environmental and social aspects of farming system’s evolution in different spatial and temporal contexts. Today, a variety of quantitative and qualitative methods exist, but there is a lack of integration in evaluating issues which range from strictly technical to social, and to landscape related attributes. Our for this symposium are to: 1) Provide an opportunity to integrate knowledge across disciplines targeted at farming system analysis, design and innovation; 2) Compare approaches being used/developed in different research groups; and 3) Identify the available operational tools and the future research needs. We hope to integrate across biophysical and social domains using quantitative and qualitative approaches from the developed and developing world because we believe there are valuable lessons to be gained from many different perspectives.

Farm-regional scale design and improvement, involves considerations operating at whole farm scale, such as trade-offs between economic, environmental and social aspects of farm operation; interactions with policy, community, landscape, and markets; action research and participatory methods; adapting to climate change; crop-livestock integration. Field-Farm scale design and improvement involves issues operating at field scale, such as optimising production systems, novel systems, production system sustainability and externalities, tools, participatory research. These will be discussed through plenary, oral, and poster sessions covering each of the topics shown in the program.

This effort would not be possible without the dedication and enthusiasm provided by the Scientific Committee. We are indebted to the following individuals for their service on the Scientific Committee.

- John Antle, Montana State University Bozeman, USA
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• Claudio Stockle, Washington State University, USA
• Martin van Ittersum, Wageningen University, The Netherlands
• Jacques Wery, UMR System (Agro.M-Cirad-Inra), France

Most of all we express our appreciation to the participants in this symposium and your willingness to share your information for this meeting. We look forward to the fruitful interactions during and following this meeting as we begin to share your thoughts and ideas on how to improve farming systems.

Jerry L. Hatfield       Marcello Donatelli       Andrea E. Rizzoli
ASA                       ESA                                IEMSS
Key notes
CRITICAL REFLECTION ON MODELLING SUPPORT IN LAND-USE DECISION-MAKING

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Introduction
Over the past 30 years, there has been a consistent rationale to justify much of the research undertaken in the field of agricultural systems analysis. Such rationale proposes that decision-makers, whether farmers, policy-makers, or other stakeholders, struggle with the complexity and uncertainty inherent in agricultural systems and would welcome access to technologies which lessen this burden. Consequently, it is argued that the management of land, whether at the field, farm or regional scale, can benefit from science knowledge and models. However, the adoption by farmer and policy clients of Decision Support Systems (DSS) derived from science models has been a disappointment to many developers and a number of assumptions underpinning this rationale have been challenged and solutions proposed (van Ittersum et al., 1998; McCown et al., 2002; Parker et al., 2002; Walker, 2002; Rossing et al., 2007).

A brief foray into the literature reveals that the nexus between science and policy is a field of significant study and that the troubled relationship between science-based decision support and political decision-making in agricultural land use is more often the typical situation than not at the broader science-policy interface (Hoppe, 2005). The objective of this paper is to try to discern possible intervention approaches using systems models into the agricultural policy domain.

Different science intervention models for POR
A number of approaches can be identified as having been employed by researchers in agricultural land use studies in engaging in policy-oriented research using their systems modelling tools. Based on the work of Hoppe (2001) we have represented these approaches as five diagrammatic models based around the interface between two spheres representing the science sphere occupied by researchers and the policy domains staffed by analysts and advisers (Figure 1). Type A symbolizes the likely traditional status quo in agriculture land use studies whereby science operates within its own sphere, aimed at creating knowledge and tools, whilst policy operates in a separate sphere with analysts (many science trained) generating policy advice for political decision-makers. The link between the two is via the large arrow, signifying that analysts go looking for knowledge and tools from the science sphere on a needs basis and bring what they want back into their sphere for use.

The history of development of agricultural decision support systems has largely operated with scientists designing and developing DSS tools for expected use by decision makers, either at the farm or policy scale. Type B represents a common, though maybe extreme view of DSS tools developed in the science sphere and passed over to decision-makers (dotted arrow) with expectations of uptake. Relative to the investment in tool and methodology development, little effort is usually placed in fostering such adoption or evaluating impacts. Types A and B are modes of operation that largely maintain divergence between the science and policy spheres and much of the past efforts in agricultural systems analysis can be readily categorised to fall within such schema. However, governments and research funders are increasingly demanding more cost-effective outcomes from shrinking public-good funding for research. We can identify three additional models whereby science intervention in the policy sphere has been attempted using systems analysis tools in land management studies.

We all know of prominent scientists who have become embroiled within the political sphere. They have not simply engaged with politicians, they have worked to become part of the political establishment and in doing so have been able to have science heard in political debates. Type C
can achieve significant impacts from efforts emanating from the science sphere but it will remain the path for a select, talented and motivated few amongst us scientists.

Most countries have agencies with mandates to sit between the science and policy spheres (Type D) and this unambiguous mandate to support policy largely distinguishes them from science organisations. They are generally staffed by science graduates who act as analysts, although many of their scientists are active in the disciplinary science activities of knowledge generation and publication despite reward structures often being unrelated to such pursuits. Type D creates two new interfaces: between the science policy agencies and both the science sphere and the policy sphere. At the latter boundary the reality is that, for researchers in most science-policy agencies, their project agenda and funding is set by those in the political sphere. Alternatively, the interface between the science-policy agency and the science sphere offers mutual opportunity for researchers in both organisational types. Lastly, we scientists can engage with advocacy groups who are aligned with our research interests (Type E).

**Figure 1**: Five diagrammatic models based around the interface between two spheres representing the science sphere occupied by researchers and the policy domains staffed by analysts and advisers

**Conclusions**
This paper proposes to help by being more explicit about the alternative interfaces between the science and policy domains. While the traditional bureaucratic arrangement continues and may justify much of the research undertaken within the science sphere, it is arguable that the claims of policy support emanating from such work will continue unchallenged. Taking a participative learning approach is clearly difficult, but we believe there are opportunities at the different interfaces with the policy domain. A key learning is that there are differing roles for scientists within the nexus between science and policy. Organisations with aspirations to fulfil policy needs have to recognise and reward these different roles. For our part, scientists need to see where we and our models fit within the possible interfaces between the science and policy domains. Purposeful intervention in land-use decision-making at a range of scales remains our challenge.

**References**
Designing crop management systems by simulation
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Introduction
The fast change of agricultural context (global change, market globalisation, environmental concerns) implies a constant development of new ways of production in order to guarantee sustainable agriculture. Experimentations and prototyping are useful tools for investigating new cropping systems but they are too slow to give on-time answers to such fast evolution. Modelling and simulating is then an interesting way to propose new agricultural management systems that tackles current social, political and environmental concerns. In the 1980s, large efforts were made to develop biophysical models (Sinclair and Seligman, 1996). Due to the failure of transferring such models or their simulation results to farmers or extension advisors, some researchers extensively studied farmer’s management practices (McCown et al., 2002). They thoroughly analyzed decision-making process from on-farm observations. This led to the concept of cropping systems (Sebillotte, 1990) and to decision making modelling based on decision rules (Aubry et al., 1998). In the last decades, biodecisional models were developed. They link the biophysical and decisional approaches (Bergez and Garcia, 2003). Using such models may help in developing new and innovative crop management systems. This paper presents different methodological works using simulation models to design crop management systems.

Designing crop management systems with simulation

A four-step loop: Designing crop management systems may follow a four-step iterative process (Figure 1):
1. From a seed, generation of one or a set of candidate crop management plans.
2. Simulation of these management plans in soil/climate contexts.
3. Evaluation of the simulated management plans.
4. Choice of some “interesting” crop management options and/or improvement through a new generation process that loops to step 1.

The loop will stop when no better crop management options may be found. The model used may be a biophysical model using look-up table or a biodecisional model using a proper developed decision model. Accordingly, different methodologies may be used to carry out this so-called GSEC loop.

Generation: There are two ways in developing the set of management plans that will be simulated: starting from a seed and improving it step-by-step or creating a huge bunch of management practices (either on date/quantity or rules) and simulating them. In both cases some methods may be used to create or improve the set of management practices that will be tested. A biophysical model generally requires only dates and quantities as inputs management data. Such kind of data was required by Matthews (2002) to qualify the management options of its virtual experiments. To generate this kind of data, boundaries have to be given to these dates and quantities in order to provide realistic management. Different methods may be used such as simple “hand-written” combinatory processes (Ghaffari et al., 2001), agronomical filter and combinatory processes (Dogliotti et al., 2003) or constraint satisfaction programming (Loyce et al., 2003). On the opposite, if one uses a biodecisional model, rules have to be specified. In this case, either thresholds to rules may be given or completely new rules may be provided (Bergez et al., 2006). The former approach belongs to the field of the simulation-based optimization. Several methods are available to optimize
thresholds of rules: branch and bound optimization, systematic optimization, gradient-based optimization, genetic algorithm… The latter approach belongs to the field of control-based optimization and is more a field of artificial intelligence research. Methods such as approximate dynamic programming, reinforcement learning of decision rules may be used.

**Simulation:** There is no specificity in the simulation step. Multi-simulation can be performed for any set of management plans that have been generated. However it is important to design proper experimental plan for virtual experiment.

**Evaluation:** Evaluating a simulated management means affecting it some indicator values. Indicators are chosen to help selecting managements plans that will be kept for a new iteration of the general loop. There are several points to keep in mind (Girardin et al., 1998): 1) Defining some proper indicators is a difficult task when the different dimensions of the sustainability (social, economic and environment) are to be considered; 2) Indicators have to be calculated from the simulation outputs; 3) Calculating the indicator needs to answer several questions such as: How accounting for the climate variability? Should we use a single average value? Do we take into account variance or quantiles of the results distribution?

**Choice:** The choice step consists in selecting one or several simulated management plans, qualified by indicator values. Ranking, sorting, choosing are typical questions of multi-criteria decision analysis (Schärli, 1995). The main problem in choosing on multi attributes is that the notion of optimal is no more valid. Some crop management plan may lead to good results for some attributes and less good results for some other attributes. Most of works on this are based on multi-criteria decision aid (or making) methods (MCDA or MCDM). This is a crucial methodological issue, particularly to automate the designing loop. Unfortunately, for crop management systems, only few works on this exist (Sadok et al., 2008).

**Conclusions**

Using simulation to design crop management is an alternative way of designing crop management than experimentation and prototyping. Current research issues deal with uncertainty and multi-criteria analysis. Another important point is that there is still a large gap of knowledge concerning biotic interaction and modelling. If one wants to design crop management plans, pest management has to be accounted for. Specific frameworks should be developed to help in running the GSEC loop. This is the case of the French RECORD platform that has been designed as a modelling and simulation software platform where researchers can build, assemble and couple their own pieces of model to pre-existing ones, and can simulate the resulting models (see poster in this symposium). Once some management plans have been designed, they still have to be tested and adapted to real farm as modelling is a “simplification of the reality”. Using simulation model is just a step. Involving social sciences scientists is necessary to “bridge the gap” between the simulation results and the on-field application.

**References**


INTEGRATED ASSESSMENT OF FARMING SYSTEMS

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Introduction
Farming systems around the globe differ enormously – driven by the natural, economic, social and political conditions within which they operate. As a result they show a broad range of resource endowments, available technologies, designs and performance. Common features of all farming systems are that they manage natural and economic resources and conditions that vary in time, with limited production alternatives while facing relatively low profit. They have to adapt to either unstable or unstructured policy environments or to policy environments that aim at enhancing the economic, environmental and social sustainability of farm systems and, more importantly, the contribution of farming systems to sustainable development at large. They must adapt and innovate within this changing context. Both the variation in farming systems and the common characteristics of farms lead to uncertainties about the effectiveness of decisions, from a farmer’s and from a policy perspective. The assumption underlying our contribution is that ex-ante integrated assessment of farming systems can reduce these uncertainties.

Integrated assessment and modelling has been defined as an interdisciplinary research approach enhancing the management of complex environmental systems (Parker et al., 2002). Integrated assessment is a notion stemming from the climate change, environmental pollution and water management domains and it has been used relatively little in the context of agricultural and farming systems. Agricultural science has a history in applying systems analysis. Although the concept of integrated assessment has been used rarely, many studies of agricultural systems hold an integrated perspective and could serve integrated assessments.

We introduce some key requirements for integrated assessment of farming systems aimed at reducing the uncertainty about the effectiveness of innovation decisions and policy proposals, and illustrate approaches taken through recent examples.

Methodological requirements for integrated assessment
Integrated assessment of farming systems may have at least two categories of aims and associated users. First, to contribute to the design and innovation of farming systems, with farmers, applied researchers and stakeholders working with farmers as major users. Second, integrated assessments may target assessment of alternative policy options, with policy experts, policy researchers and stakeholders being the major users. We suggest the categories have some overall methodological requirements for research supporting integrated assessment. First, the methods must treat the economic, environmental and social dimensions of sustainable development in a balanced way. Many of the quantitative methods currently used are biased towards either the economic or environmental aspects and largely miss out the social issues. Second, methods must have the capability to analyse across multiple scales. At farming systems level decisions are endogenous, whereas farming systems are composed of activities at field or animal herd level for which decisions are exogenous. Prices are exogenous at individual farming system level, but endogenous at market level. Further, farming systems shape the agricultural landscape jointly with other land uses. As a result of this, research methods for integrated assessment of farming systems require multi-scale capabilities. Thirdly, model-based research for integrated research must be performed at the proper level of detail for the questions at stake. Too much detail bears the risk of compromising on modeling the most important processes whereas overspecification and too much complexity of the models results in data demands that cannot be met. Too little detail implies that relevant indicators may not be assessable with the required reliability. This requirement relates to the fourth issue: usability and usefulness of the research tools. To meet this requirement the tools should be targeted at well-specified questions, have credibility, transparency and be well-embedded in innovation or policy processes. Finally, since questions at stake usually change rapidly over time - both for innovation and policy development - re-use and flexibility of the tools is important to justify the research investment.
Examples of integrated assessment methods and applications

Examples will be elaborated in our presentation to illustrate the methodological requirements introduced in the previous section. A first example assesses rice-based systems in Ilocos Norte, in the Philippines at three hierarchical levels, i.e. farm, municipal and regional levels (Laborte et al., 2007). The aim of the developed methodology was to explore and assess alternative agricultural land use options and technologies. The analysis was targeted primarily at stakeholders at these hierarchical levels to raise their level of understanding as to options for innovation, and associated policies that might stimulate such innovation. The second example aimed at innovation of vegetable farming systems in Uruguay. Alternative vegetable farming systems, with or without integration of livestock, are assessed in terms of their economic and environmental performance and tested as to their social acceptability through an interactive process with farmers (Dogliotti et al., 2005; Sterk et al., 2007). In a third example a model-based system is developed to assist understanding of smallholder farming systems in Africa, focusing on heterogeneity within such farms and between farming households as well as their functioning in time (Giller et al., 2006). This is used to identify key entry points for improving performance of the farms, and to explore policy conditions that enable or constrain innovation by farmers. The fourth example assesses alternative policy proposals in the European Union, for the broad range of farm types that differ in size, intensity, land use and specialization. For this purpose an integrated framework (SEAMLESS-IF; Van Ittersum et al., 2007) is being developed that allows the assessment of agricultural systems at field-farm-regional and market level. The framework includes both field level simulation models, bio-economic farm models, a market model and a procedure to link from the micro level to the macro level, i.e. to simulate farm-market interactions.

Reflections and challenges

To conclude we discuss the main challenges for the development of quantitative methods for integrated assessment of farming systems, within the context of several sessions of this Farming System Design symposium. We suggest that joint consideration and analysis of economic, environmental and social issues is achieved with increasing insight. Economic and environmental issues are assessed in a more balanced way (though a lack of consistent micro-macro linkages still hinder developments). We argue that social indicators could be assessed to some extent through post-analysis interpretation of model results with users and stakeholders, and the use of primary data sources. This would allow estimation of social indicators related to acceptability of innovations and policies, institutional compatibility, education and gender. A major challenge for multi-scale capabilities is the scaling of information from field to farm and from farm to higher levels of organization. General principles and methods are hard to identify as best methods often depend on the question and conditions at stake. Linking micro (farm) and macro (market) analysis is currently addressed with econometric procedures using statistical representation, but remains to be validated. The last three issues: integrated assessment with proper degree of detail; usefulness and usability; and re-use and flexibility are interrelated. Issues of availability of consistent data, software requirements and transparency are key. Model-based analyses are powerful learning tools in interactions with stakeholders, in theory, but proper and iterative embedding of research efforts in integrated assessment processes is equally important. This highlights a challenge for the interface between science and society in which we as researchers have an ambition to play a role.

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INTegrated Assessment of Agricultural Systems: A Challenge of System and Model Complexity

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Introduction

There is an increasing demand for the integrated assessment of complex agricultural systems. Integrated modeling approaches are a common tool to deal with this type of analysis. However, despite the fact that simulation models are simplifications of reality, we see that these models become increasingly complicated. Additional processes are included to make the models generic and to describe properly the observed variation in these agricultural systems. The complexity of these models coincides with an increase in data requirements. As a result of the almost unrealistic data requirements, many applications are unable to collect the input data. Several approaches are being used to deal with the data requirements. Many studies use default model values for data that were not available and/or difficult to measure. In other studies transfer functions are used to estimate e.g., complex hydrological properties on the basis of soil texture and organic matter contents. In the case of significant spatial variation, studies use a limited number of representative locations (e.g., representative weather stations, representative soil profiles, or farm types). The question that remains is whether we should search for simplifications or whether we should look for more simple models that are capable to run the key processes using mostly available data?

In this study, we looked at the Tradeoff Analysis Model and its application to the potato-pasture-wheat system in the Peruvian Andes (Antle et al., 2007). Crop growth simulation models, econometric simulation models, and mechanistic erosion models are integrated through the Tradeoff Analysis Modeling system (Stoorvogel et al., 2004) to properly describe this complex system. The advantage of the integrated modeling approach is that we can evaluate a wide range of alternative scenarios ranging from climate change, terrace adoption, to economic policies. The key question that remains is whether we need such a complex modeling system if we are interested in a specific policy or research question. To illustrate this we will look at the specific issue on the adoption of terraces.

Methodology

The study focuses on the semi-arid La Encañada watershed in the Cajamarca region in northern Peru. The 10km² watershed ranges between 2,950 to 4,000 meters above sea level and is located between 7°00' and 7°07' southern latitude and between 78°15' and 78°22' western longitude. Average annual rainfall is low ranging between 430 mm/year in the valleys up to 550 mm/year in the higher parts of the watershed. The data used in this analysis were collected through farm surveys conducted in 1997-1999 for a random stratified sample of 40 farm households in five communities in the watershed. The data show that crop yields are low and parcel size is small, as is typical of this type of semi-subsistence agriculture. The analysis reported here is based on the lower-hillside region where cropland is the principal land use. In the last decades a large number of fields were terraced to reduce soil erosion and maintain soil fertility. The Tradeoff Analysis Model simulates land allocation and management decisions of a population of farmers in a site-specific manner. First, the expected productivity for potato and pasture for the various fields is simulated using calibrated crop growth simulation models from the DSSAT suite of models (Jones et al., 2003). Subsequently, production functions for input demand and output supply are estimated for the three main cropping systems: potato, wheat, and pasture. The expected productivity for the different crops is an important driving factor in these production functions. The production functions can now be used in an econometric simulation model to simulate management decisions under various scenarios. Land allocation is determined on the basis of profit maximization. After simulating land use for the population of agricultural fields, farms can be evaluated in terms of soil erosion by simulating soil erosion for the various fields with the WEPP model (Flanagan and Nearing, 1995). Various elements of the modeling approach are evaluated in this study. Firstly, a simple statistical relationships to assess crop production was assessed rather than crop growth.
simulation models with their high data requirements. Secondly, a simple minimum data approach was developed in which the econometric simulation model was simplified to a model that calculates the opportunity cost related to the switch in farming practices. The modeling approaches are applied to evaluate the adoption of terraces under different prices of terracing.

Results
The results show that the inherent productivities calculated by the crop growth simulation models are strongly correlated to a few environmental properties representing the local weather and soil conditions. This correlation indicates that for specific questions we can use the environmental characteristics rather than the inherent productivities as input for the econometric simulation model. However, the statistical relationships are not useful if we deal with changes in agricultural management or climate change. We obtain similar results if we simplify the econometric simulation model to study the adoption of terraces. A relatively simple analysis of the opportunity cost to switch practice presents similar results as the rather complex econometric simulation model. We can describe the processes being modeled in terms of their spatial and model complexity. Spatial complexity refers to the spatial heterogeneity and dependence observed in biophysical conditions (e.g., topography, soils, and climate) as well as in economic and related human dimensions (e.g., prices and market institutions). Model complexity refers to features of model processes such as nonlinearity, dynamics, feedbacks, and spatial dependence. The various combinations of spatial and model complexity require a specific model design. This is illustrated with the Peruvian case study but also in an earlier study dealing with payments for environmental services (Antle and Stoorvogel, 2006).

Conclusions
If we deal with very specific research questions, the complex potato-pasture system in the Peruvian Andes can be described by a relatively simple model. However, a more generic but also more complex model becomes important if we broaden the research questions. There is a general demand for simpler methods that provide adequate approximations. Alternative, minimum data approaches based on relatively simple empirical approximations to the relevant spatial distributions may be a new innovative way to deal with these problems. While further research will be needed to assess the adequacy of this type of simpler modeling approaches in different ecological and economic settings, the results suggest that this type of approach may often suffice and in fact be the only one feasible to support policy decision making, given time and other resource constraints.

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MODELLING FOR INNOVATION IN DESIGN AND CONSTRUCTION OF CROP PRODUCTION SYSTEMS

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The role of models in innovation has become widely recognised in many fields (Schrage, 2000). Schrage notes that innovative prototypes create innovative teams and treating prototypes as conversation pieces caters for the complex human interplay required in innovation. This is his notion of serious play. Hence, model prototyping and simulating are important, but not sufficient, factors underlying innovation. Focusing on participation of key players, and realising the central roles of dialogue and co-learning, are equally important factors in the innovation process.

These general concepts have now been largely accepted and adopted in various approaches leading to the development of improved cropping practices with farmers (e.g. Hammer, 2000; Keating and McCown, 2001; McCown, 2001; Meinke et al., 2001; Carberry et al., 2002; Nelson et al., 2002). Scientists can bring potential innovation to farming systems practice, but this must be explored within the context of the real farming system. Simulation-based discussion provides an effective means to achieve this.

But farmers and their advisers are not the only relevant players in using models as tools for production system innovation. Hammer et al. (2002) set out a case for the use of models in understanding genetic regulation and aiding crop improvement. Physiological dissection and modelling of traits provides an avenue by which crop modelling could contribute to enhancing integration of molecular genetic technologies in crop improvement (Yin et al., 2004; Hammer et al., 2005; White, 2006). Models are seen as a bridge between the explosion in capacity and knowledge in molecular biology and genetics, and its application to plant improvement. Hammer et al. (2006) and Yin and Struik (2007) have recently reviewed the potential for models to help navigate this complexity and a symposium was devoted to this topic at the most recent International Crop Science Congress (see Cooper and Hammer, 2005). There has been a focus on ways to quantitatively link model coefficients with underlying genomic regions (e.g. White and Hoogenboom, 1996; Tardieu, 2003; Messina et al., 2006). It is then possible to incorporate such gene-to-phenotype models within breeding system simulators to compare breeding strategies (Cooper et al., 2002; Chapman et al., 2003; Hammer et al., 2005). Attempts to date have reinforced the need to address the inherent level of detail and quality of crop models for this task (Hammer et al., 2002; White, 2006). It is becoming clear that enhanced rigour in process representation, so that interactions and feedbacks are captured correctly, is required for effective gene-to-phenotype modelling. It is also clear that participatory research and co-learning with plant breeders, molecular biologists and other players in this field is a key aspect of using models for innovation in crop improvement programs (Hammer and Jordan, 2007). Again, the models and simulations become the discussion piece in seeking innovation.

To date innovations associated with the use of models in crop management or crop improvement have been incremental. They have been targeted at either management-by-environment (M*E) or genotype-by-environment (G*E) interactions. While useful changes have resulted in agronomic practice (e.g. Meinke et al., 2001; Carberry et al., 2002) and breeding efficiency (e.g. Campos et al., 2004; Loeffler et al., 2005), progress has been evolutionary.

In this paper we explore possibilities for revolutionary change in cropping systems by using models to help design and construct novel and innovative production systems. We consider that new possibilities for simultaneous consideration of genotype-by-management-by-environment (G*M*E) interactions provide the impetus. It was over a decade ago that Cooper and Hammer (1996) outlined the concept of fusing the agronomic (M*E) and plant breeding (G*E) perspectives of crop improvement into a single G*M*E (or G*E*M) approach. They outlined the concept of crop improvement as a search strategy on a complex adaptation or fitness landscape. The landscape consists of the phenotypic consequences of G and M combinations in target E. The phenotypic consequences of only a very small fraction of all possible G*M*E combinations can be evaluated...
experimentally. Hence, most of the fitness landscape remains hidden to its explorer. However, technical developments in molecular genetics, computing, crop physiology and modelling now allow us to glimpse much more of the adaptation landscape in seeking ways forward. Here we set out thinking and initial steps in this regard for an on-going case study for the sorghum industry in NE Australia, where modelling is being used to aid industry planning and to help design and construct novel production systems for environments where water limitation is a dominating factor.

References


Session 1.1:
Integrated assessment of agricultural systems: environmental and socio-economic trade-offs, part I

Session Convenors:
Maria Blanco and Martin van Ittersum
EVALUATION OF THE CROPLAND MODELING COMPONENT OF THE U.S. NATIONAL SCALE CEAP PROJECT

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Introduction
The USDA-NRCS is partnering with other US government agencies to conduct a national scale assessment of environmental benefits of 2002 Farm Bill programs. The resulting Conservation Effects Assessment Project (CEAP) uses the National Resources Inventory as a sampling base and the Agricultural Policy Environmental Extender (APEX, Williams et al., 2000) simulation model to evaluate on-site benefits of conservation practices in cultivated croplands. Use of a simulation model for a range of crops and management systems requires robust parameterization and a large number of assumptions and abstractions, which require prior assessment. Different evaluation criteria are used to assess the approach, e.g. the general correctness of simulations in terms of various output attributes, and the relative sensitivity of the model to the various management practices. The goal of this collaboration is, therefore, to provide an in depth review of the modeling approach: the underlying databases, the model’s processes, assumptions and abstractions.

Methodology
We used a preliminary version of the APEX model, the database assembled in 2003 underlying the cropland component of the CEAP (http://www.nrcs.usda.gov/Technical/nri/ceap/cropland.html), and USDA-NRCS proposed parameterization and scenarios to run the model. The database is a data collection of over 4600 sites throughout the US, representing different crop rotations, tillage operations and implemented conservation practices.

When limited field data are available on the outputs of the simulation, data mining tools and historic research findings can be useful to explore input-output relationships and conclude about the general correctness of a simulation model. Database contents and model outputs are being compared to historic research results collected from international literature and from the benchmark watershed research report collection of USDA-ARS. We also use regression and classification tree methodology as a known data mining tool to explore input-output relationships in the derived nation-wide simulation results in order to identify patterns in which the model yields expected/unexpected results. Variables that are inputs and that are outputs were (and are being) cross examined and systematic omission of variables and selection of data subsets are being continually performed based on prior tree analysis findings. Examples are given for unexpected data correlations, which need to be addressed further in the database and/or the model.

Results
Literature search and comparison can help justify expected data patterns or reveal unexpected data patterns even prior to running the model and analyzing model responses. Figures 1 and 2. show an example of unexpected data pattern. The textural distribution of 1052 soil layers in the CEAP 2003 database according to the USDA textural triangle is shown in Figure 1, showing a wide range of soil textures that are represented. Available water holding capacity (AWC) for each of those samples - formulated as the difference of the volumetric water content at -33 kPa water retention and at -1500 kPa water retention - is shown in Figure 2, as stored in the CEAP database versus as calculated using a commonly used pedotransfer function for US soils (Rawls and Brakensiek, 1982). The comparison revealed a significant difference between the two AWC data series. The narrow range of AWC values in the CEAP 2003 database is unexpected and suggests that revision of the formula used to calculate AWC in the CEAP database is needed.
Developed regression trees were pruned to consist of only 10 terminal nodes. The tree analysis helped to delineate expected and unexpected data relationships, suggesting either the validity of
data/processes/assumptions or initiating further examination of particular types of data and/or processes (Figure 3). Data were limited to corn crop growing sites; 30 input variables were used to identify the most significant factors in determining differences in grain yield. Two unexpected data patterns were identified, along with a number of expected patterns. Data and model solutions are being examined in more detail to identify and remove the cause of such data patterns.

Figure 3. Regression tree analysis of the most significant factors – out of 30 variables - related to corn grain yield. Enframed are data patterns that oppose historic findings.

Conclusions

Historical research results and regression tree analysis are tools that can be successfully used to analyze and judge model input/output relationships. Such approach helps improve modeling solutions and successive versions of the underlying input databases for large scale environmental impact studies. Future research includes further analysis of the underlying data and model process solutions with other solutions that exist in the literature. Results of existing and new sensitivity analyses will also be used to describe the expected impact of model abstractions and choices of model parameterization on the model output. Influential parameters and processes will be examined in detail and potential alternative solutions sought. Due to the ongoing development of the APEX model and related databases the presented results at this point are only considered indicators of the capabilities of this methodology rather than conclusive results.

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INTEGRATED EX ANTE ASSESSMENT OF AGRO-MANAGEMENT INNOVATIONS BY COMBINING CROP, FARM AND ADOPTION MODELS

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Introduction
To increase the likelihood of adoption of innovative cropping systems by farmers, it is essential to design such systems according to the characteristics and leeway of each farm type (Joannon et al., 2005; Sterk, 2007). To date, ex ante assessment of innovation uses two approaches: i) the use of crop models and ii) the use of sociological or econometric methods. The first approach is sometimes combined with farm models and focuses on the biophysical performance of the innovation. However, it restricts farmer’s behaviour to its economic dimension. The second approach allows capturing farmer’s perception of innovation but with a lack of realism of the system’s performance at field level. The objective of this paper is to present a new method that combines both approaches for an integrated ex ante assessment of different agro-management innovations and under various economic and policy conditions (e.g. evolution of banana price, EU subsidies, pesticides regulations), for the case of banana farming systems in French West Indies.

The approach
The approach developed is presented in figure 1. To enhance the relevance of innovations and their assessment criteria, they are selected after a preliminary diagnosis of farmer’s main issues and crop management diversity, and with the involvement of experts and farmers. This analysis led to a wide range of possible innovations (e.g. rotations, intercropping, organic fertilization, Integrated Pest Management) and three types of evaluation criteria (farm income and costs, labor demand and seasonality and environmental impacts). A farm typology has been developed to model diversity at the territory scale in terms of crop management, pedoclimatic conditions, action models, and farm endowments. The crop model SIMBA was used to simulate the production and externalities of the banana-soil-nematodes system at the field scale (Tixier, 2007). Then, a farm bio-economic model, which included the farm typology, was used to compare both innovative and current cropping systems under real farm conditions. The overall result of this model was a series of indicators that combined results from several fields during several years. These simulations allowed simplified matrix of quantitative impacts of innovations adoption for each farm type, which are then used to develop an econometric adoption model by implementing an exhaustive farm survey (n=770) about farmer’s preferences under different economic and policy outlooks. The adoption model, which is based on utility function maximization (Sidibé, 2005), yielded a probability of adoption for each innovative system as a function of farm and innovation characteristics.

Conclusion
To increase the effectiveness of the innovation design, we assess the probability of adoption of each innovation by each type of farmer by combining three kinds of models never used together before to our knowledge. This approach can be useful for the design and adoption of sustainable farming systems and for agricultural policy making.

References
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**Figure 1**: representation of tools and models chain for integrated *ex ante* assessment of innovation

- **Preliminary diagnosis**: Farm survey and field measurements
- **Experts and farmers consulting**
- **Frameworks for innovation design and assessment**:
  - Hierarchy of agri-environmental problems
  - Diversity of farmer’s practices and leeways
- **Assessment criteria**
- **Indicators**
- **Farm typology**:
  - Pedoclimatic conditions
  - Action models
  - Production factor endowments
- **Pilot farms**
- **Biophysical database**
- **Economic database**
- **CROP MODEL**: Quantitative assessment of innovation performances at field scale
- **FARM MODEL**: Quantitative assessment of innovation performances at farm scale
- **Innovations impacts matrix**
- **Econometric survey**
- **ADOPTION MODEL**: Quantitative assessment of farmer’s preferences for innovation
- **ADOPTION PROBABILITIES** = f(innovation, farm type, outlook)
  - Quantitative assessment of innovation performances at territory scale under various policy outlook
MULCH AND COVER CROPS BASED CROPPING SYSTEMS: DO THEY FIT INTO SMALL SCALE FARMS OF THE TROPICS?

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Introduction
Smallholder farming systems in the tropics are characterized by poor productivity and unsustainable soil management. Over the past three decades many attempts have been made to reverse this situation by introducing new, more sustainable cropping systems. However, only few of them were successful. Direct seeding mulch-based cropping systems (DMC) based on no-tillage and with a permanent cover of a mulch of plant residues are increasingly cited as a promising and innovative alternative to conventional cropping systems with tillage. The potential of DMC systems to improve soil fertility and sustain crop productivity is widely cited. It is also often supposed that DMC systems bring an economical advantage to farmers because of savings in energy, labor and operational costs. Yet, while DMC is rapidly disseminating among large, mechanized farms in north and south America and in Australia, their adoption by smallholder farmers in the tropics remains rare.

In this paper we present results of ex-ante evaluations of DMC systems using simulation modeling and linear programming with the aim to gain insight in factors that influence adoption by smallholder farmers in the tropics.

Methodology
Although adoption decisions are complex and depend on a range of personal, economic, social and cultural factors, the degree to which innovative cropping systems provide relative benefits compared to the existing systems is often a determining factor. A systematic ex-ante assessment of the relative agronomic and environmental advantages or benefits of DMC opposed to tillage-based cropping systems can be done through quantitative simulation models that represent the current process-based knowledge.

For the evaluation of DMC systems at field scale we modified the crop growth model STICS (Scopel et al., 2004) to simulate effects of surface crop residues on soil water, carbon and nitrogen dynamics and tested the modified model against experimental data from studies on DMC in west Mexico (semi-arid climate) and central Brazil (subhumid to humid climate). As indicators for productivity we considered grain yield and its variation with rainfall. Soil organic matter and nitrogen balances were used as indicators for sustainable soil management. To quantify the effect of DMC on long-term dynamics of soil organic matter we used the linked plant-soil model G'DAY (Corbeels et al. 2006). The performance of the model was tested against data from a DMC chronosequence in central Brazil.

For the assessment of the feasibility and impact of DMC at farm level, we developed a linear programming model, and used this model in a case study in the northern mountain region of Vietnam. In this study different farm types were considered, ranging from subsistence farms to farms that were market oriented. The potential adoption of growing maize under DMC on these farms was analyzed. The objective functions of the model maximized household food security and cash income.

Results
Evaluation of DMC at field scale
Retention of crop residues on the soil surface is the major factor that contributes to a better soil water balance under DMC. Our modeling results showed that under the semi-arid conditions in Mexico, where rainfall variability is high, even small amounts of surface residues are effective at reducing water loss (surface runoff and soil evaporation) giving rise to higher crop yields with smaller risks of crop failure. Under the humid conditions of the Cerrado region in Brazil, potential
gains in water trough a decrease in runoff and evaporation are largely offset by increased drainage losses, with possible leaching of nutrients. As a consequence, under these climatic conditions the impact of DMC on water-limited crop yield is small and the use of cover crops as nutrient recyclers becomes crucial. A reduction of the bare fallow period under DMC by implementation of a cover crop induces positive effects on the nitrogen balance and maize productivity.

Continuous DMC cropping is effective in increasing soil organic matter in the long-term in the context of the large, mechanized farms in the Cerrado region of Brazil. The extra biomass produced through the cover crop allows rates of soil carbon storage of between 0.7 to 1.2 Mg of C ha$^{-1}$ year$^{-1}$. In contrast, our modeling scenarios show that the lower crop productivity as a result of the lower inputs of nitrogen and phosphorus in the smallholder farms of the Cerrados limits the potential of DMC for soil organic matter storage under these conditions.

**Evaluation of DMC at farm scale: a case study in Vietnam**

The linear programming model allowed us to test whether farmer’s objectives are best met by adopting DMC or conventional cropping given the available land and equipment resources and taking into account seasonal cash and labor constraints. The feasibility of DMC for the various types of farms in the study area was highly variable as a result of the (i) strong variation of the agronomic performances of DMC across environments as compared to the conventional systems, and the (ii) strong heterogeneity of the farming systems, especially with regard to their access to markets and assets. In many cases incentives would be required to counterbalance the reduction of farm income associated with adopting DMC during the first years after implementation due to the higher input and labor requirements, especially at planting time, compared with conventional systems. Even though the profitability of DMC may increase with the number of years, the first-year income reduction is likely to determine the attractiveness of DMC for smallholder farmers. Moreover, DMC systems require a greater intensity of management than the conventional systems and may be perceived as increasing the overall complexity of the farming system. More complexity may contribute to an increased risk of non-adoption.

**Conclusions**

Mechanistic, process-based crop growth models are an excellent tool for an ex-ante quantitative evaluation of agronomic and environmental performances of DMC systems at field scale. Our results underlined the great potential of DMC for improving crop productivity through a better water and nitrogen use efficiency. In terms of environmental indicators (soil organic matter and nitrogen balances) the modeling scenarios confirmed the clear advantages of DMC over the conventional cropping systems. Evaluation of DMC at farm scale highlighted, however, the constraints for adoption of DMC as a result of higher labor and cash inputs.

Our ongoing research aims at a more integrated evaluation of DMC, taking into account social indicators and perceptions by farmers and other stakeholders (Lopez-Ridaura et al., 2005). This will allow a more refined understanding of DMC adoption constraints and can help in identifying economic measures that may support adoption of DMC by farmers. Further evaluation of the environmental services provided by DMC systems is also required in order to test whether these services are worth the cost of incentives.

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HELPING PRACTICAL WISDOM: A NICHE FOR WHOLE FARM SYSTEMS MODELLING
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Introduction
In this work we argue that intuitive decision making (what farmers call "gut feeling" and psychologists call "practical wisdom"), seems to be widespread among our relatively aged Australian farmers, while younger growers (probably lacking some of that wisdom which is provided by years of practice) mostly rely on sets of rules governing planting times, identifying planting opportunities, and deciding on levels of investment. In addition to contrasting levels of experience ("practical wisdom"), it can be argued that Australian farmers are being constantly exposed to new uncertainties e.g. new technologies, perceived changes in climate and commodity markets, which might impair the capacity of those "wiser" farmers to identify and make good decisions. In this work we propose that more than ever before there is an urgent need for the generation of more holistic approaches in the analysis of farm businesses to: help less experienced farmers more quickly generate relevant information that translates into knowledge and practical wisdom; and generate farm business scenarios that include the potential impacts of new technologies, changes in climate and markets to allow the more intuitive growers adjust to the new rules of the farming game. Crop simulation models have proven to be essential tools in Australian research and extension programs. The objectives in this paper are to, (i) describe a rule-based framework i.e. the APSFarm whole farm systems model; and (ii) research optimum strategies for adaptation to contrasting historical climate series.

Methodology
Based on a number of interviews with farm managers and consultants, we set up APSFarm to simulate a 2000ha cropping farm business near Emerald, Central Queensland, Australia (23.53 °S, 148.16 °E). The business operates a no-till cropping system comprising three major soil types. The cropping enterprises included sorghum, wheat, chickpea and maize. About one third of the cropping area is dedicated to winter crops. Depending on soil water at planting, double cropping is considered, though summer cropping is predominant. Available farm machinery determines work rates e.g. a planting rate of 13 ha/h, and a spraying rate of 23 ha/h, and incurs an operating cost for every activity. Farm scale economics are monitored, thus the current cash status can be used as an input to management decisions. The management of the farming system is modelled as a set of state and transition networks e.g. finite state machines. Each paddock has a current state e.g. fallow, wheat, sorghum, etc., and ‘rules’ that allow transition to adjacent states. These rules represent both the capacity e.g. availability of machinery, land, labour, and capability e.g. cropping skills, farm business strategies, risk attitude. These rules are usually expressed as a Boolean value (true for feasible, false otherwise), but can also be real valued; higher values representing the desirability of a particular action. Each day, the model examines all paths leading away from the current state to adjacent states, and if the product of all rules associated with a path is non-zero, it becomes a candidate for action. The highest ranking path is taken, and the process repeats until nothing more can be done for that day. In this work we used APSFarm to evaluate the performance of the case study farm business by comparing farmer’s present tactical and strategic management, with an optimised farm business strategies derived from applying a multi-objective optimisation differential evolution (DE) algorithm. The solution of the DE algorithm provided a surface of possible improved trade off options between the ‘objective functions’ i.e. profit, risk, and soil loss. The alternative managements were characterised by different threshold values of available extractable soil water (ESW) to decide the planting of any crop, and the maximum possible proportion of farm area dedicated to each crop enterprise (AP). The model was run for a wet (1986-1995) and a dry (1996-2005) decades. The DE algorithm was configured with a population of 150 individuals, using crossover and mutation rates of 50%.
Results
Table 1 shows present farmer’s management rules for ESW and AP, and the mean value of each variable in the top rank of the final DE population for the wet and dry decades. During the dry years the optimised ESW was similar to the present farm management (Farmer), i.e. similar cropping intensities. However, AP was higher indicating benefits from a more opportunistic cropping system, i.e. whenever a planting opportunity is available the farmer should plant a bigger proportion of available land, this accounts for existing machinery and labour constraints. Lower values of ESW during the wet decade indicate that a higher cropping intensity would further increase profits without significantly changing the risk profile and environmental outputs of the farm. During wetter years, the optimised maximum fraction of land allocated to each crop varied little across enterprises, and was less opportunistic than during the dry seasons.

Table 1. Farmer’s management rules i.e. extractable soil water (mm) required for planting crops, and maximum proportion of the farm area planted (ha) to each crop, before (Farmer), and after optimization for wet and dry decades.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Extractable soil water</th>
<th>Area planted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farmer</td>
<td>Wet</td>
</tr>
<tr>
<td>Chickpea</td>
<td>100</td>
<td>88</td>
</tr>
<tr>
<td>Maize</td>
<td>110</td>
<td>92</td>
</tr>
<tr>
<td>Spring sorghum</td>
<td>110</td>
<td>88</td>
</tr>
<tr>
<td>Early sorghum</td>
<td>80</td>
<td>87</td>
</tr>
<tr>
<td>Sorghum</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Late sorghum</td>
<td>60</td>
<td>91</td>
</tr>
<tr>
<td>Wheat</td>
<td>80</td>
<td>90</td>
</tr>
</tbody>
</table>

Figure 1 shows the average annual operating return with the present farm management, during a wet and a dry decade, and before and after the model of the farm business was optimised, to identify strategies that maximise profits while minimising financial risk (down side risk), and soil loss. During the dry years it would be difficult to significantly improve the profitability of this farm business, suggesting that even our best growers would be highly vulnerable to an increased climate change signal. This also brings up several issues: have we closed the gap between ‘achievable yields’ and ‘farm yields’? and if so, where is the next innovation coming from ?. Present management could still be improved during the wet years. Which gives a good lead into how important it is to be able to identify good seasons early enough to make the most of those opportunities?

Conclusions
So far benefits of developing APSFarm have been threefold: (1) in the process of model design and development APSFarm became the framework that ‘packaged’ the knowledge and discussion whilst allowing the actors to identify opportunities for change and improvement; (2) modelled results provided realistic measures of trade-offs between profit – risk – environmental impact across a number of possible alternative futures; (3) our farmers benefited from the test benching & fine tuning of cropping rules by reducing/accounting for the dimensionality of their complicated production systems.

References
BIO-ECONOMIC ANALYSIS OF CROSS-COMPLIANCE AND AGRI-ENVIRONMENTAL MEASURES AGAINST SOIL EROSION: A CASE STUDY IN SOUTH WESTERN FRANCE

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Introduction
Soil erosion, and its associated impacts, is one of the most important of today's environmental problems. To handle this problem, the 2003 CAP reform has introduced, through the second pillar, a set of compulsory cross-compliance requirements and agri-environmental schemes. Among the nineteen measures proposed by the EU, France has retained nine which have a direct correspondence with soil protection. Using a bio-economic farm model, this study seeks to analyse the technical, economic and environmental impacts of the implementation of grass buffer strips and the establishment of minimum level of soil maintenance. This approach was applied to a virtual arable farm located in the Lauragais' area.

Methodology
The used bio-economic farm model links the crop model “CropSyst” to a mathematical programming model. The crop model was used to quantify, at field level and according to agro-ecological condition, the effects (in terms of yields and soil loss) of the current and alternatives activities defined as a combination of crop soil type, previous crop, agro-management type and production system. The mathematical programming model seeks, after including the generated information from CropSyst as well as other economic data (costs, premiums, prices, resources requirement...), to represent the farmer's observed behaviour and predict his responses under agricultural and environmental policy changes. The principal outputs generated from the bio-economic model are the land use, production, input use, farm income and environmental effects (soil erosion). The economic model takes risk into account through the Mean-Standard deviation method. This approach has been repeatedly applied for farm-level studies and is well suited to embrace mixed ecological-economic analysis (Falconer and Hodge, 2001; De Koeijer et al, 2002).

The general structure of the retained bio-economic farm model1 is formulated as follows:

Maximise: \[ U = p^'y^'x - c^'x + s^'x - \phi\sigma \]

Subject to: \[ Ax \leq B ; \ x \geq 0 \]

Where: \( U \) scalar of the objective function, \( P \) (n x 1) vector of producer prices, \( Y \) (n x 1) vector of yields of each agricultural activity, \( C \) (n x 1) vector of accounting costs per unit for each agricultural activity, \( S \) (n x 1) vector of subsidies per unit for each agricultural activity (depending on the Common Market Organisations (CMOs)), \( X \) (n x 1) vector of agricultural activities' level, \( A \) (m x n) matrix of technical coefficients, \( B \) (m x 1) vector of available resource levels. \( \phi \) scalar of the risk aversion coefficient, \( \sigma \) scalar of the standard deviation of income according to states of nature defined under two different sources of instability: yield -due to climatic condition- and price.

Three policy scenarios were simulated in this study: (1) the implementation of «grass buffer strips along water courses » (i.e. 3% of COP (cereals, oilseeds and proteins crops), fallow, hemp and flax land should be kept as buffer strips); (2) the introduction of «minimum level of soil maintenance »; and (3) the combination of the two previous policy scenarios. These scenarios are performed for the year 2007.

Results
Results of the three simulated scenarios are compared to the reference scenario. Technical results of the first policy scenario show that the cross compliance requirement has been respected, as an area of 3.3 ha of grass buffer strips appeared in the crop pattern. This means that the 5% of penalty is enough to induce farmers to adopt the environmental cross-compliance. In the second scenario “the implementation of minimum level of soil maintenance” shows a radical change of crop pattern illustrated by the dominance of activities including catch crops (durum wheat - radish, soft wheat - radish and maize – radish). The impact analysis of the third scenario shows a crop pattern similar to the second scenario. The only difference is the substitution of barley by grass

1 The model is written in GAMS (General Algebraic Modeling System) language; full details are available from the authors
buffer strips. As expected, the model chooses crop activities including catch crops, as they generate the more profitable gross margins, and the grass buffer strips in order to avoid premium cut. Economic results: As shown in Table 1, the changes of economic results in the first scenario are tiny for the whole selected variables, except for the remained coupled payment which shows a fall of 8%. Farmer’s net income marks a decrease of 2% due to the decline of cereals on the detriment of grass buffer strips. Results of the second scenario show a considerably better performance (intercrop+ conservation system): the farm income increase by 20% explained mainly by the additional premiums received in response to the respect of the agri-environmental measures. The economic changes observed in the third scenario shows a similar tendency as the second scenario. Environmental results: Graphic 1 summarises the environmental performances achieved by the different simulated policies. The introduction of grass buffer strips reduces soils erosion by 13.3%. In the second scenario erosion falls 36.7% (introduction of catch crop) and reaches the 51.5% in the case of the adoption of the conservation system. The effects of combining cross compliance with agri-environmental measures (scenario.3) are more marked than expected. The reduction of soils erosion reaches 65.4%.

Table 1: Economic results of policy and reference scenarios

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>Scen. 1</th>
<th>Scen. 2</th>
<th>Scen. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value</td>
<td>Value</td>
<td>Dev*</td>
<td>Value</td>
</tr>
<tr>
<td></td>
<td>(1000€)</td>
<td>(1000€)</td>
<td></td>
<td>(1000€)</td>
</tr>
<tr>
<td><strong>Total costs</strong></td>
<td>17.4</td>
<td>17.4</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td><strong>Total subsidie</strong></td>
<td>37</td>
<td>36</td>
<td>-3</td>
<td>40</td>
</tr>
<tr>
<td>Coupled subsidies</td>
<td>13</td>
<td>12</td>
<td>-8</td>
<td>11</td>
</tr>
<tr>
<td>Single payment</td>
<td>24</td>
<td>24</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Additional premium</td>
<td>5</td>
<td>5</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td><strong>Farm income</strong></td>
<td>91.3</td>
<td>89.4</td>
<td>-2</td>
<td>97.2</td>
</tr>
</tbody>
</table>

Dev = % deviation compared to reference (%); Cons. Sys = Conservation system; Source: model results

Fig. 1: erosion level of scenarios simulations

Conclusion

The main results of the three scenarios show the good efficiency of the simulated instruments in reducing soil erosion. Even if this reduction may appear too optimistic and may be difficult to implement, the global tendency remains realistic. Indeed, the same results were obtained in others studies showing the beneficial effect of these kind of policies based on a good combination of inputs, in comparison to classical policies such as tax, permit systems or standards,... acting on the outputs (Louhichi et al, 2007). The realistic tendency of results informs us also about the relevance of the bioeconomic modelling approach developed in this paper, which seems to be of great interest to analyse the complex relationship between agricultural production and environment and to assess the impact of agri-environmental policies.

References

A BIO-ECONOMIC MODELING APPROACH TO ASSES THE ENVIRONMENTAL AND ECONOMIC SUSTAINABILITY OF FARMING PRACTICES IN A TUNISIAN WATERSHED.

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Introduction
In agriculture, short-term objectives to increase farm income often conflict with long-term objectives to maintain soil fertility. In semi-arid regions such as Northern Tunisia, deficit irrigation to reduce water use and nitrate leaching may reduce the long-term production potential due to soil salinization. Until now, the impact of water management on nitrate leaching, soil salinization, production potential and economic performance of irrigated farms has not been quantified. This study aims at analyzing the effects of different water and nutrient management on three farm performance indicators, i.e. nitrate leaching, soil salinization and farm income. We use a new analytical bio-economic approach to assess the environmental and economic performance of irrigated farming systems in northern Tunisia (Cebalat region) taking into account inter and intra-annual rainfall variability and different soil types and crop rotations.

Methodological framework
In semi-arid regions with highly variable rainfall, stochastic programming methods are appropriate to study the effect of water and nutrient management practices on farm performance (Li et al., 2005). In this paper, we use a new hybrid methodology based on a recursive stochastic programming method (RSP). In general, a farmer has an expectation regarding the response of the soil-crop system to his/her management decision(s). However, the result of any decision is uncertain because of the partial information at the time of decision-making. The RSP method consists of solving dynamic problems using a series of sequential dynamic optimization sub-models. After the first decision and taking into account the development of the system the farmer can adapt future decision(s) based on newly available information. The recursive stochastic model allows to test the research hypothesis, namely that farmers prefer short-term profit over long-term profit and neglect possible negative effects of soil degradation. In order to assess the sustainability of the system, two different discount rates have been considered: a 10% discount rate (base scenario), reflecting the current situation (farmer’s preference for present over future income) and a zero discount rate (sustainable scenario), illustrating a more sustainable scenario (valuing the future as much as the present).

The modelling approach here combines a linear programming model (LP) of economic farm behaviour with a cropping systems model, consisting of two steps and scales: i) quantification of the relationships between crop production and environmental factors at field level using the Cropping Systems Simulation Model (CropSyst) (Stöckle et al., 2005) for a range of management alternatives taking into account information on previous crops, soil and rainfall characteristics, and ii) application of a recursive-stochastic bio-economic farm model in which farm income is maximized and data of step 1 is used as the set of production activities to select from.

Results
Soil salinization
The rate of soil stalinization is higher in the base scenario. For example, in year 4 the salt content of the soil is 12.6 kg/ha for the base scenario and only 6.2 kg/ha for the sustainable ones due to differences in crop choice and in the amount of water used for irrigation and for salt leaching. In fact, the amount of water used is higher for the scenario of sustainable soil fertility showing that, in this scenario, a portion of water is used not for meeting crop requirements but for soil salinity leaching. This difference reaches 55% for the sequences K20 (dry autumn, wet winter) and K21 (dry autumn and winter). For all crops the amount of irrigation water is higher for the sustainable scenario (Table 1). For oats even 63% more water is used for leaching of salts to sustain the long-term productivity.
Table 1- Comparison of the area and the amount water applied for each irrigated crop using two discount rates, i.e. 0% and 10%.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area (ha)</th>
<th>Amount of Water supply (mm)</th>
<th>Difference* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>Sorghum forage</td>
<td>26.2</td>
<td>33.0</td>
<td>20.7</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>27.4</td>
<td>29.7</td>
<td>7.6</td>
</tr>
<tr>
<td>Oats</td>
<td>6.4</td>
<td>8.3</td>
<td>22.6</td>
</tr>
<tr>
<td>Maize forage</td>
<td>0.80</td>
<td>1.2</td>
<td>34.4</td>
</tr>
<tr>
<td>Berseem</td>
<td>6.8</td>
<td>0.7</td>
<td>-868.6</td>
</tr>
</tbody>
</table>

Nitrogen leaching
Nitrate leaching is lower for rainfed crops than for the irrigated crops as illustrated with rainfed wheat and irrigated maize (Figure 1). The amounts of nitrogen applied and leached for the maize are higher for the sustainable scenario compared to the base one. This difference becomes less important for rainfed wheat showing a very low nitrogen leaching (<10 kg/ha).

Farm income
Figure 2 compares farm income for the two discount rates. Under Mediterranean conditions farm income is correlated with rainfall variability. Income variation for the two scenarios is similar but income difference between the sustainable and the base scenarios increase over time with 45% after 10 years due to a lower soil salinization associated with a more diversified cropping pattern and surplus water application for leaching of salts.

![Figure 1. Amounts of nitrogen applied and leached for irrigated maize and rainfed wheat testing the two types of scenario.](image)

![Figure 2. Simulated farm income over 10 years and testing the sustainable (0%) and the base (10%) scenarios](image)

Conclusions
In this paper, we address the challenging topic of agricultural sustainability by means of a bio-economic approach. The amounts of water and nitrate fertilizer used for the sustainable scenario are higher compared to the base one, except for wheat where the nitrate fertilizer applied is higher for the base scenario compared to the sustainable scenario. However, the gross margin is higher for the sustainable scenario than for the base one. This result is explained by the fact that the profit gain due to an increase in crop yields is higher than the costs of supplement of water and nitrogen observed for the sustainable scenario, procreated by the low costs of water, which is usually greatly under priced in developing countries.

References
IDENTIFYING PATHWAYS OF CHANGE IN MIXED SYSTEMS BY LINKING REGIONAL LAND USE AND HOUSEHOLD MODELS

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Introduction

The demand for livestock products in developing countries is projected to expand very rapidly as a result of urbanization, increased incomes and market access (Delgado et al., 1999). These changes result in high and rapid land use dynamics and may lead to the evolution of production systems in the long term. These changes have consequences for the volumes of food produced, trade and farmers income and are therefore a primary concern for policy makers, researchers and other stakeholders supporting the livelihoods of rural communities, sustainability and the value chains of food production. This study forecasted crop-livestock systems evolution and the associated intensification technologies in the Kenyan highlands in the next 20 years under different development scenarios. Two complementary sets of models operating at different scales were used: regional spatially-explicit models estimated the spatial distribution of farming systems over time, and household and livestock models were used to validate the results of the spatial analysis at the local level, allowing for a more robust description of farming systems dynamics and a realistic identification of farm-level constraints and options at local level.

Methodology

Farming systems in the Kenyan highlands were characterized into 6 groups using survey data from 2866 households and using clustering techniques. The household data were obtained from three surveys conducted in central and western Kenya between 1996 and 2000, as part of collaborative efforts to design policies for the smallholder dairy sector (Baltenweck et al., 2003).

For the regional spatial modeling, location characteristics for the 2866 households were derived from a series of GIS layers. Logit models were used to predict the relative probability of finding the different farming systems at a certain location. They used the farming systems as dependent variable and the spatial variables of each location as explanatory variables. The fitted logit models were subsequently used to calculate the probabilities of finding the different farming systems across the study area based on the variability of the spatial data. The individual probability maps for the different farming systems were combined in an overall map indicating the spatial distribution of farming systems given the relative probabilities and the region-wide prevalence.

For the household modeling (HHM), three case studies were selected for each farming systems group, representing variation within each of the groups. The IMPACT tool (Herrero et al., 2005) was used in each case study to collect detailed household level information on land management, crop and livestock production, household composition and farm labour; inputs and outputs and others. Data from IMPACT were used to run a household model (HHM) for each of the 18 case studies to identify production alternatives as systems evolved. Key aspects determining production choices were prices of commodities and labour availability and price.

Both regional and household models were linked through the formulation of different development scenarios depicting different rates of population growth, market access, off-farm employment, export policies and others (van de Steeg et al 2005). The scenarios were developed in collaboration with policy makers and were based on past trends or trying to mimick proposed or currently implemented policy measures. The scenario analyses dictated how farming systems could evolve in the future, by translating projected growth trends into new spatial data layers for the drivers of the regional spatial analysis; and by the modification of some parameters and restrictions in the HHM analysis. We present the results for the equitable growth scenario as described by the Kenya Poverty Reduction Strategy. The overall methodology is presented in Figure 1.
Results
The regional spatial model predicts that about 25% of the surface area in the region under study is likely to change from one system to another under equitable growth conditions. Of this change, more than 66% of the existing farming systems evolve towards export-oriented farming systems, with the most important trajectories of change from subsistence and intensive farmers with limited dairy activities to export cash-crop farming with limited dairy activities.

Results from the household model show that in small subsistence farms, there could be a shift towards more cultivation of cash crops, even export crops in some cases. Dairy activities could increase only if land can be dedicated to the cultivation of cut-and-carry forage crops. Hired labour requirements could increase, especially if export crops became an option. For households located in peri-urban areas, this scenario could mean a decrease in farm size and more expensive labour costs. The more expensive labour costs makes farmers invest in options that give the highest returns from the land: export crops. In case of farms already exporting crops and that have dairy, dairy can only be maintained if land can be devoted to forage crops, as crop residues do not support the level of production required. The cost of labour could also constraint the expansion of dairy, as its marginal productivity depends on the marginal revenue obtained, which depends on price of milk. In general terms, as these farming systems evolve, they will invest in activities where the productivity of labour is higher, as this input becomes more expensive.

Conclusions
Changes in population density and related factors like investment in infrastructure and market access are important factors explaining the spatial distribution of farming systems and their evolution in the Kenyan Highlands. Land fragmentation has major impacts on system change at household level. The opportunity costs of labour play a key role in determining the choice of enterprises in smallholder households in Kenya.

Integration of regional spatially explicit models and household models provides a suitable base for studying trajectories of change and enterprise choices in tropical production systems. Their main purpose is to stimulate interest of policymakers and decision makers, and to enhance the discussion about the effect of certain policy measures and the future of agriculture in Kenya in general.

References
EVALUATING ALTERNATIVES FOR SUSTAINABLE FARMING SYSTEMS IN THE CERCLE DE KOUTIALA, MALI. A MULTI-SCALE APPROACH

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Introduction
Selecting, quantifying and integrating sustainability indicators is an indispensable step in designing sustainable farming systems. Indicators serve to reveal the strengths and weaknesses of current and alternative farming systems as well as to support the discussion and negotiation among stakeholders in the search for concerted actions.

A multi-scale approach is needed as different stakeholders in agricultural development assess alternative farming systems at different scales according to their mandates, objectives and concerns.

The objective of this paper is to present a Multi-scale Sustainability Evaluation Framework (MSEF) for deriving and quantifying sustainability indicators at different scales to support the design of alternative farming systems. Its application is illustrated with a case study in the Cercle de Koutiala, an important agricultural region in Southern Mali.

Methodology
The Evaluation Framework

MSEF supports the participatory identification, quantification and integration of indicators from a systems perspective (Lopez-Ridaura, 2005). Indicators at different scales are derived based on identification of critical points for sustainability of farming systems in relation to general properties of sustainable systems (i.e. productivity, stability, resilience, adaptability and reliability).

Quantification of indicators is based on the selection of quantified inputs and outputs of farming activities. Articulation of scales of analysis and quantification of trade-offs among indicators is done through a Multiple Goal Linear Programming (MGLP) model (Van Keulen, 1990) in which indicators at different scales serve as objectives and/or constraints in the optimisation.

The application to Koutiala, Mali

Koutiala is an important cotton, livestock and grain producing region in Southern Mali that contributes greatly to the regional and national economy and food self-sufficiency. However, natural resources in Koutiala are under strong pressure: Almost all arable land is under continuous cropping, soil fertility is low and declining as a result of nutrient mining, soil organic matter depletion and erosion, and stocking rates exceed the carrying capacity of common pastures.

Various stakeholders related to agricultural development in Koutiala were interviewed, including farmers, village chiefs, representatives of farmers’ syndicate and of the cotton commercialisation company (CMDT), agricultural researchers and regional delegates of the Ministries of Agriculture and Environment. Comprehensive sets of indicators at the farm-household and (sub)regional scales were selected representing the main objectives of these stakeholders for the sustainability of farming systems in the region. We used a Technical Coefficient Generator (TCG) for quantification of indicators (Hengsdijk et al., 1996). The TCG quantitatively describes 29 livestock activities as well as 384 current and 1040 alternative crop activities as a combination of 6 soils types, 8 crops and 72 production techniques based on the degree of intensification and of conservation of soil and water resources. For current activities, technical coefficients are calculated based on farm surveys while alternative activities, based on integrated soil fertility management, are computed by means of several models.

The Multi-Scale MGLP model include descriptions of indicators as well as resource availability at different scales. Optimisation variables are the area of arable land under specific crop activities and the number of animals under a livestock activity. Several scenarios were analysed by selecting specific indicators as objective functions or constraints, and the trade-off among indicators were quantified by progressively tightening or relaxing constraints.
Results
Under current activities there is an important trade-off between economic performance and soil loss at the regional (A) and farm level (B), especially for small farmers that lack traction to implement soil conservation measures (Fig. 1).

Figure 1. Trade-offs between economic performance and soil loss at the regional (A) and farm (B) level

Using regional indicators, Fig. 2-A compares current and alternative activities while maximising the economic performance and maintaining food and forage self-sufficiency in normal and dry years at the farm household level. Fig. 2-B shows the comparison for an average farm household. Both Figures indicate that alternative activities based on integrated soil fertility management combine high economic returns and conserve soil resources, and thus offer promising sustainable options.

Figure 2. Integrated comparison of current and alternative activities at the regional (A) and farm (B) level.

Conclusions
The MSEF allows integrated evaluation of alternative and current farming systems in terms of attaining private and societal objectives; it facilitates the identification and quantification of comprehensive sets of environmental and socioeconomic indicators at different scales and the analysis of their trade-offs. Application of MSEF to Koutiala reveals conflicts between objectives for sustainable development at different scales and for various stakeholders, such as food security, economic performance and resource conservation. Agricultural intensification and integrated soil fertility management can improve the sustainability of agriculture in Koutiala by increasing the productivity of farming systems and reducing their environmental impact. However, the increased use of costly external inputs (fertilisers and biocides) may limit adoption of such alternative farming systems.

References
A REGIONAL MODEL FOR THE ECONOMICAL ANALYSIS OF THE AGRICULTURAL WATER USE IN A MEDITERRANEAN AREA

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Introduction
In Italy, many agricultural areas are affected by recurrent periods of water scarcity that generate an increasing competition for water use. Often, these problems induce the Public Administration to limit the amount of water distributed by the Consortiums to the farmers. Moreover, the costs of water distribution and those connected with the use of water services tend to increase. In particular, these last ones can include: the long period cost of the supplying water system, the water opportunity cost and the environmental cost for the water use.
Differently from the past, the EU Water Framework Directive 2000/90 asks to cover a larger share of these costs. Hence, the Consortiums have been applying a volume-based payment scheme that takes into account all the distribution costs and the real water use. This method requires relevant changes in the management of water.
The water scarcity, the increase on water cost and the new payment scheme, encourage farmers to use their wells and, consequently, to exploit the aquifer with negative environmental consequences.
The objective of this paper is to evaluate the impact of these changes by applying a territorial mathematical programming model in a region situated in North-Western part of Sardinia (Italy). In particular, the model is used to evaluate the consequences of a reduction in Consortium water supply on the agricultural sector in terms of farm income, aquifer exploitation and Consortium financial situation.

Methodology
The territorial mathematical programming model is used to represent the agriculture in the study area by considering 24 farm typologies that are differentiated by size and production orientation. Some of them are specialized (milk and meat cows, ovine, wine-growers, olive-growers, horticultural farms) while other ones are mixed. The model represents the variations of the farm typologies choices as a consequence of the expected economical and technological changes in the territory. The model maximizes an objective function that takes into account revenues and costs of all farm activities. The maximization is subject to several constraints referring to requirement and availability of water, land and labour and also to policy, livestock and rotational constraints.
Together with the data of the National Agricultural Census (2000), a field survey has been useful to structure and to represent in detail the irrigation needs and the different supply water conditions. The Consortium guarantees the water distribution from the Cuga lake to the farmers, who pay the water according to their effective water use. However, this supply is not always sufficient to satisfy the irrigation needs. Therefore they also use water from wells, exploiting the aquifers.
The objective function includes the cost related to pumping water from wells and the variable cost of the Consortium water distribution, This latter cost is identified by using a cubic cost function that has been estimated by considering the amount of water used and the amount of irrigated land. This cost function allows to verify the variation of water distribution cost as a consequence of the farmers behaviours.

Results
Different simulations concerning the reduction of water supply have been carried out. These reductions cause the decrease in the income of those farmers who use water on annual crops. These crops cultivations use more than 80% of the water provided by the Consortium. A 5% decrease of water availability causes a reduction of 59% of the farmer’s net incomes.
The reduction of the availability of surface water increases the amount of water pumped from wells. A reduction equal to 5% causes an increase of the pumped water equal to 14% and this percentage hits 36% for a 20% water availability reduction. Finally, a reduction in the amount of water distributed by the Consortium has a negative effect on its financial situation. The reduction of the quantity of water distributed for the agriculture causes a less than proportional decrease in the Consortium's costs. This increases the average cost of the water provided by the Consortium and paid by farmers.

Conclusions
The decrease in the availability of surface water generates a very negative impact on farm’s net incomes. However, this also implies an increasing exploitation of the aquifer. In the Mediterranean areas, this generates serious environmental concerns, especially because it can increase the salinity of the aquifer. The resulting increase of average water costs makes the water pumped from the wells even more convenient and causes a decrease of the Consortium earnings. The conclusion is that reduction on water supplied by the Consortium can worse the environmental and economical sustainability of the considered water distribution system.

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HOLISTIC MANAGEMENT AND VALUE CHAINS WITH A LIVELIHOODS PERSPECTIVE: INCLUDING AND TRANSCENDING TO MAKE A DIFFERENCE

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Introduction
After three decades of experience, integrated farming systems approaches remain at the core of innovative methodologies for development practitioners, researchers and communities. There has been an increasing demand for holistic solutions to address complex problems that simultaneously address social, economic and environmental aspects of development, yet the practical tools were not evident (Neely and Dixon, 2006, Scharmer, 2005). The objectives of this paper are to illustrate the potential for a fused holistic and value chain framework for effective decision making at the farm and value chain level.

Results
The Approach
The Holistic Management (HM) decision-making framework (Savory and Butterfield, 1999) provides the opportunity to understand the whole that is being managed and articulate a holistic goal towards which decisions can be tested - ensuring that sustainability in the short and long term. Further, with global changes (national and international trade and markets, biofuel demands, realities of climate change) that require integration into local, national, and international markets, it has become evident that the whole value chain (VC) must be taken into account. In this paper, we present an enriched framework that fuses HM and VC approaches from a livelihoods perspective to ensure that decisions taken by communities and farmers can lead to substantial and sustained impact.

Holistic Management (HM) provides a framework for decision-making that emphasizes what is most important in life, what has to be created or produced to achieve this, and what future resource base (behaviours, ecosystem process, services, etc) must be in place to sustain this long into the future. It is against this higher level holistic goal and desired outcome that decisions are “tested” in an integrated fashion to ensure social, environmental and economic viability. Complexity has limited our capacity to handle these different aspects simultaneously. From a holistic perspective, the world operates in “wholes” and subsequently we must recognize and manage the assets in any given whole under management. The whole comprises decision makers, the current resource base (human, social, physical and natural capital or assets including those institutions that influence decision making) and available money (financial capital). Holistic Management offers a practical framework for identifying and testing the sustainability of potential strategies (including livelihood strategies) and motivation for implementation, monitoring and controlling towards the desired outcome.

The set of actors and institutions which bridge rural service providers, farmers/pastoralists and processing and marketing services can be referred to as a value chain (VC) Framework, or as a U-impact pathway (Dixon et al., 2007). Functional VCs could be viewed as dynamic wholes (Carrell et al., 2004) where the various decision makers share a common vision and values and evolve through competitive cooperation. The chain is a complex non-linear system where efficiency and sustainability could be enhanced through Holistic Management decision making both by individual actors within a value chain or by the full group.

Illustration
The HM-VC fusion is illustrated for conservation agriculture (CA) in the irrigated rice-wheat system of the Indo-Gangetic Plain. In a world where farmers and consumers depend on a few centimeters...
of soil and water, which are being rapidly degraded, conservation agriculture (CA) is viewed as a viable approach towards sustainable agriculture and rural development. Small farming communities are creating a quiet revolution in the rice wheat farming systems of the Indo-Gangetic Plains of South Asia with the rapid adoption of resource conserving technologies which are an important step towards CA. Yet experience with CA across continents confirms that farmer and business cooperation is essential to reap the full benefits of CA its management requires a holistic multi-institutional approach.

An Indian farming community manages a whole that consists of decision makers (farmer leaders, farmers, workers, family members); a resource base (farmer networks, researchers, extensionists, service and input providers, buyers, land, water, equipment, skills and knowledge) and money (income from sales and savings). Through facilitated community discussion, their holistic goal could be: “We the farm women and men of this village wish to have a strong relationships among family and community, be financially secure, enjoy healthy and safe working lives, and be continually learning and improving the state of our natural resource base. To have this, we must create opportunities for farming in a sustainable way, generate income from meaningful work, and create opportunities to learn from one another and others and build transparent communication and information strategies. To sustain this, we must be honest, trustworthy and innovative producers with. Our land must be covered with residues, have diversity of plant/animal species and have an effective water cycle. Service and input providers and markets must be available and supportive”.

As a whole within a larger whole (the value chain), the farmers might test the decision to adopt conservation agriculture principles (minimum tillage, residue retention, rotation) to meet their holistic goal - enhance livelihoods, profitability and the environment. By using this framework, they may find that to achieve their holistic goal, they must interact differently with or even change those with whom they do business, i.e., VC participants. This effort to achieve sustainable livelihoods could be enhanced further if each of the entities and actors with whom they engage in the larger whole (services, input providers, processors, markets, consumers) had a holistic goal by which their decisions were also tested. They could each - through enlightened self-interest - in turn make decisions that produced better results (socially, financially, and environmentally) for themselves while influencing positively others across the chain. As we advance our capacity to truly implement multi-stakeholder processes, it is envisaged that conversations hosted among the actors across the value chain using a holistic decision making process can lead to enhanced awareness, relationships and mutually agreed to sustainable solutions.

Conclusions
Such a fused HM-VC Framework has great potential to organize and assure more effective decision making, improved management of resources and viable pathways to livelihoods improvement and poverty reduction in a wide range of complex rural development settings.

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SURVEYING CROP MANAGEMENT DATA FOR BIO-ECONOMIC FARM MODELS

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Introduction
Given the ongoing discussion concerning environmental topics such as climate change, water or air pollution, it seems more and more important to internalise such matters in agricultural-economic modelling. While hitherto agricultural-economic modelling stressed often mainly economic outcomes of farming, it becomes increasingly an issue to consider externalities of agricultural production in more detail. Bio-economic farm models (BEFM) are a relatively new category of models that meet this challenge by linking formulations describing farmers' resource management decisions to formulations that describe current and alternative production possibilities in terms of required inputs to achieve certain outputs and associated externalities (Janssen & van Ittersum, 2007). These models have in common that they maximise farmers' utility. In doing so, they integrate a sophisticated set of constraints including restrictions with respect to different types of externalities. This approach facilitates not only to compute policy-driven scenarios with environmental indicators in addition to the usual economic outputs but also goal driven scenarios that allow for quick generation of trade-offs between economic and environmental outputs (Zander, 2003). As a precondition, these models require detailed data of the management of land based production activities, for which currently no strategic data collection exists at EU level. Therefore, this paper describes an approach developed within the EU FP6-project (Van Ittersum, M. et al., 2006), that offers a database and user interfaces to collect and store data of current production systems.

Project background
In SEAMLESS (System for Environmental and Agricultural Modelling; Linking European Science and Society) a model framework is developed that examines, ex-ante effects of agro-environmental policies on the farming sector from field up to the global level. One step in this model chain is a bio-economic farm model called FSSIM (Farm System Simulator) that takes into account information about production activities from surveys or experts. FSSIM is applied to 23 representative regions out of ca. 300 EU NUTS-2. The sample regions were selected as being representative for so-called agro-environmental zones in order to allow for extrapolation of farmers’ responses to the entire EU. This extrapolation (done using the SEAMLESS model EXPAMOD) is used for the upscaling of price-supply responses to a market model. As a consequence of the application of such comprehensive model chains the availability of detailed and consistent data on agricultural management is crucial. Such data are not available through existing datasets (e.g. the Farm Accountancy Data Network - FADN), which motivated the development of a survey to collect these data from existing local databases and / or experts.

Methodology
The data collection tool consists of a user interface and an underlying database. In most cases the expert is asked to combine different items from existing lists, e.g. assign crops to a rotation or fertilizers to a crop. The survey is designed to obtain the most complete information set on production practices with a minimum of effort. It is supposed to be completed by local experts with several years of experience in agricultural cultivation making use of existing local data collections. Such experts ought to be familiar with region-specific cropping zones and current agricultural practices. They are expected to provide detailed information on crop rotations and the production system.
processes of each crop and livestock activity. Estimates of yields but also of inputs should be based on long-term averages with respect to the realised yield level and the current practices of crop management. In order to be able to validate FSSIM results on the basis of existing statistical data, the crops considered in the survey are limited in a way that reflects crop distribution according to FADN data. The tool includes a semi-automatic cost calculation procedure. The final version of the survey will ask for some economic information like prices and machinery costs on the basis of rental prices. Thus, variable costs of management procedures can be computed.

The basic structure of the crop management data contains the following hierarchy: (i) project and user, (ii) region and subset of data, (iii) sequence of crops, (iv) crop and product quality aimed at, (v) management procedures and related to that: in- and outputs, timing and optional: frequency of executed works and share of land that is treated. Management procedures classify the field activities in terms of e.g. soil tillage or yield of main product. By adding region specific machinery or directly labour demand, fixed and variable costs for every management procedure, the corresponding machinery costs can be calculated. Together with prices for in- and outputs complete gross margins become available, which can be checked by users. To facilitate this, the survey offers overviews that can be opened directly from the graphical user interface.

Additionally to this detailed procedure a second survey was developed that concentrates on aggregated economic data for crop farming as well as on livestock and policy variables. If the data are available, the completion of this second form should not take more than two days for all crops and livestock activities. The surveys are server-based tools, i.e. the user just has to install a small application on his personal computer to be able to use it. Entered data are directly stored in a PostgreSQL database on a server at ZALF, Germany. In order to avoid misuse every user has an own access protected by a password. From this database the data are uploaded into the integrated database of SEAMLESS.

Conclusions
Whereas simple economic models are mainly based on information concerning gross margins and constraints in the region, the consideration of externalities in a precise way requires data on the quantitative, temporal and spatial aspects of management procedures. Only when having such information, it is possible to estimate environmental indicators such as N-leaching and greenhouse gas emissions. As currently no strategic data collection on production activities exists at EU level, we built up an EU wide applicable database of agricultural activities that allows for detailed economic and ecological analysis of these activities. Having one consistent database will allow for the development of standards in farm level modelling, which could lead to enhanced comparability of different Common Agricultural Policy impact assessment models. This contribution aims at raising awareness of the importance of having such data at EU level and at combining efforts to realize this.

Acknowledgement
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References
MODELLING RISK IN FARMER DECISION MAKING

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Introduction

The economic approach to risk management seeks a combination of decision variables (e.g. mix of farm enterprises) that best suit a farmer's normally conflicting objectives of increasing average profit and reducing variability of profit. Most studies find that attitude to risk varies considerably. For example, Pennings and Wansink (2004) report that 39% of a sample of Dutch pig producers were risk averse; the remainder were either indifferent to or actively seeking risk. Even for the risk averse case, the best plan will not be to eliminate all sources of variability: risk averse farmers are also interested in profitability. Thus, an economic analysis will reject methods of reducing risk if this reduction in risk is worth less to the farmer than the associated profit foregone.

There are a wide range of approaches to determining optimal levels of risk and profit (see Hardaker et al. 2004). One that fits well with a farm systems approach is utility efficient programming: farm constraints such as rotations, labour and machinery availability are included in a model with an objective function that maximises expected utility for a given utility function. The function is modified by a coefficient reflecting the degree of risk aversion; coefficients are normally calculated from information obtained through farmer interviews. Those with high levels of risk aversion will gain more utility from plans that reduce risk. Less risk averse farmers gain more utility from riskier, more profitable plans. The programming framework allows different methods of risk to be evaluated in terms of their impact on overall farmer utility. In this paper, we build on work originally conducted by Ramsden and Wilson, 2006, and consider two risk management techniques within a utility programming framework: crop diversification and risk free payments linked to reducing the environmental impact of wheat production.

Methodology

Ramsden and Wilson (2006) used a simplified version of the Farm-adapt model to assess the benefits of different methods for managing risk on five ‘combinable crop’ farms in the East Midlands region of England. Data for each farm were taken from the Farm Accountancy Data Network and Farm-adapt was adjusted to take account of differences in yields, land area, labour and machinery availability and fixed costs on each farm. A simplified representation of gross margin distribution for each crop was constructed using farm yields and daily ‘spot’ price data. The procedure maintained covariance between different crop gross margins; however, it was assumed that there was no significant relationship between yield and price for each individual crop. The probability that a given gross margin would occur is a product of the combined probability of achieving a given yield and price (variable costs were assumed to be non-stochastic). For a risk averse farmer, the additional utility of an uncertain ‘high’ gross margin will be less than to a farmer who is not as risk averse. Increasing the probability of achieving a given gross margin will have a greater benefit for the risk averse farmer; for the risk indifferent or ‘risk neutral’ farmer, changing probability has no effect on utility. Results were generated for Agenda 2000 and Mid Term Review conditions and with crop diversification and use of futures markets as risk management techniques. For this paper, one case study farm was also run to assess the impact of a risk free environmental payment, linked to wheat production. Results were expressed in ‘certainty equivalents’ (CE). A CE is the value of a guaranteed sum of money that would make the decision maker indifferent between this guaranteed return and the risky alternative, for example, cropping the farm (Hardaker et al., 2004). It can therefore be thought of as a financial measure of the utility associated with different farm plans.

¹ That is, we assume that in order to receive the payment, wheat has to be managed in an environmentally beneficial way – for example, by reducing the amount of nitrogen applied.
Results

Diversity of crop mix was relatively unresponsive to level of risk aversion on four of the farms: expectations were that the risk averse strategy would be to grow a greater range of crops. Combinable crops in the East Midlands tend to have positive gross margin covariance and thus the scope for reducing risk through crop diversification is limited. CEs were much greater for the less risk-averse case on all farms (e.g., on Farm D, the risk averse CE was £42,500; the less risk averse CE £61,550). Thus, in itself, risk aversion substantially reduces farmer utility.

Under Mid Term Review conditions, CEs fell on each farm (reductions ranged from £3,385 to £13,160) in comparison to Agenda 2000 conditions. The effect was similar for different levels of risk aversion: in England, de-coupled farm payments are not sufficient to offset the removal of area aid payments and all case study farms were worse off because of the fall in income. There is little impact on risk as both the de-coupled payments and the area aid payments are non-stochastic.

Simulating the effect of a fixed, per hectare, environmental payment demonstrates the problem of ‘over-compensation’ when risk is ignored. Using one of the larger case study farms (315 hectares) and wheat as an example of a crop that might be ‘environmentally managed’, results showed that a flat rate payment, equivalent to the probability weighted average gross margin for conventional winter wheat, improved farmer utility (risk averse case) by 55% (£29,340 to £45,502). Note that we assume in this comparison that the gross margin of the ‘environmental wheat’, net of the flat rate payment, is zero. For the risk averse farmer the reduction in variability makes the environmental option – ignoring other factors – much more attractive. Policy mechanisms that base environmental payments on gross margin foregone alone will therefore tend to over-compensate risk-averse farmers. As a second example, results for a flat rate environmental payment of £200 per hectare, used to compensate a £20 per tonne reduction in wheat price, increased farmer utility by 9% when compared to conventional, unsupported wheat production. The 9% utility benefit is similar to that achievable through hedging all the farm’s cereal crops using a Futures Market (see Ramsden and Wilson, 2006).

Conclusions

The systems approach described above has two drawbacks. First, it was assumed that the farmer is interested in reducing risk for the whole farm, rather than for individual components of the farm – such as the price of an individual crop. In England, for example, advice on using futures markets is largely confined to stabilising the price of wheat. Second, unlike other system approaches, such as Agent Based Modelling, the decision maker was assumed to be motivated by profit and risk only. In reality, the adoption of agri-environment schemes is likely to be influenced by a range of behavioural factors (Mathews and Selman, 2006). However, as shown by Grilches as long ago as the 1950s, profitability does influence the adoption of new techniques, although lags in adoption can often be explained by other factors. Relatively simple models of decision making, such as the one described here, are often effective predictors of farmer responses to changing market and policy conditions. For example, the model captures the shift to wheat and oilseed rape-based rotations, currently (2007) prevalent in Eastern England. Subsequent analysis (for example, of the type used by Jaggard et al., 2004) can be used to assess the potential environmental impact of changes in farm profitability. Moreover, despite differing objectives, all farmers need to assess the impact of their decisions on profitability - and policy makers need to know the extent of this impact.

References

R. Mathews and P. Selman, Landscape as a focus for integrating human and environmental processes, 2006. J. of Agricultural Economics, 57 (2), 199-212.
EXPLORING ALTERNATIVES FOR RICE-BASED FARMING SYSTEMS IN TAMIL NADU, INDIA

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Introduction

The livelihood of farmers in Tamil Nadu, India depends on scarce resources. Rice is the predominant crop cultivated which consumes 70% of water available for irrigation. Inefficient use of commonly available water in rice cultivation leads to a water scarce situation and competition for irrigation water used in other crops. In a first step, experiments were conducted on water-saving rice cultivation techniques under on-station and on-farm conditions. Results showed that up to 40% water can be saved in rice without reduction on yield (Thiyagarajan et al, 2003; Senthilkumar et al, 2007). Adoption of water-saving rice cultivation by the farmers, however, was lacking due to technical difficulties in the novel cultivation practices, labour constraints and gender issues (Senthilkumar et al, 2007). We therefore analysed possible other options to improve current farming through different strategies of farmers. The analysis focused on rice based farming systems, however, other crops cultivated by the farmers such as banana, pulses, vegetables etc. were also included. Farmers differ in resource endowments and likely in possible strategies. Farms were therefore classified in to four farm types with varying resource endowments based on results of a participatory farm survey using principal component analysis (PCA) (Table 1). The difference in resource endowments leads to variation in farm income and livelihood strategy of the farm family.

Table 1. Farm resource endowments of the identified farm types. Farm characteristics per farm type are averages of three sample farms quantified in a year.

<table>
<thead>
<tr>
<th>Resource endowments</th>
<th>Farm type I</th>
<th>Farm type II</th>
<th>Farm type III</th>
<th>Farm type IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land available (ha)</td>
<td>5.9</td>
<td>3.2</td>
<td>0.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Family labour use (Labour days)</td>
<td>98</td>
<td>357</td>
<td>144</td>
<td>73</td>
</tr>
<tr>
<td>Hired labour use (Labour days)</td>
<td>1,244</td>
<td>759</td>
<td>247</td>
<td>275</td>
</tr>
<tr>
<td>Water use (‘000m³)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canal</td>
<td>66.1</td>
<td>8.8</td>
<td>7.9</td>
<td>0.0</td>
</tr>
<tr>
<td>System tank</td>
<td>0.0</td>
<td>7.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Well</td>
<td>9.0</td>
<td>34.9</td>
<td>0.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Rainfed tank</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Rainfall</td>
<td>50.5</td>
<td>25.0</td>
<td>7.8</td>
<td>27.4</td>
</tr>
<tr>
<td>Farm income from crops (US $)</td>
<td>2,349</td>
<td>1,498</td>
<td>146</td>
<td>305</td>
</tr>
</tbody>
</table>

The objectives of the study are to optimize (1) the current resource use for income maximization of the farms per farm type and (2) to explore effects of changes in water and labour availability.

Methodology

A multi-objective linear programming model was developed. The analysis was carried out for one sample farm per farm type. Input and output data for each cropping unit for a complete cropping year was obtained through weekly farm surveys in farms representative for each farm type. Model analyses were carried out to maximize the farm profit for 1) current water and labour availability, 2) 20% less water availability, 3) 20% more water availability, 4) 20% more hired labour availability and 5) 20% more water and hired labour available, while keeping other resources constant. Changes in the model results of scenarios 1 to 5 are expressed relative to the observed results from actual farm practices.
Results of model output

Farm type I: Profit can be 26% higher than actual observed values when using current water and labour more efficiently leading to a doubling of the area under banana and a reduction of the rice area by half. Observed profit was reduced by 12% when the water availability was reduced by 20% following from the reduction of land area under banana. There was no change in income with 20% increase in water availability as hired labour available is a constraint at this moment. This effect was observed in the analyses for all the farm types. Farm profit increased by 29 with 20% more labour and 42% with 20% more water and labour use, due to similar changes in land use to more profitable banana. The area cultivated with vegetables remained unaffected when water availability increased but increased with higher labour availability.

Farm type II: Profit can be 72% higher than actual observed value as water and labour are allocated to more profitable activities. In this farm type, the improvement is attained by increase in area under pulse crops. Area under banana remained the same while rice was not selected at all. Profit increased by 40% even when water availability is reduced by 20%, suggesting water can be efficiently used by changing the land use under different crops with higher profit. Profit increased by 75% with 20% more labour and 103% with 20% more water and labour. Land use change show a similar pattern to that found under optimization with current water and labour availability.

Farm type III: Profit of this farm type can not be improved with current water and labour availability. The land available and crop choices (only banana and rice) are restricting options of this farm type. When the water availability is reduced by 20% the land area under banana and rice correspondingly was reduced, reducing profit by 19%. For other scenarios the land area under banana and rice remain unchanged.

Farm type IV: Profit of this farm type was 125% higher than currently observed using the available water and labour more economically. The yield from fodder crops used for animal consumption and income from animals kept in this farm type is not yet included in the model. Thus the model result is biased since costs on fodder crops were saved. The area under rice, pulses and vegetables correspondingly increased or decreased with the introduction of 20% more labour and water or 20% less water available.

Due to lack of space, the differences in possible strategies based on the farm resource endowments of each farm type were not presented, that will be presented in the full paper.

Conclusions
The model allows analysing current farm practices and identifying options to improve farm operations. Opportunities exist to increase the farm income by reallocating the currently available water and labour resources in the farm types I, II and IV. Increasing farm profit in farm type III is only possible with increased resource endowments and other crop choices. The analysis is farm type specific and helps in identifying crops which are profitable for allocation of the limited water and labour resources. Other important alternatives (e.g. water-saving rice cultivation) and animal components have to be included in the model to improve identification of options to improve the livelihood of the farm households.

References
AGRI-ENVIRONMENTAL MEASURES, EU CAP AND CHOICE OF A SUCKLER CATTLE PRODUCTION SYSTEM: A FARM-SCALE MODELLING APPROACH.

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Introduction
The multifunctional role of agriculture recognized in the UE Common Agricultural Policy is based on the co-existence of multiple commodity and non-commodity outputs that are jointly produced. Farmers are viewed not only as food suppliers but as potential producers of environmental goods that may complement or compete with their agricultural production, these goods being paid for through agri-environmental measures (AEM). Before committing to an AEM, farmers have to evaluate the concomitant constraints in terms of farm management, adaptations to the production system that may be needed, and the likely economic impacts. Suckler cattle farmers in the Massif Central (France) who are concerned by grassland measures (maintenance of grass area and extensive management of grasslands) must also arbitrate between the CAP premiums and the market. To provide farmers with decision-making aids for choosing the best production system for their farms, we constructed Opt'INRA, a linear programming model that optimises suckler cattle farming systems. This paper outlines the model and reports on the incentives for a farmer located in a mixed crop-livestock area but who is not a signatory to the agri-environmental grass premium (AEGP) over the period 2002-2006 to subscribe to this contract in 2007 within the framework of the new CAP (decoupled premiums).

Methodology
The majority of models developed for cattle farms are used for optimising meat production under allocation constraints of the on-farm-produced feed resources (Crosson et al., 2006). Other models have been built to evaluate the environmental impact of dairy farming systems (Pacini et al., 2004). Our objectives were to study the impact of AEMs (depicted through a system of technical constraints) on the choice of production system, taking into account the AEM allocation rules which can in some cases run against those of the CAP premiums. We used Opt'INRA, a LP model that represents the mixed crop-livestock farms of the north Massif Central (France) by incorporating a large number of animals and crop activities as well as the allocation conditions for CAP and AEM premium (Veysset et al., 2005a). Opt'INRA can be configured to choose whether or not to claim each premium, factoring in all the concomitant constraints involved. Figure 1 represents the choices and the decisions the farmer is faced with for his farming system.

The farm studied is a mixed crop-livestock farm type with 150 ha of useable land. The main features of the optimal production system for 2005 are shown in table 1 (basis: 2005). The agri-environmental grass premium (AEGP: €60.98/ha of grassland if (i) grassland area > 75% of the farm area and (ii) stocking rate < 1.4 livestock units/ha of grassland area) is not economically relevant under this CAP (Agenda 2000) and market context, and was therefore not chosen by the model. We will study the adaptation of the production system for this farm within the framework of the new CAP with partial decoupled premiums and the single farm payment entitlements.

Figure 1: Simplified diagram showing the functioning of a mixed crop-livestock cattle farm system, the decisions to be made by the farmer and the overall gross margin composition.
Results
If the study farm is not authorized to subscribe to the AEGP (table 1, 2007 AEGP forbidden), the new CAP does not have a tangible impact on either agricultural outputs or production system, although corn silage was abandoned (effect of the decoupling of the crop premiums) in favour of grass. The total gross margin drops by 1.4% as a resulting of changing premiums. In this scenario, the increase in grassland area brings this farm closer to the eligibility conditions for AEGP. By authorizing subscription to the AEGP contract (table 1, 2007 AEGP authorized), the model adapts the system to be AEGP-eligible. The drop in the stocking rate that is a prerequisite constraint for AEGP eligibility is done by reducing the cereals area while maintaining meat production levels: the decoupling means that the total amount of CAP premiums cashed in is not penalized by the 7.1 ha drop in cereals land. The fall in grain production is compensated by the AEGP, while total product remains stable, the reduction of cereals area in favour of grassland area results in a 10% cut in costs, and the total gross margin increases by 2.4% compared to 2005.

Table 1: results

<table>
<thead>
<tr>
<th></th>
<th>Basis: 2005</th>
<th>2007 AEGP forbidden</th>
<th>2007 AEGP authorized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farming area (ha)</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Cereals (ha)</td>
<td>32.5</td>
<td>32.4</td>
<td>25.3</td>
</tr>
<tr>
<td>Forage area (ha)</td>
<td>113.2</td>
<td>113.9</td>
<td>121.8</td>
</tr>
<tr>
<td>Including grassland</td>
<td>106.6</td>
<td>113.1</td>
<td>121.8</td>
</tr>
<tr>
<td>Number of calvings</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Stocking rate</td>
<td>1.61</td>
<td>1.52</td>
<td>1.40</td>
</tr>
<tr>
<td>Grass Premium</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Grain sold (tons)</td>
<td>131.9</td>
<td>123.9</td>
<td>80.3</td>
</tr>
<tr>
<td>Meat sold (tons)</td>
<td>43.2</td>
<td>43.2</td>
<td>42.9</td>
</tr>
<tr>
<td>Total production (k€)</td>
<td>169.3</td>
<td>166.1</td>
<td>167.9</td>
</tr>
<tr>
<td>Total costs (k€)</td>
<td>42.6</td>
<td>41.2</td>
<td>38.2</td>
</tr>
<tr>
<td>Overall Gross Margin (k€)</td>
<td>126.7</td>
<td>124.9</td>
<td>129.7</td>
</tr>
</tbody>
</table>

Discussion, conclusions
The Common Agricultural Policy aims to guarantee a multifunctional, sustainable, competitive agriculture spread across the whole European territory. For the beef sector, this results in a drop in intervention price that is compensated by specific premiums and by extended fodder area incentives. The conditions governing how these premiums are allocated change regularly (1992, 2000, and 2003 applicable in 2006 in France) and farmers have to keep a sharp eye on the various incentives for adapting their production system (Veysset et al., 2005b). Farmers must sometimes arbitrate between the production of agricultural goods and environmental goods, since there is often competition between the two in terms of the respective incentives (Havlik et al., 2005). Thus, by changing the attribution rules of the CAP premiums (partial or total decoupling), the same AEM can become economically interesting and incite a farmer to produce an environmental good (grassland) to the detriment of an agricultural output (grain). Agro-environmental policies and incentives must be analyzed, taking into account the jointness between the various goods produced on a farm (Havlik et al., 2006).

References
Session 1.2:
Farm models and market interactions

Session Convenors:
Thomas Heckelei and Kathrin Happe
SIMULATING THE DYNAMICS OF AN AGRICULTURAL CATCHMENT DRIVEN BY MARKETS, FARMERS ATTITUDE AND CLIMATE CHANGE

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Introduction
The impact of climate change on an entire agricultural region is often not clear (IPCC Report 2007) due to the complex interactions between individual farmer’s behavior and the bio-physical landscape processes, the large range of multiple external and internal factors and the further complication from continuous changes of variables in time and space. To study likely scenarios of climate change impact and adaptation and its consequences on socio-economic and environmental indicators of an entire agricultural region, an agent-based simulation model is developed with CORMAS (Bousquet et al. 1998). The model aims to simulate the complex interactions between bio-physical processes of paddock cover, dry-land salinity changes, rainfall changes, market signals, farm profitability and individual farmer decisions on lands use in a salinity-prone agricultural catchment.

Methodology
An agent-based simulation model is developed with CORMAS combining simplified bio-physical processes of paddock cover, dry-land salinity changes and rainfall with farm profitability and individual farmer decisions on land uses. The agricultural catchment is parameterized for the Katanning region (a sub-catchment of the Blackwood River) in the South-West of Western Australia. The Katanning region consists of 300,000 ha with about 280 crop/sheep or mixed farms, 84% arable land, 10% native vegetation and 6% salinity. Average farm size is about 1100 ha, with individual farms ranging between 50 and 9000 ha. In the model, farmers (agents) make individual land use decisions based on the performance of their past three years land cover productivity and market returns. With current market prices, returns are higher from cropping in wet seasons, whereas in dry seasons, returns from pastures are higher. Therefore, the market prices, the sequence of seasons and farmers adaptations characteristics will influence a structural shift to increase cropping or pasture. This structural shift is modeled as a percent change (randomly between 0 and 15% per year, to constrain adaptation within reasonable changes as observed in the last 20 years in this region) of the current crop-pasture ratio of a farm. The modeled willingness to adapt to market drivers (randomly distributed economic adaptors and non-adaptors for each new farmer’s generation) and the ability to maximize returns varies across farmers (randomly distributed across farmers but constant for a farmer’s generation to achieve between 70 and 100% of a seasonal potential production). To consider technology uptake over time, the potential itself and the degree of achievement can be increased via a trend function. In addition, farmers in the model are portrayed with various attitudes (not profit driven) towards salinity mitigation as a consequence of salinity being on their farm, in the neighborhood or region and can adopt land use changes with less salinity impact.

Results
The simulation using historical rainfall records indicates similar trends of crop-pasture ratios, salinity area changes and farm number declines observed in the last 20 years in the Katanning catchment of Western Australia (data not shown). Using the model as an explorative tool for future scenarios highlights the importance of rainfall changes and wide-spread willingness of farmers to combat dry land secondary salinity caused by excess water in annual cropping and pasture systems. Draining this excess water below the potential root zone consequently increases water table rises (which is highly saline or mobilizes large amounts of salt stored in the soil which is than brought up to the surface). Figure 1 show results from a 100-years simulation experiment with randomly created rainfall data based on the rainfall of the last 20 years in the Katanning region. Current input costs and market returns are assumed constant for this experiment, which of cause...
are likely to change in the future. Of particular interest in this hypothetical experiment are the different periods of high and low rainfall years. In periods of high rainfall, e.g. 2005-2020 or 2040-2050 (Fig. 1a), cropping would be favored over pastures due to higher returns from wheat in wetter seasons (Fig.1b), farm numbers would decline less (Fig1c most obvious during the wet period 2070-2080), but salinity would continue to increase (Fig. 1d), while regional income would be relatively high compared to other periods (Fig. 1e). In contrast, during dry periods (Fig. 1a: e.g. 2020-2025 or 2080-2090), the cropping area would decline in favor of pastures which are less profitable but better suited to dry conditions (Fig. 1b), farm number decline would be accelerated due to increased bankruptcy (Fig. 1c), salinity spread would hold (e.g. 2020-2025) or even decline (e.g. 2080-2090) (Fig. 1d) and the regional income would be relative low (Fig. 1e). Adaptation to these different periods of rainfall is temporally and spatially non homogeneous, depending on farming history and rate of adaptation of individual farmers (data not shown). In other simulation experiments not shown here, but can be also derived from the results in Figure 1, future rainfall changes as a consequence of climate change are likely to have a large impact on reducing dry-land salinity. Moreover, continuous reductions in future rainfall might have more impact on salinity reductions than local or even wide-spread approaches of farmers in land-use changes (by introducing perennial pastures and trees for higher water use and less ground water recharge) trying to mediate salinity. While this model allows to explore some of the complexity of scenarios for the future of an entire agricultural region, prediction of the future are not possible, due to the simplistic nature of the decision making processes in the model, the uncertainties in learning new ways of adaptation, uncertainties in the degree of climate change and the large unknown behavior of markets even in the next few years.

Figure 1: Simulation experiment using randomly created rainfall data based on the rainfall of the last 20 years of the Katanning region assuming current input costs and market returns.

Conclusions

A agent-based simulation model is developed to simulate the complex interactions of individual farmer’s behavior in a landscape with bio-physical processes of paddock cover, dry-land salinity changes, rainfall changes, market signals and farm profitability. The model could reproduce some historical dynamics of an agricultural landscape and was used to explore the sensitivity of socio-economic and environmental indicators of an agricultural region to climate change scenarios. Rainfall changes and in particularly changes in the sequence of dry and wet seasons and the adaptation to these sequences by farmers seems to be critical for crop/pasture adaptation, salinity spread and farm survival in this catchment.

References

Introduction
Farms are the basic decision units in agriculture and, therefore, influence market outcomes, land use and the environment. Moreover, farmers perceive prices as given, since production in each production unit is small compared to total production in the sector. Farm level optimization models share a similar perspective. As long as the policies investigated are such that market prices remain stable, the error made by taking prices as exogenous is negligible. However, agricultural policies are horizontal and affect all farmers at the same time. Therefore, their aggregated response and their interaction may have profound impacts in agricultural markets, which in turn influence commodity prices. Agricultural sector models such as CAPRI (Common Agricultural Policy Regionalised Impact) are able to capture price changes from policies. Their relative weaknesses compared to farm models is the use of highly aggregated data, the lower level of detail in modelling agricultural production programs (e.g. rotations) and the lack of consideration of biophysical processes.

The integrated project SEAMLESS (www.seamless-ip.org) aims at providing a consistent integration between a farm management model specified for a selection of farm types (FSSIM, Louhichi, et al. 2006) and an EU wide aggregated agricultural model with an explicit market component (CAPRI, Britz 2005). This paper focuses on presenting conceptual methodology for linking these models and addresses theoretical aspects related to the consistency between micro and market level models. It reports on some key empirical considerations about the choice of regions, calibration approaches, rules for mapping meta-data between both models, choice of explanatory variables for estimation and selection of aggregation weights reflecting farm type economic relevance at regional level.

Methodology
Given the ca. 250 NUTS2 regions and high diversity of farm types within the EU27, FSSIM is only capable of considering a subset of regions and farm types in detail. This is why a complementary procedure for expanding FSSIM results to all other regions is needed. The principle behind the presented methodology (EXPAMOD) is to make the regional supply modules of CAPRI behave like the aggregate of the FSSIM models of the same region.

In order to map the supply behaviour of farm management models to the market model, the EXPAMOD methodology comprises the following sequence of steps (see Figure):

1. Price shocks are modelled in the existing FSSIM farm type models, with initial prices coming from CAPRI;
2. EXPAMOD is used to extend the results of FSSIM to all other regions;
3. Market clearing prices for the final run are computed using the expanded results from EXPAMOD;
4. These prices are then used in the CAPRI model to simulate the market outcomes.

Figure Flow of prices (1, 2 and 4) and price supply elasticities (3) between models under a policy scenario
(2) estimation of supply responses as response functions of price variations, farm characteristics, regional soil and climate conditions; extrapolation of supply response to other farm types and NUTS2 regions; aggregation of supply response to level of CAPRI regions (administrative units) and CAPRI product categories;
(3) calibration of regional supply modules in CAPRI to aggregated supply responses;
(4) a final run of FSSIM with market clearing producer prices from CAPRI results in the final consistent specification at the farm level.

Results
Since the approach is still being tested, this section refers only to some empirical implications of the theoretical approach. In order to arrive at the sensible number of FSSIM models to generate supply-price responses and enable the extrapolation from sample regions to all EU regions, a specific farm typology has been derived within the SEAMLESS project (Andersen et al, 2007). According to this, 3 to 10 most-representative farm types per sample region are selected, so that they adequately represent farm, soil and climate differences among regions. The current simulation design includes the generation of pseudo-observations by running the farm management models on different price sets for products (i.e. input data based on a sensitivity analysis of farm model behaviour, prices being changed one-at-a-time). The level of prices for the baseline scenario is kept at the 100% level to the initial prices levels obtained by CAPRI in a similar scenario. Prices of each product are set at 60%, 80%, 120% and 140% of the base level, providing a sufficient number of simulated observations. The choice of agro-environmental variables links closely to the determinants of farm typology (size, intensity, specialization) as well as agro-environmental typology (soil, climate) used in farm spatial allocation procedure. The list of selected variables in modelling the supply response function: economic size unit, machinery, labour, carbon content, root depth, minimum temperature, precipitation, radiation is supported by earlier studies of crop yield variability (see Reidsma et al., 2007).

The response function estimated at one scale is not representative for the projection at another scale. Estimation of the response function is based directly on the simulated FSSIM data. Aggregation from farm types within one NUTS2 to the regional level, as needed by CAPRI, is performed by using the shares of land area of each farm type obtained during the farm spatial allocation exercise. The calibration of the response of the CAPRI supply module to the aggregated response of the FSSIM farm management models and the extrapolated regional models is done through regional price-supply elasticities.

Conclusions
This paper presents a methodology based on a statistical response function approach that allows the calibration of the supply behaviour of a market model to a small sample of farm management models. Given the non-linear mapping in combination with large variances of explanatory variables, a rather flexible functional form for the response function is needed. Introducing a polynomial of order two would result in having too many cross-terms. Therefore, a non-parametric approach will be considered at a later stage which is generally capable of approximating any non-linear relationship over the range of the explanatory variables. Although the linking of farm and market models is performed through price elasticities, this approach is applicable in addressing further needs on up-scaling of other economic as well as non-economic indicators and calls for further investigation.

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P. Reidsma et al., Analysis of farm performance in Europe under different climatic and management conditions to improve understanding of adaptive capacity, 2007. Accepted for publication in Climatic Change.
A RESEARCH APPROACH FOR THE ANALYSIS OF LIVESTOCK DYNAMICS INTERACTING IN MARKET FORCES

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Introduction
In North Cameroon, the current status of cattle breeding is illustrative of the studies that showed that extensive farming often evolves under pressure such as the lack of resources (Cochet, 2001; Tiffen et al., 1994). To meet challenges raised by the shortage of pasture land, livestock farmers elaborate defensive strategies (settlement, reduction of the herd, diversification of activities) which are alike to those observed in West Africa where the phenomenon is already underway.

The defensive strategies of farmers are well known, but there is a lack of knowledge about their responses to the development of market, caused by the increase of external beef demand (Nigeria) and particularly local demographic trends: the growth rate is + 2.8% per year in north Cameroon, and the population of Garoua, the main provincial town, is actually estimated at 370,000 inhabitants will possibly double within 15 years.

It has been found that, when conditions are favourable, farmers modify their practices to respond to opportunities generated by good market trends (Cour, 2000). The support of this innovative capacity, which is seen as one of the main operational levers to meet the challenge of food security, raises two important questions: 1) what is the impact of market on livestock farmer’s practices? 2); how does the evolution of livestock in the above context influence beef supply? This communication presents a methodological approach for the study of livestock dynamics interacting in market forces.

Methodology
The systemic and contextual nature of this research suggests the designing of an appropriate approach. This approach was organized around three axes: territory, market channel and time. The territory entry makes it possible to consider cattle rearing as a technical act constrained by the farmer’s projects and the characteristics of the environment. This entry is a tool to appraise the local farming conditions and to approach the diversity of livestock farming systems (pastoral, mixed-farming, cattle-fattening in the urban area). The market channel approach puts farming as a constituent of a chain whose various components have functional links. It helps to identify the demand, analyse and understand the strategies of stakeholders who intervene in response to this demand. The Time axis is used to evaluate adequacy between demand and supply.

Beyond the specific contribution of each axis, this methodological process is focussed on understanding the interactions that exist between these three axes. Thus, the analysis of the exploitation and marketing practices of livestock farmers help to appraise the effect of market on livestock dynamics, whereas the study of beef supply throw more light on the action of livestock on market. Time assists to apprehend the seasonal variations and to carry out short and long term projections, thus highlighting the issues of food security and farm sustainability.

To investigate the various axes, surveys and follow-ups related to the practices and strategies of the various classes of stakeholders were carried out: 60 farmers (25 pastorals, 20 mixed farming, and 15 cattle fattening units in the urban area), 10 dealers, 20 tradesmen, 36 butchers and 300 consumers. An annual follow up was carried out at the level of the herd, farm, cattle market and the municipal slaughter-house.

Results
Unlike the mono-disciplinary approach, the systemic process makes it possible to apprehend at the same time market trends, livestock dynamics and the relationships between these two phenomena. Effects of market on breeding practices vary according to farming systems (Tab 1). Most farmers modify their renewal and exploitation practices to benefit from market opportunities (level 1). Farms that show characteristics of levels 3 and 4 are mostly emergent systems with a net
economic goal. They have high production costs and need to plan their sales in order to avoid competition from extensive farmers who are mostly found in level 1.

Table 1. Evolution of farmer’s objectives and practices under market influence

<table>
<thead>
<tr>
<th>Influence of market</th>
<th>Effects of the market</th>
<th>Characteristics</th>
<th>Farmer objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1. Modification of renewal and exploitation practices of herds (65%, n=40)</td>
<td>Increase and planification of the sales of cattle</td>
<td>Increase of the renewal rate of the herd</td>
<td>Earn a higher profit from cattle sales without additional investments/changes</td>
</tr>
<tr>
<td>Level 2. Improvement of breeding practices (47%, n=28)</td>
<td>Improvement of feeding health follow-up of livestock Good body status of livestock</td>
<td></td>
<td>Improve conformation and technical performance of cattle to gain higher margin at sales</td>
</tr>
<tr>
<td>Level 3. Transformation of the farm structure (30%, n=18)</td>
<td>Development of cattle fattening and milk production activities Splitting up of herds</td>
<td></td>
<td>Have a the return from the exploitation of the economic function of livestock</td>
</tr>
<tr>
<td>Level 4. Management and contractual arrangements (15%, n=9)</td>
<td>Creation of farmers organisation, contracts with other stakeholders</td>
<td></td>
<td>Realize economies of scale, Better bargain with stakeholders</td>
</tr>
</tbody>
</table>

(): percentage and number of farms found at this level

To a certain extent, the diversity of adaptations found, matches the different stages of an increasing farm market linkage process: from levels 1 to 4, the economic function of cattle predominates progressively over its social role. This trajectory observed in very few pastoral farms with offensive strategies (15%) is neither linear nor valid for all farms. It rather shows that to obtain full benefit from opportunities raised by market trends, a minimum transformation of the farm and farming practices is necessary. Despite the attractiveness of the market, the pastoralists, who are currently preoccupied by the sustainability of their farms, still hesitate to modify the structure and functioning of their farms. The fact that the market leads them to early reform their “good old cows” and to replace them by heifers can in the long term generate an improvement of the productivity of their herds. Almost all the farmers (90%, n=55) diversify their activities to minimise effects of price variation and market demand.

This approach also shows that the status and evolution of livestock influence the functioning of market channel. Local farms contribute 45% of the beef supply in Garoua where beef consumption is estimated at about 9.3 kg per capita. The complement is comes from Chad. During transhumance and arrival of Nigerian tradesmen, supply on the market drops to about 30%. Supply also varies qualitatively due to the career management practices on cattle. The diversity of farming systems helps to reduce these seasonal fluctuations. Comparison between supply and demand shows a deficit of 15% (540 tons), which, according to projections, will double in the next 10 years if suitable measures are not taken. In the context, characterised by deficiency in supply and a weak requirement for quality, the prevalence of the extensive farming systems, whose production vary, and often of poor quality (thin and sick animals), are always bought by the low income populations.

**Conclusion**

The approach designed makes it possible to appraise determinants and patterns of interactions between market trend and livestock dynamics. These interactions which are necessary to equilibrate demand and supply are constrained by the context (purchasing power, lack of pasture lands, influence of Nigeria) and especially, by dynamics peculiar to market and livestock. Results obtained show that this approach could be further completed into a model usable for the development of livestock and food security policies. The analysis of farmer’s strategies in relation to those of other stakeholders of the market channel highlights that insertion in markets requires the improvement of the bargaining, management and organisational skills of farmers.

**References**

EVALUATION OF COLLECTION STRATEGY OF GM AND NON GM PRODUCTS AT THE SCALE OF A TERRITORY

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Introduction
Coexistence between GM and non-GM productions rises questions such as harvest purity (considering low thresholds to be achieved), crop transformation, transport and segregation efficiency. Concerning maize drying and storage, farmers deliver their harvest to the collection silos of a purchasing firm. One way to limit the risk of GM adventitious presence in non-GM products is to dedicate silos to a specific production (Le Bail et Valceschini, 2004). To incite farmers to adopt this strategy, collection firms should take into account difference of prices between GM and non-GM products and of transportation costs between the different silos (Coléno et al., 2005). To evaluate efficiency of this strategy for maize crops, we have combined economic and agronomic approaches. Firstly, we propose an economic model of variety choice by farmer based on the gain at field level for the considered production, taking into account delivery cost and differences in prices and costs between GM and non-GM products. The model gives maize crop distributions, whether GM or non-GM, that were used as input data for a spatially-explicit gene flow model (MAPOD). It was thus possible to calculate the level of GM adventitious presence in the non-GM silos, and therefore to evaluate the possibility to access non-GM and food markets.

Methodology
The model used is a maximisation of farmer profit at field level. To calculate this profit we take into account: the yield of the production (Y); the price of the product (P); the cost of seeds (Cs); the cost of pesticide (Cp) linked to the nature of GM variety; the transportation cost (Ctr) and the distance of the field from the silo where the product is accepted (d). So we have:

\[
\text{Profit}_{\text{GM}} = Y_{\text{GM}} \times P_{\text{GM}} - C_s - C_{\text{tr}} \times d \\
\text{Profit}_{\text{nonGM}} = Y_{\text{nonGM}} \times P_{\text{nonGM}} - C_s - C_f - C_{\text{tr}} \times d
\]

This model was used on a 10 km² territory¹ (Figure 1), considering that a field will be sown with GM maize if profit is higher than with a non-GM variety. Four silos are located on this territory. Work hypotheses used to calculate GM and non-GM varieties distribution are described in Table 1.

Figure 1: Map of the territory used for simulations. Silo locations are shown by circles

¹ Map: Courtesy of the Institute for the Protection and Security of the Citizen, Joint Research Centre of the European Union and AUP-ONIGC - ex ONIC (Office National Interprofessionnel des céréales/French Interprofessional agency for cereal crops)
Table 1: Work hypothesis

We simulated two separation strategies: 1) we consider one firm owning silos 1, 2 and 3, the latter one being dedicated to non-GM harvests; 2), we introduced a competing firm that would accept all products whether GM or not, at the same price in silo 4. These two scenarios of maize allocations were used as input data for the gene flow model MAPOD © (Angevin et al, submitted) in order to estimate the rate of GM impurities in the non-GM silo (n°3). The compass card of the region was used to simulate realistic conditions of pollen dispersal.

Results

<table>
<thead>
<tr>
<th></th>
<th>One firm in the territory</th>
<th>Two firms in the territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of field with GM in the territory</td>
<td>48%</td>
<td>55%</td>
</tr>
<tr>
<td>Wind distribution</td>
<td>0.16%</td>
<td>0.54%</td>
</tr>
</tbody>
</table>

Table 2: GM adventitious presence in the non-GM silo according to two scenarios and different wind conditions

Table 2 shows the results of the simulation of the two models. Only adventitious presence resulting from cross-pollination was taken into account by the gene flow model. Seed impurities could be considered in an additive manner (Messéan et al., 2006). The thresholds under discussion at the European level are 0.3% and 0.5%. We can see that if one firm doesn’t have any price difference between GM and non GM there is an increase of GM fields, as there is no interest for the farmer closer to this firm silo to sow non GM varieties. This competitor strategy affects the rate of GM impurities in the non-GM silos. In both cases, the “one firm” case is the one which allows achieving the legal threshold (0.9%) to avoid GM labelling.

Conclusions

The model we presented in this paper is only based on a farmer profit maximisation at field level. It does not take into account agronomic constraints and advantage of GM use at field level and the farm organisation which could be modified by GM use. Other studies taking into account the whole farm organisation are therefore needed to balance these results. Moreover, results of this modelling approach address some questions about the governance of coexistence. Co-opetition strategies (Nalebuff and Brandenburger, 2002) should be considered by collection firms in order to guarantee access to the different maize markets. The condition of existence of such strategies about GM and non-GM co-existence could be explored using different cases studies at a territory level.

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INTEGRATED SOCIO-ECONOMIC AND BIOPHYSICAL MODELLING TO ASSESS AGRICULTURAL POLICY IMPACTS

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Introduction
Agriculture and Agri-Food Canada (AAFC) is developing the capacity to evaluate potential agricultural production choices and environmental impacts of a range of policy scenarios. Such a capacity has been necessitated by the disparate scales at which socio-economic “signals” and biophysical responses function. While agricultural land use is responsive to broad-scale economic and environmental drivers, the extent and rate of land use change is dependent on localized factors such as attributes of the land base that affect its suitability (soils, topography, climate), competing land use demands, proximity to markets, production costs, existing production systems and their flexibility for change (Olson et al., 2004; Verburg et al., 2004). Most studies to date have mainly focused on ex post facto land use response to changing economic drivers. These have led to reasonable understanding of broad shifts in land use at regional scales. There is, however, insufficient linkage to changes on actual landscapes within regions, and a tendency to assume uniform land use change across a given region (Reidsma et al., 2006). This is inadequate for determining the environmental impacts of land use change, as land resource response to land use change is significantly affected by where on the actual landscape these changes take place. This study outlines the approach used in linking the Canadian Regional Agricultural Model (CRAM) – a socio-economic model, to a suite of biophysical Agri-Environmental Indicator (AEI) models.

Approach
Previous efforts to link policy and biophysical models have not always achieved a high level of integration (Lambin and Veldkamp, 2000). The challenge arises from the disparate scales and approaches encompassed in each model set. Policy models are based on political boundaries dictated by available economic data and are construed to have a uniform outcome across a broad landscape (Fig. 1a). Conversely biophysical models aim to reflect the detailed characteristics within a landscape and the environmental responses of each characteristic to a set of land use practices. Key to downscaling policy scenarios to ecological polygons is the identification and quantification of land use change drivers in the economic model (Fig. 1b) and the biophysical factors that will be considered when decisions on land use are made on specific parcels of land.

Figure 1: CRAM Output Allocation without (a) and with (b) the inclusion of land use change drivers

CRAM, the socio-economic model used in our study, is a macro-scale analytical model for determining agricultural production decisions resulting from economic/policy studies (Horner et al., 1992). It provides output in terms of generalized changes in production over a whole region. Conversely, the biophysical AEI models determine the potential impact of specific agricultural management practices on the environment in a given landscape (see Lefebvre et al., 2005). The AEI models apply to Soil Landscapes of Canada (SLC) polygons, where each SLC polygon is characterized by unique landform, climate and production potential attributes. While CRAM
effectively represents key factor and product markets, the broad scale at which it represents land use change is not suited to environmental impact assessments. This is addressed through an integration framework which consists of rigorous methodologies to scale down policy outputs to the AEI level to assign land use changes to specific locations, as well as to scale up local impacts to the policy level, through a Land Use Allocation Model (LUAM). Development of LUAM entails three stages: 1) identification of land use change drivers; 2) quantification of the influence of each driver; and 3) validation through a series of back-casting exercises.

### Preliminary results

Agricultural land use change in Canada has been captured over successive census surveys, and validated through a range of other data (e.g. ground truthing, remote sensing). An example of land use change over a 15 year period in a CRAM region is given in Fig. 2. Analyzing the changes over the period has shown that the main external drivers have been technology (development of hybrids suited to a given climate) and commodity prices. The landscape attribute that was a main decision criterion was soil/land class. The enterprises that were more apt to change were cash cropping systems, with livestock and specialty crop enterprises being more resistant to change, even when land class and access to technology made them favorable for change.

### Perspectives and Conclusion

We are currently conducting a series of analyses across a range of landscapes in order to quantify the relative (spatial and temporal) magnitude of biophysical properties correlated with land use change. We will then carry out a series of back-casting exercises for a range of landscapes important to Canadian agriculture. The back-casting would entail i) taking land use scenarios from a given census year (e.g. 1981); ii) using LUAM to project land use distributions for a current year (e.g. 2006); and iii) comparing these to actual land use patterns as obtained from the latest census. These exercises will help us identify and quantify land use change criteria in Canada and will enhance our policy development capacity by allowing us to evaluate the land use change implications and environmental impacts of a range of policy scenarios. LUAM provides an important capacity for localizing, as best as possible, land use changes within an agricultural landscape such that an assessment of subsequent environmental impacts can be carried out. Such modelling provides the capacity to evaluate a range of policy scenarios to achieve desired environmental outcomes.

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ASSESSING THE FORECASTING CAPACITY OF A BIO-ECONOMIC FARM MODEL CALIBRATED WITH DIFFERENT PMP VARIANTS

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Introduction
To enable micro-macro linkage for policy analysis, multiple simulations at the farm level are required. To ensure the quality of the analysis at farm level an automatic calibration procedure, with limited data requirements must be selected. In recent years, a number of Positive Mathematical Programming (PMP) variants have been developed and used for calibration in many bio-economic studies. All PMP variants guarantee exact calibration. Nevertheless, different variant can produce different results when they are used to predict future behaviour of the farmer.

The objective of this paper is to evaluate different versions of PMP that are used to calibrate bio-economic farm models. The approach that performs better will be used to calibrate the bio-economic model developed within SEAMLESS that aims to ex-ante evaluate agri-environmental policies at regional and market level. The approach presented in this paper is close to that of Gocht (2005) but in this paper we test also the Röhm Dabbert (2003) approach, which accounts for substitution effects among similar activities.

PMP Variants

The Standard PMP approach (ST.PMP): The mathematical formulation of a typical LP model is presented below:

\begin{equation}
\max \left\{ U = p'x - c'x \right\} \text{ s.t. } A \cdot x \leq b \quad \left[ \pi \right], \quad x \geq 0
\end{equation}

Where $U$ is the objective (e.g. profit, total gross margin) of a certain farm type, $x$ is a $1 \times n$ vector of production activities, $p$ is the $1 \times n$ vector of activity revenues, $c$ is the total costs per activity, $A$ is the $m \times n$ matrix of the technical coefficients, $b$ is the $1 \times m$ vector of upper bounds to the model’s constraints and $\pi$ the shadow prices of the resource and policy constraints.

The standard PMP approach, as this has been described in (Heckelei, 1997) is a two step approach. Step 1 is the extension of model 1 by adding a set of calibration constraints which are used to fix the simulated crop levels to the observed base year data. A small perturbation $\epsilon$ is allowed in order to guarantee that all binding resource constraints of model 1 remain binding.

\begin{equation}
\max \left\{ U = p'x - c'x \right\} \text{ s.t. } A \cdot x \leq b \quad \left[ \pi \right], \quad x \leq x^0 + \epsilon \quad \left[ \lambda \right], \quad x \geq 0
\end{equation}

Where $x^0$ are the observed activity levels, $\epsilon$ is a $1 \times n$ vector of small positive numbers, and $\lambda$ the $1 \times n$ vector of the dual values of the calibration constraints.

In step 2 the marginal values of the calibration constraints are used to specify a non-linear quadratic cost function of the following form:

\begin{equation}
C = d'x + 0.5 \cdot x'Qx \quad \text{to be specified such that:} \quad (4) \quad \frac{\partial C(x^0)}{\partial x^0} = d + Qx^0 = c + \lambda
\end{equation}

Where $d$ is the $1 \times n$ vector of parameters associated with the linear term and $Q$ the symmetric ($n \times n$) positive semi-definite matrix of parameters associates with the quadratic terms.

Assuming that $d=c, q_{ij}=0$ if $i \neq j$ and $q_{ij}=\lambda/x^0$ if $i=j$ for each $i,j \in \{1 \ldots n\}$, the structure of the PMP calibrated model will be:

\begin{equation}
\max \left\{ U = p'x - c'x - 0.5 \cdot x'Qx \right\} \text{ s.t. } A \cdot x \leq b \quad \left[ \pi \right], \quad x \geq 0
\end{equation}

Almost linear (extended) version of PMP (E.PMP): This version of PMP uses very small parameters for the extended terms of the standard PMP approach. The differences from the standard PMP approach is in step 2 where instead of assuming that $d=c$ we assume that $d=c+0.95 \cdot \lambda$. To satisfy equation 4: $q_{ij}=0$ if $i \neq j$ and $q_{ij}=0.05 \cdot \lambda/x^0$ if $i=j$ for each $i,j \in \{1 \ldots n\}$.

Röhm & Dabbert approach (RD.PMP): This extension of PMP (Röhm & Dabbert, 2003) divides the slope of the cost function of each activity into two parts. One part depends on the different variants of a certain activity (e.g. same crop with different managements) and the other depends on the total activity level. An additional set of calibration constraints is added to model 2 which restricts...
the area of each activity variation to the observed levels. Moreover, a different cost function (equation 6) is assumed.

\[ C = d^\lambda x - \lambda x + x^\lambda x \cdot (x^0)^{-1} \]

**Experimental set up**
The three PMP versions described above were used to calibrate a bio-economic farm model (Louhichi et al., 2007) which is developed within SEAMLESS to simulate farm types across EU25. An arable farm type of Flevoland (the Netherlands), was simulated. The model was calibrated to the base year 1999 and was used to predict the cropping pattern of year 2003. Average prices of years 1996-1998 were used for the base year scenario, while the average prices of years 2000-2002 were used for forecasting. The average crop product prices decreased from year 1999 to 2003. The Percentage Absolute Deviation (PAD) (Hazell & Norton, 1986) was used to measure the difference of simulated results from observed data.

**Results and Discussion**
The predictions of the farm model (LP version) but also of the three models calibrated with the above described PMP versions are presented in Table 1.

**Table 1: Model simulations for the base and the forecasting year. Calculation of PAD.**

<table>
<thead>
<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>LP PMP</td>
<td>LP ST.PMP E.PMP RD.PMP</td>
</tr>
<tr>
<td>Fallow</td>
<td>1.3 0.0 1.3 0.0 0</td>
<td>1.3 0.0 1.3 17.4 16.1 9.9 8.6 15.2 13.9</td>
</tr>
<tr>
<td>Potato</td>
<td>23.7 0.0 23.7 0.0 0 2797</td>
<td>25.7 0.0 25.7 13.9 11.8 0.0 25.7 18.2 7.5</td>
</tr>
<tr>
<td>S.beet</td>
<td>11.8 8.0 3.7 11.8 0.0 1394</td>
<td>9.5 8.0 1.5 10.6 1.1 15.9 6.4 10.6 1.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>6.2 0.0 6.2 6.2 0.0 350</td>
<td>11.7 0.0 11.7 7.5 4.2 0.0 11.7 5.5 6.2</td>
</tr>
<tr>
<td>Onion</td>
<td>8.7 43.6 34.9 8.7 0.0 9205</td>
<td>9.7 49.9 40.2 8.5 1.2 7.2 2.5 8.5 1.2</td>
</tr>
<tr>
<td>Total:</td>
<td>52 52 70 52 0</td>
<td>58 58 80 58 34 33 55 58 30</td>
</tr>
<tr>
<td>PAD (%):</td>
<td>135 0</td>
<td>139 59 95 51</td>
</tr>
</tbody>
</table>

The calibration constraint of Fallow land which is the least favourable activity in terms of gross margin is not binding \((\lambda_{\text{fallow}}=0)\). This is because of the small positive number added to the right hand side of the calibration constraints. The area of fallow land is restricted only by the land constraint that remains binding. This is the reason that when all prices decrease, the levels of all activities (except fallow) are reduced, while fallow receives the remaining available land.

For this specific case, the RD.PMP approach gave the lowest PAD. This is because the slopes of the marginal non-linear cost function are larger in the RD.PMP than in ST.PMP or E.PMP. For that reason, in RD.PMP the changes of the activity levels, due to price reduction, are less significant and closer to what is observed in reality.

For the extended (almost linear) version of PMP we observe that not all available land is utilized. The reason for this is a policy constraint on fallow land which does not allow the total fallow area to exceed 30% of the cropped land.

**Acknowledgement:** The work presented is funded by the SEAMLESS integrated proj., EU 6th FP.

**Literature**
A KERNEL BASED METHODOLOGY TO ANALYSE FARMING SYSTEM INTENSIFICATION PROCESSES IN VENEZUELA

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Introduction
One of the difficulties of investigating the important processes of farm intensification is that there is no agreement on a single conceptualization of the process. Even though the significance of agricultural intensification in increasing food production has been widely accepted, there is still debate about what are the drivers of agricultural intensification and its environmental and socio-economic impacts. The development of earth sensing satellites has made available to scientists large amounts of data about the Earth's surface, which have served as a basis for many investigations related to natural resource monitoring. Change in land cover, including land use, has been one of its most common applications. Most agricultural research based on remotely sensed imagery has been concentrated on the spectral reflectance of specific land cover types. However, some studies have classified farms on the basis of spectral characteristics in a way that could enable a link to be made between spectral signature and agricultural intensification. This could become a cost-efficient way to monitor this important process and to investigate its drivers from a spatial perspective. The current research uses a new methodology to explore the relationship between agricultural intensification patterns and the spectral response of farms. The overall aim of the study is to describe the relationships between key drivers, including access to markets, and intensification and to use these relationships as input to an agent based model that can be used to explore the temporal and spatial evolution of farming systems.

Methodology
The study area was Urdaneta Municipio, Aragua State in Venezuela which is characterised by a progressive intensification of land use. The altitude above sea level ranges from 100 to 730 m and the climate is tropical with a wet season from May to October. Mean annual rainfall is 1200 mm and the mean temperature is 28°C. Multispectral information was obtained from Landsat Enhanced Thematic Mapper images. This methodology involves the use of a Kernel Adatron (KA) Machine (Friest et al., 1998) and census data to interpret remotely sensed land cover images. A survey of 224 geo-referenced farms in the study area was carried out to obtain values of attributes relevant to the intensification process such as machinery use; crop pattern; irrigation use and fallow system. The data were first analysed using linear principal component analysis. A discriminant analysis was then performed to cluster and define farm intensification levels. The spectral signature of each farm was then found by using the methodology of Garcia and Moreno (2004). A kernel principal component analysis (Schölkopf et al., 1998) was used to reduce the dimensionality of the data. One fifth of the censused farms were used as input data to train the following kernel machine: $f(x) = \sum \alpha_i y_i K(x, x) + b$. The data from the remaining farms were kept unseen so that they could be used to test the machine performance.

Results
Fig. 1 shows how the representation of the kernel feature space reflects the systematic variation of the input data. Depending on the kernel function used, three levels of intensification can be linearly separated. Differences are expected to be due to the distinct type of feature space generated by the kernel function in response to the way intensification levels affect the spectral signature through crop choice, leaf area index, field size, etc. The generalisation capacity of the KA machine to unseen instances is shown in Fig. 2. Thus, kernel functions can be used to linearly separate different groups even though they are not separable using conventional statistical techniques. As the hyperplanes separating the groups were found by exploiting the most information-rich region of the feature space, the choice of kernel function is crucial for efficiently separating out the desired categories.
Conclusions
The findings suggest that levels of farm intensification can be derived from abstractions that are difficult to observe directly. Moreover, the spectral complexity of remotely sensed images can be effectively handled by this means without sacrificing the simplicity of linear representations. It was clearly demonstrated that this non-linear strategy was very effective in minimizing intra-class variance. Further research is needed to ascertain how intensification drivers and attributes actually affect the different spectral bands, which sensors perform best, and how far the results can be extrapolated to other regions. With good data on the spatial distribution of intensification, the task of relating intensification to drivers such as proximity to markets and availability of water will become much easier.

References
SIMULATION OF A FREE MARKET FOR MILK QUOTA: AN INTEGRATED MODELLING APPROACH

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Introduction
Recent policy reforms such as the Mid Term Review of the Common Agricultural Policy has set in place the process for a major change to EU milk quota policy. It is now confirmed that the milk quota regime will not continue beyond 2015. However, debate remains on how this can be achieved without causing a major shock in EU dairy market. One proposed option is to allow the international trade of milk quota. This paper presents a methodology that can be used to simulate the trade of milk quota between producers. Ireland is used as a case study. To date the transfer of milk quota in Ireland has been “ring-fenced” to milk processors which means farmers linked to one milk processor cannot sell or buy quota from farmers with other milk processors. The paper describes an integrated modelling approach that is used to simulate a free market for milk quota in Ireland. Some example results for one Irish region are presented.

Methodology
Irish National Farm Survey data for 2004 are used (NFS, 2004). The methodology first looks into the structural change in dairy farming systems under policy reforms by using econometric models of retirement and succession. The probability of succession is modelled as the farm heir’s occupational choice. The heir of the farm has the choice of continuing the farm full-time or part-time or entering some non-farming occupation. This discrete choice is modelled using a multinomial logit model. The probability of farm heir \(i\) choosing farming \(j\) as an occupation is:

\[
\text{Prob}(i \text{ chooses } j) = \frac{\exp(\beta'x_i)}{\sum_{k=1}^{m} \exp(\beta'x_k)}
\]

where, \(x_i\) denotes the vector of variables that influence the utility associated with each occupational choice \(j\) as perceived by \(i\) and \(m\) equals the number of possible occupations. This model can be used to test the influence of farm size and probability on each retiring farm being continued. A Profit Maximization (PM) model is then used to estimate the economic value of milk quota. The model considers four major factors for calculation; (i) the outlook for milk prices, (ii) costs of production, (iii) the number of years that the quota will produce a profit, and (iv) the cost of producing the additional milk.

\[
QVs = \sum_{t=1}^{n} (R_t - C_t) \text{ } \text{ } \text{ (a)}
\]

\[
QVd = \sum_{t=1}^{n} (R_t - C_t - E_t) \text{ } \text{ } \text{ (b)}
\]

where, \(QVs\) = quota value for selling; \(QVd\) = quota value for buying; \(R_t\) = returns from per litre of milk; \(C_t\) = costs per litre of milk production; \(E_t\) = cost producing additional milk and \(t\) = number of years quota exists \((1, \ldots, n)\). Prices and costs of milk production over the length of milk quota life are generated using price indices projected by FAPRI-Ireland model (Binfield et al., 2003). The estimated quota value thus generated is \((a)\) the minimum break-even price that a farmer should accept if selling quota and \((b)\) the maximum affordable price a farmer can bid if expanding production. Aggregation techniques are applied to arrive at national and regional normative demand and supply curves for quota. Once plotted together, these curves provide an equilibrium price for quota where demand for quota is equal to supply.

A farm level Linear Programming model (LP) is then used to determine milk quota transfer between farms. The LP model optimizes farm profits under a set of constraints such as total land
available, stocking rate, feed requirements, labour and total milk quota available. The estimated equilibrium price for quota is used in the LP model and milk quota transfer is allowed between farms. The milk quota constraint is set in such a way that a farm can buy or sell a quota if it is profitable to do so. However an additional constraint is placed on quota transfer so that a farm can buy quota only if other farms are selling it;

\[ \sum_{f=1}^{n} q_{buy_f} \leq \sum_{i \neq f}^{n} q_{sell_i} \quad \forall f \neq f \]

where, \( f \) = the number of farm types and \( ff \) = an alias of \( f \).

For equilibrium, total quantity of bought and sold quota within a region remains same;

\[ \sum tq_{buy(f)} = \sum tq_{sell(f)} \]

where, \( tq_{buy(f)} \) = total quota buy and \( tq_{sell(f)} \) = total quota sell within a region. This constraint can be relaxed at various degrees to determine quota transfer within a region, a nation or between nations. As the LP model is an optimising model, it provides farmers more flexibility to change their management practices within the limits of constraints and decrease costs of production.

**Results**

The results presented here are for the South-West region which is the largest milk producing region in Ireland with 8 different milk processors in operation. There are almost 10,000 dairy farms producing a total of 1.7 billion milk. The econometric models projected a decline in active dairy farms with almost 40% of farmers exiting farming by 2014 under the current policy reforms of the CAP. The models also show that besides lower family income, higher educational level is the most significant factor to lead a young farmer away farming. The PM model estimated farm quota value for farms in the region varies from 0 to 87 cents per litre (cl\(^{-1}\)). It also estimated that 1830 farms make no profit at all on milk production. These farms have a higher production costs than returns and hence produce milk at a loss. On the other hand there are almost 1700 farms which have a quota value estimated more than 50 cl\(^{-1}\). These are highly efficient farms in the region. The normative supply and demand curves produced an equilibrium price of 17 cl\(^{-1}\). At this price, the LP model projected a total of 0.36 billion milk quota (8% of total regional quota level) to be traded between farms. There are a total of 1442 dairy farms projected to sell quota whereas 4184 dairy farms are projected to buy milk quota. The model suggested that almost 400 of previously non-efficient farms have a capability to decrease their production costs and stay in business.

**Conclusions**

This simulation showed that almost 96% of the farmers which were not making a profit from dairy production benefit from selling their quota. The January-2007 milk quota exchange in Ireland resulted in about 5 million of milk being traded in South-West region which was only 13% of the amount that is traded in free market simulation. There were fewer farmers selling their quota in the exchange than in the simulated figures. In free market conditions, dairy farmers in a region have a larger market to buy or sell their quota thus providing efficient farmers a greater opportunity to increase their production and providing non efficient farmers with a better chance to exit production. However, it should be noted that the estimated equilibrium quota price is based on the economic value of quota for each farm over a number of years and assumes that farmers are profit maximisers. The methodology described here can be expanded to a national as well as EU level to determine which EU member states would supply and demand milk quota if an international market for quotas was established.

**References**


A MULTI-LEVEL ANALYSIS OF POLICY IMPACTS ON MULTIFUNCTIONALITY INDICATORS IN THE RIVER GUDENÅ STUDY LANDSCAPE, DENMARK

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Introduction
Multifunctionality in agriculture refers to the facts that agriculture, besides its traditional function as a producer of food also fulfils other functions for society, such as pollution control, groundwater proliferation, landscape stewardship, cultural heritage, recreation, rural settlements and employment (Belletti et al. 2002). The European Union has adopted the concept of multifunctionality for the amendment of their Common Agricultural Policy (CAP) to improve the sustainability in agriculture (EC 1999). The CAP should encourage farmers to better meet demands for environmental and social functions while keeping agriculture competitive and economically viable. Changing political framework conditions in the future, e.g. with regard to WTO negotiations are expected to affect agricultural production and trade, both statically with respect to the incentive prices of agricultural inputs or outputs, and dynamically with respect to the farmers’ investment decisions.

Methodology
Assessing the impacts of these influencing factors on the multifunctional character of agriculture is the central task of the policy oriented EU project MEA-Scope. MEA-Scope aims at covering explicitly both the demand side of multifunctionality, from the rural development perspective, as well as the supply side of multifunctionality, from the agricultural production perspective. In the centre of the project stands the development of an ex-ante policy impact assessment tool (entitled MEA-Scope tool), which is based on a combined modelling approach (cf. Damgaard et al. 2006) that is built upon three micro-level-simulation models operating on different spatial and temporal scales. AgriPoliS, a dynamic agent-based model, simulates the structural change of individual farms in the course of time at the regional level (Happe et al. 2006). Subsequently, MODAM, a bio-economic farm model, conducts a detailed analysis of land use related environmental and economic effects at the farm level (Zander and Kächele 1999). Finally, FASSET/FARM-N, a biophysical model, allows for an in-depth analysis of nutrient flows at the farm and field levels (Berntsen et al. 1999). The combined modelling approach analyses both, structural change of the farming sector and agricultural-management-related environmental impacts.

Case study region
In this paper, we will apply the MEA-Scope tool to the case study region River Gudenå in Denmark and analyse the impacts of alternative policy scenarios on relevant social, economic and environmental indicators. The River Gudenå study landscape is situated near the city of Viborg in the Western part of Denmark. It covers the 112,000 ha river catchment north of Lake Tange, and is an intensive agricultural region dominated by cattle and pig production. In 2002, 1871 farms larger than 1 ha were situated in the landscape, with an average farm size of around 42 ha. The region is characterised by numerous lakes differing markedly in trophic level. Parts of the area belong to the Natura 2000 network. In the past, the river and the lakes in the region suffered from pollution, for which the reduction of nutrient entries into ground and surface water is an important focus of political action in the region.
For the application of the MEA-Scope tool, altogether five policy scenarios have been derived in a participatory approach involving representatives from the EU commission, regional stakeholders, scientists and computer modellers: a baseline scenario which assumes a continuation of the Agenda 2000, a reference scenario which imitates the current settings in the region and three additional scenarios characterised by alternative settings of pillar 1 and 2 of the CAP. In addition, a framework for the assessment of multifunctionality impacts has been developed on the basis of established impact assessment and indicator systems in a multi-stage process. The final indicator list for River Gudenå including economic, environmental and social indicators has been chosen by regional experts to cover the regional specifics in the best way.

Results
Given the landscape characteristics of the region, our analysis will give special focus to water quality related environmental indicators, but we will also analyse trade-offs between the environmental and economic performance in the different scenarios. The majority of our modelling results though calculated for single farms will be presented at regional level. However, in some cases it becomes also necessary to show the implication of our policy scenarios on single farms. The next paragraph will outline some exemplary results regarding structural change and environmental effects for the reference scenario in comparison to the baseline scenario.

According to the scenario runs, decoupling slows down structural change, which means overall more farms remain in production. This concerns in the first place arable farms, while mixed and forage growing farms are dropping out of business. The average farms size is increasing over time for both scenarios, but the trend to bigger farms is less distinct in the reference scenario. In the decoupling scenario more farms diversify by taking up non-agricultural activities, consequently a higher share of the income stems from off-farm activities. Compared to the baseline scenario more land is taken out of production. Additionally, a higher part of the area remaining under agricultural management is extensified. Thus, the average nitrogen input per hectare decreases resulting in lower risk regarding nitrogen entries into groundwater.

Conclusion & Outlook
Regarding structural change, decoupling appears to slow down the process, as fewer farms are dropping out of business due to economic considerations. With respect to environmental effects payment decoupling seems to provide positive effects regarding the water quality related aspects in the analysed region. Further results can be presented for the different policy scenarios with respect to trade-offs between different environmental as well as environmental and economic or social indicators.

References
Session 1.3:
Model-based intervention in land management practice and policy, part I

Session Convenors:
Keith Matthews, Johanna Alkan Olsson and Barbara Sterk
ENVIRONMENTAL FARM MANAGEMENT: A FARMER’S EXPERIENCE WITH THE LIFE CYCLE ASSESSMENT TOOL «SALCA»

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Introduction
Politics and society expect from farmers environmental-friendly production methods. In the European Union and in Switzerland, authorities support these requests with agri-environmental programs, contributing to a better harmonization of agriculture with environment. Regardless of governmental initiatives, there is a need for environmental management tools in order to support the farmers in their own efforts to improve their production from an environmental point of view. The objective of this paper is to present a farm’s environmental profile based on the farm management tool SALCA (Swiss Agricultural Life Cycle Assessment), show what recommendations have been derived, how the results have been communicated to the farmers and what insights farmers have gained from using SALCA.

Methodology
SALCA has been developed at Agroscope Reckenholz-Taenikon Research Station ART. It is a life cycle assessment (LCA) method and a tool for analyzing and optimizing environmental impacts of agricultural production. Its application for farm management is described in [1]. SALCA consists of a database with more than 700 life cycle inventories [2], models for the estimation of direct field emissions and a selection of methods for impact assessment of environmental areas of particular concern (e.g. energy demand, global warming potential, eutrophication, ecotoxicity, and other more)[3].

SALCA presents the results as an environmental profile – strengths and weaknesses – of the farm which operates with benchmarks as reference values. The profile consists of the four impact categories: energy demand, eutrophication, aquatic and terrestrial ecotoxicity. They represent the resource, nutrient and pollutant management of the farm [3]. The reference values are taken from so called model farms which have been defined by ART. Those 27 model farms represent each of them a certain farm type current in Switzerland in different production regions (lowlands, hills or mountains) and with different farming systems (integrated or organic). This allows analyzing the different input groups’ contributions to the impact categories and a derivation of recommendations [4]. The communication is structured in levels of different detailing: overall assessment and detailed contribution by different input groups (e.g. energy sources, buildings, fertilization, feedstuffs, etc.). The farmers receive a document consisting of a theoretical background of SALCA, graphs and tables with the results, the analyses and the derived recommendations.

The farm management tool SALCA has been tested on a network of 13 farms, where data for two production years have been collected [5]. The example given here discusses a dairy farm with arable crops and 18ha of utilized agricultural area (UAA). Half of the surface is cultivated with crops, i.e. wheat, barley, sugar beet, soya beans and silo maize. The other half is grassland. A special feature is that 20% of the surfaces are ecological compensation areas (ECAs).

Results
The results of the four main impact categories show that the farm has similar or favorable environmental impacts compared to the reference farm with the exception of aquatic ecotoxicity in 2002 (Fig. 1). The farm’s strengths are within the impact categories energy demand (input group: energy sources), eutrophication (animal husbandry) and terrestrial ecotoxicity (bought feedstuffs). Further analyses show that there is an optimization potential for energy demand (machinery) and aquatic ecotoxicity (use of mineral P fertilizer as well as choice of bought feedstuffs), because i) the machinery fleet is too large compared to the UAA, ii) the farm employs double the amount of mineral P fertilizer compared to the reference farm which results in a higher cadmium emission and iii) it covers its lack of feedstuffs by the purchase of barley, whereas the reference farm buys hay. Due to different fertilization practice (mineral fertilizer vs. liquid manure) there are more cadmium
emissions linked with barley production than with hay production. Consequently the recommendations derived are that a) the farmer should rent or sell some of his machines and either hire a contractor or extend the use of machines from a machinery ring; b) reduce the fertilization with mineral P and c) replace the brewer grains (barley) by another protein feed, e.g. sunflower meal.

![Environmental impacts of farm (per ha)](image)

**Fig. 1:** Environmental profile of case study farm (CH). Results are shown per ha utilized agricultural area.

The environmental assessment of the farm has already resulted in first implementations by the farmer: Within forage production he has changed the conservation technique from tower silo to bales silaging. This led to the selling of machines which so far were little used.

**Conclusions**

The application of SALCA on farm network has shown that the method is suitable for environmental farm management. The farmers found the documents with the results and the analyses useful. Particularly the clearness of conclusion from results and the ease of perception due to the choice of reference farms as a benchmark were appreciated. It also became apparent that the participating farmers are interested in an environmental optimization of their farms. Some farmers, as in the shown example, have been inspired by the results and analyses with the management tool SALCA and have applied changes in their management. In the framework of the project LCA-FADN (i.e. life cycle assessment within the farm accountancy data network) the communication concept of SALCA for farmers and their facilitators is currently being developed further.

**References**


AUSTRALIAN FARMING WITHIN NATURAL RESOURCE CAPACITY – THE ROLE OF SYSTEMS MODELLING TO IDENTIFY IMPROVED OPTIONS

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Introduction
All forms of agricultural practice have effects on the condition of soil, water, native vegetation and biodiversity. Without conscious and considered planning and action, agriculture can degrade many functional components of these natural resources. Increasingly, there is potential for compromise and trade-off between the productive use and conservation of natural resources. In Australia, the public responsibility for natural resource management (NRM) is vested in regional NRM organisations. These government directed organisations have the challenging task of identifying and prioritising policies, actions, and incentives to protect and enhance the condition of natural resources. This paper describes two regional examples of processes and modelling tools that have been developed to assemble bio-physical, social, and economic information to provide numerical and visual output for the evaluation of alternative environmental policy and management options.

Regional Context
The first example is set in a large irrigated region where the major system issues are the management of water to minimise excessive drainage to groundwater and control of salinisation. The second example is a rain fed region with concerns about wind induced soil erosion, accessions to groundwater and induced salinity and maintenance of biodiversity. In both regions, a major driver is concern for economic viability of farming practices and for the maintenance of social structures and community.

Irrigated region representation
The irrigated region example started with a period of intensive consultation with irrigators and regional water and land managers. The level of understanding of the key biophysical processes of water distribution, interaction between surface and groundwater and the accumulation of salt was poor. A series of education modules were developed and delivered in parallel with the development of models that represent the linkage between irrigation practice, groundwater and salinity. Crop growth, water use and yield models provided information on seasonal yield and economic returns. Model outputs were used as input tables and functions for a multiple objective optimisation program. This program operated at individual farm level and aimed to match personal preference of the particular irrigator with the need to maximise financial returns and to meet regional resource constraints. These constraints include limiting surface and subsurface drainage, limiting salt build up in soils and irrigating within the water allocation. Additional models were developed to assist the monitoring and management of the groundwater system. There was close connection between the optimisation at the individual farm level and the requirements of the region in order that the region could comply with government requirements for maintaining natural resource condition.

Rain fed region representation
The representation of the rain fed agricultural region was strongly embedded in a geographic information system (GIS). The GIS was used to manage, model, analyse, and visualise the complex spatial-temporal information and to link the many
models and indices used. A variety of databases and models were used. These included soils, vegetation, and land use data, climate and climate change models, a crop growth, water use and yield model (Agricultural Production Systems Simulator, APSIM), a tree productivity model (3-PG), specific indicator species response models, agricultural production economics models, and others. The agricultural production system model provided climate and soil sensitive yield data from which biomass, water and financial inferences were made. This was teamed with biomass estimates of native vegetation for inferences about carbon balance, with models of biodiversity needs associated with remnant and replanted vegetation and with indices of soil erosion risk. This example highlights the diversity of interdependent processes and the diversity of possible production and conservation responses when trying to manage the system in a holistic way. A systematic regional planning framework was developed to quantify the amount and distribution of natural resource management actions in the landscape needed to meet the regional NRM targets. The outputs are indicative of the possible landscape futures and are assessed in terms of the environmental, economic, and social effects in the region.

What effect have these modelling systems had?
Involvement of interested people from the regions at an early stage in the development of these systems models indicated that the understanding of regional hydrology, of the distribution and condition of natural resource assets and shared social expectations was limited. Developing the systems representation and gathering data was informative for both researchers and regional people. The development process also rekindled interest in data acquisition which was seen to be potentially enabling rather than an unnecessary expense.

In the irrigation area case the close connection between irrigation practice and regional requirements for water and drainage management lead to modification of their land and water management plans and encouraged the adoption of much improved water measurement and control.

The dry land region representation has caused a reassessment of priorities for management of regional soil, water and biodiversity resources. Potential policy incentives that encourage changes in land use and improve soil or vegetation condition have been shown to be more significant in changing the future landscape than projected climate change and commodity requirements.

Conclusions
The two examples of model representation of farming systems within a greater regional bio-physical, social and economic context have shown that systems representation is possible and can be used to assist future management of these regions. What have we learned?

- Many different models are needed to for systems representation
- Data availability and quality will almost always be limiting
- Education and learning of researchers and end users is equally important
- Natural resource management within regional agricultural production systems is expensive and difficult to implement
- Spatial targeting of NRM actions enables substantial increases in the cost effectiveness of scarce NRM funds
- Systems representation to allow analysis of landscape futures enables:
  - Informed, evidence-based evaluation of regional planning
  - Quantification of triple-bottom-line impacts of regional targets
  - Ex-ante (“beforehand”) policy analysis
  - Estimation of future impacts of external climate and market drivers
  - Comparison of trade-offs
Designing a tool for wheat cultivar assessment by analysing its potential uses

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Introduction
Assessing new wheat cultivars (or wheat varieties) performance in a diversity of environments (soil, climate, crop management) is a key issue for the actors along the chain linking plant breeders to food suppliers. During the 90s, researchers designed a theoretical model (DIAGVAR) to assist these actors in achieving this aim (Brancourt-Hulmel et al., 1999; Lecomte, 2005). However, as many tools developed by researchers have not been used by non-researchers, the agronomists involved in this study chose to work with ergonomists to develop a tool through a participatory research process. As agronomists and ergonomists, we were willing to study the impact of such a process on agronomists’ and involved users’ activities as well as on the designed model. We chose to organize users’ participation by putting the designed prototype and the analysis of users’ activities at the core of a dialogical process between researchers and users as suggested by Béguin (2003). Accordingly, our study had two objectives: (i) finding a design strategy that allows co-development of the tool and of the activities; (ii) checking how the design process promotes changes in the activities of all the participants involved in the design process.

Methodology
To assess the performance of cultivars, various actors use large networks of field trials (NFT), composed of trials located in different environments all over France. DIAGVAR model uses information from all the NFT, in order to (i) characterize, in each trial, the factors which limited the yield of well-known cultivars by using an agronomic diagnosis (Meynard & David, 1992), (ii) identify the complementarity of the NFT environments (e.g. those sharing the same limiting factors or those showing specific limiting factors), and (iii) characterize how the new cultivars assessed in the NFT withstand the identified limiting factors. Through interviews, we identified three groups of potential users interested in DIAGVAR: (1) a group of plant breeders who wanted more information on the new cultivars they were breeding, (2) people in charge of the national examination of the new cultivars who wanted to improve their practices of examination, and (3) people from the technical institute for cereals who wanted to improve their knowledge of cultivars to give farmers better advice. We developed a design strategy based on 4 steps spread over a 3-year period. It aimed at building interactions which enabled: (i) users to question the agronomists’ model, (ii) researchers to acknowledge the way actors assess cultivars in their working situations, and (iii) users to question their own activity of assessing various cultivars’ performance by analysing the information produced in NFT.

Results
Step 1 firstly resulted in the development of a software prototype of the model flexible enough to meet the various needs the users had expressed. This step also showed that some input data might be difficult to get in the users’ NFT. Discussions arose about the Nitrogen Nutrition Index which was used by DIAGVAR to assess the nitrogen status of cultivars. The users told the agronomists that they would not be able to measure it, although they valued the way it was used in the software and the information it could produce on cultivar performance. To meet the
experimenters’ constraints, the agronomists carried out a field experiment and tested a new and easier way to measure the required indicator in the field. During Step 2, both the tool’s interface and its conceptual model were commented on by the users, who also questioned their own activities and made some proposals for improving the use value of the tool. We gathered a huge number of comments that we sorted into three classes: those dealing with interface design, those dealing with questions about the conceptual model and its results, and those dealing with use issues. The comments about the conceptual model and its results were then discussed by the agronomists in Step 3. They chose issues which allowed them to answer the main problems raised by the users and which had good potential from a scientific point of view. For example, as users tested the software for a great diversity of NFT data sets, they pointed out the sensitivity of the outputs to the shape of the data set (e.g., the range of cultivars and environments). The agronomists started to check the sensitivity of their statistical model in relation to the shape of the data set, and to develop adjusted solutions against specific data set ranges with statisticians. Even if the tool is not yet operational for users and even if the data collected must be analysed further, the interviews carried out during Step 4 allowed us to highlight the changes the process fostered. Changes in the tool, firstly, because the prototype was deeply questioned and modified. Changes for the users secondly: the interviews showed that they changed their view of their own work, being more focused on NFT and not anymore on the field trials individually. That also raised new questions about the tools they used in their activity. Some changed their global computing system to have more power for processing the results of their NFT. Some systematized the collection of new measurements (e.g., meteorological measurements) that had proven to be relevant to characterize the cultivar performance. Because they had tested different NFT with the prototype, some started to think about optimizing their NFT to improve their efficiency in discriminating cultivars, which led them to improve their training in statistics and modelling. Besides, because of the collective work we induced with our design strategy, several actors underlined changes in their relationships with colleagues. Thirdly, this process initiated changes for agronomists too, notably during Step 3: they had to change their view of cultivar evaluation by confronting it to the users’. The comments on the tool led them to rethink about the way of automating agronomic diagnosis in link with the shape of databases. It also questioned them about many subjects (characterization of the diseases, thresholds of action of the limiting factors, etc) they would like to investigate.

Conclusions
Sharing the design of a tool between researchers and potential users was made possible by promoting debates around the use of a prototype and by giving each participant the opportunity to become aware of the diversity of the participants’ points of view on cultivar assessment. The way we gave the prototype to users so that they could “play” with it on their respective databases seems interesting in two respects. Firstly it gave the researchers an insight into users’ real work. It secondly gave the researchers some means to enable the users to stand back from their routine work and think about new ways of using their NFT to assess their cultivars. Our design strategy resulted in an in-depth redesign of the tool and fostered changes in activities of both researchers and users. Users called notably into question their way of conceiving a NFT or the methods they used to interpret the data. The researchers questioned their modelling activity, their envisioning of users’ activities and their way of dealing with heterogeneous data sets. Two factors seemed decisive in the observed changes: (i) the dynamics of collective debates on the model and (ii) the way we suggested the users “play” with the prototype that did not exactly match their routines. We still need to assess the role of these methodological choices on developmental issues.

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CAN A MODEL BE A USEFUL TOOL IN FARM SYSTEM DESIGN?
- PRATICIPATORY NUTRIENT MANAGEMENT IN A SWEDISH DRAINAGE AREA

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Introduction
The involvement of stakeholders is today seen as crucial for the mitigation of environmental problems (Jonsson et al, 2005). This is acknowledged by the EU directive on water (Council of the European Communities, 2000) which strongly emphasise the potential and need for increased stakeholder participation in water management. It is argued that public participation may contribute to achieve several interrelated goals such as better-informed stakeholder groups, transfer of knowledge from local stakeholder groups to regional and national planning authorities, socially accepted mitigation measures (leading to higher efficiency in implementation) and reduction of conflicts between stakeholder groups (Pahl-Wostl, 2002). At the same time models are more and more frequently used in natural resource management which to a certain extent is a contradiction as models mean the use of more expert knowledge (Alkan Olsson and Berg, 2005). This paper presents results from a project aiming to improve a methodology for how models can be used in a participatory process. The objective of the paper is to discuss if and for what purpose the involved stakeholders perceived the employed model as a useful tool in a participatory process.

Methodology
The study has been performed in the draining area Kaggebofjärden (Sweden) draining in the Baltic Sea. The aim has been to produce a locally suggested remedy plan to reduce nutrient transport to the sea in the studied drainage area by involving stakeholder groups in a sequence of meetings using a model (HBV-NP) as the basis for the communication (Arheimer and Brandt, 1998). Included stakeholders have been farmers, and rural households (permanent and summer cottages), municipal environmental officers, hydrological modelling experts, and process leaders with a background in social science. Also regional authorities, responsible for water resource management have been involved. A sequence 30 formally structured meetings including 100 stakeholders (using the DEMO methodology) have been organized around 8 formalised steps; definition of today's level of pollution (model based interaction), collection of local data (interaction), definition of local pollution goals (interaction), analysis of needed reduction (model based interaction), prioritising of possible measures (interaction), discussion on hindrances for implementation of measures (interaction), model based assessment on where to implement measures to reach the defined goals (model based interaction) and definition of locally suggested remedy plan (interaction). Around 50 stakeholders have also been interviewed individually. The formal acceptance by authorities and practical implementation of the locally suggested remedy plan is outside the mandate of the project.

Results
The involved stakeholders perceive the employed hydrological model as a useful in relation to mainly three issues; Firstly, they appreciated the models ability to give a general picture of the nutrient status in the drainage area. Several interviewees argued that the discussions around the models gave a clearer picture of what the problem and who the polluter is. Some interviewees also argued that the discussion on the pollution status created a feeling that “this is our problem and we have to solve it”. In the discussions on source-appointment it were found that the emission of phosphorous from rural households not connected to wastewater treatment plants were relatively high something that to a certain extent changed the stakeholders understanding of who actually is the polluter in the drainage area. This new insight was highly motivating for the involved farmers who before had seen their agricultural activities as the major polluter. Moreover, on several occasions the source-appointments provided by the model clarified the contribution of pollutants from the traffic which by some stakeholders were seen as larger than it actually was.
The second issue is related to the possible to estimate the needed quantity of reduction to achieve locally as well as nationally defined goals both at a sub-catchment level as well as in the total...
drainage area level. The third issue is related to the measure package, that were prepared using the model. In these packages the needed reductions were related to actual measures. However when it came to the selection or priority of measures it became obvious that there were many other factors influencing stakeholders’ decisions such as the easiness to implement the measure, the cost of implementation as well as the possible economic benefit for implementing it as some of the farm measures were linked to money contributions such as buffer strips and creation of wetlands. Moreover, equality between stakeholders in the drainage area to implement measures was seen as more important than finding the most efficient spot for implementation. However, especially in relation to wetlands stakeholders found it important to receive and indication of environmentally efficient locations. They argued that this information served as a basis for the discussion where it is technically and economically possible to place the wetland i.e. where is there one or several land owners that are willing to engage in such a project. However, most stakeholders concluded that it has rather been the participatory process in itself that have been the most influential on their understanding of the problem as a well as their possibilities and willingness to take action in the future.

Conclusions
The model employed in this particular participatory process has assisted in creating a consensus around the nutrient pollution problem in the drainage. The model has put environmental changes in a tangible spatial and temporal perspective which may serve as a basis for effective planning and mitigation. The employed model has also assisted in increasing the understanding between the different stakeholder groups which indirectly may decrease future conflicts in relation to implementation of measures. It is however clear form this particular study that the decision on which measures to implement and were to implement them were to a large extent influenced by factors outside the scope of the employed models. However, most stakeholders concluded that it was the process in itself that had been influential on their understanding and possible future action. This indicates that the use of the model cannot be separated from the employed participatory methodology. Hence the usefulness of the models in aiding to design farming system is highly dependent on the ways in which the model is used. Compared to traditional use of models in environmental decision-making the experts’ role is radically transformed from a one-way communication of final results to assistance in various steps of a participatory process. However, to use scientific experts in a local environmental management context is expensive and it may not feasible to employ that much modelling expertise in all drainage areas in Sweden or in Europe to create the remedy plans that are scheduled by the WFD. One solution could be to focus the employment of the model to the steps where stakeholders have identified it as most useful. This could also assist in creating a clearer time plan as to when different model output are used in the participatory process.

References
INTEGRATED IMPACT ASSESSMENT TOOLS
– A WAY TO DESIGN FUTURE FARMING SYSTEMS IN THE CASE OF THE SEAMLESS INTEGRATED FRAMEWORK?
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Introduction
The European Commission (EC) has introduced a formal procedure for Impact Assessment (IA) of its future policies. The SEAMLESS integrated project (System for Environmental and Agricultural Modelling; Linking European Science and Society) develops a computerized framework to assist in the impact assessments, focusing on the effects of agricultural and environmental policies across a range of scales. In the preparation for the World Summit for Sustainable Development a new model for sustainability science was consolidated where inter-disciplinarity, policy-relevancy, holistic perspectives and stakeholder involvement were cornerstones under the lead words of reflexive science and an extended peer review (Beck, 1994). The political call for IA includes several of these characteristics of the new model for science (EC, 2005). The scientific approach employed in the SEAMLESS project is deeply embedded in this new model of science where policy relevance and stakeholder interactions have a central place. One problem has however been that the proposals to democratize scientific expertise by means of a reflexive science and extended peer community have not so frequently provided concrete guidance on how these ideas can be put into practice (Gallopin, Funtowicz et al. 2001). One important reason may be that the combination of increased stakeholder influence and the use of new scientific findings or methodologies are far from as simple and straightforward as it may seem as the political and scientific processes have different logics and perceived roles in the IA process. Another reason is that there are several actors or stakeholders influencing the scope and content of IA which also have ideas on the role of science in this process; decisions makers; research funding agencies, funding projects like SEAMLESS, the scientific community developing the tools and the policy developers, i.e. users of the IA tools. The objective of the paper is to discuss with a focus policy developers’ views on the scope and content of IA and on the role of scientific assessment when creating a computerized IA tool. The paper will also briefly discuss how the SEAMLESS project have handled or are planning to handle policy developers views to ensure the use such a tool in designing future agricultural systems. It is important to systematise the stakeholders’ views on the scope and content of IA both to create a more policy relevant science as well as to improve methodologies for the policy science interactions.

Methodology
The empirical material of this study consists of general comments and reactions forwarded in relation to computerised tools from the SEAMLESS User-Forum meetings and individual interviews. The interactions with stakeholders in SEAMLESS include a formal User Forum that meets twice a year, with representatives from various DGs and targeted meetings with DG officials. The approached policy developers have so far mainly been officials at DG Agriculture, DG Environment and the meetings and interviews took place in between 2005 and 2007.

Results
When compiling the result form the consulted stakeholders three issues related to the scope and content the IA process and the role of science can be identified. One is related to the relevance of the information that is produced, the second is related to the flexibility of a computerised tool and the third concern its transparency.

Relevance – The approached policy developers argues that is important that this type of computerised IA tools is able to give answers to policy relevant questions, including addressing relevant issues and time span. The user community consequently sees it important that there is no miss-match between the given answers and the need. It is argued that it is important that these
computerised tools do not produce too much or irrelevant information. For policy developers it is also important to receive information with the needed precision. Precision is deemed especially relevant when dealing with politically hot issues. As one representative from DG Agriculture stated, “If I do not get precise information how could I otherwise motivate the results to an angry stakeholder phoning me up”.

Flexibility – IA is in the EU guidelines for impact assessment (European Commission, 2005) forwarded as a way to produce better and more sustainable policies by the political establishment. However there is frequently a more or less open disagreement between different groups of policy developers on what to include in these assessments and how impacts on different dimensions of SD should be weighted against each other. From the policy development perspective it has hence been forwarded that flexibility, as to what to incorporate in the IA assessment is important and it is stressed that and IA is essentially a political process where stakeholders’ views should be taken into consideration.

Transparency – For the policy developers it is also essential that any computerised tool assisting in IA is transparent, i.e. it should be easy understandable how the assessment has been done and which the underlying assumptions are. There is an apparent contradiction between the increased use of science and models as a basis for IA and the increased demand for transparency and stakeholder participation. One official from DG Environment argues that “If I cannot see or be able to understand the underlying assumption of a model how could I judge which model to use. Scientist lining up arguing that they have a new model that can assist me in assessing this or that”.

Conclusions
To be a useful in assisting in the design of future agricultural systems it is from the policy developers’ perspective crucial that this type of IA tool is generic and flexible. It should not provide too much or unwanted information but it should be able to produce precise information especially when dealing with politically hot issues. Moreover it should be transparent so non expert can understand its underlying assumption. To create a balance between generic flexibility precision and transparency is of course and apparent difficulty for all tools based on models, as models are constructed for a specific purpose and scope. However from a technical perspective the construction of the SEAMLESS-IF using open-MI and ontologies which facilitates the inclusion of policy developers’ views and needs. The SEAMLESS-researchers are also continuously engaged in a dialogue with its potential users both by actually testing the tool with users as well as through extended peer-review of its components. As for the possibility to create a flexible way of defining which aspects that should be included in the IA assessment SEAMLESS has developed a specific indicator framework that is flexible in the way policy developers want but it is also possible to use the framework in a more limiting way (Bockstaller et al, 2007).

However, to ensure a good dialogue and ensure an appropriate balance between technical and communicative rationality it is crucial to improve the methodology for these interactions. It is important that scientists improve their understanding of what policy developers understand with relevance, flexibility and transparency. In the same manner scientists have to improve their ability to explain scientific terms for example preciseness is always a problem when related to ex-ante assessment as it is a prediction on the future. A similar argument could be forwarded in relation to how to assess SD. The role of science in the sustainability science could be to explain the result of different approaches not imposing one.

References
OPTIMIZATION OF FARMING SYSTEMS CHANGES AT THE WATERSHED SCALE FOR PRESERVING THE ENVIRONMENT

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Introduction
Agricultural practices may have an adverse impact on natural resources and pollution of soil and water can be the result of inappropriate agricultural practices and land use. Sustainable agro-systems should maintain or improve the economic viability of agricultural production and conserve if not enhance the natural resource base and ecosystems that are influenced by agricultural activities. Sustainable farming systems solutions must then cater for the spatially diverse farming enterprises based on land of varying capability, risk and past usage. In this study, we attempt to optimize at the water basin scale, the objectives of reduction of nutrient losses to the environment while securing farming profitability by adjusting land use intensity and patterns. The main contribution of the proposed technique is its ability to address uneven spatial distribution of criteria values in the evaluation of alternative solutions and to determine the best one for each geographic location within the watershed.

Methodology
The methodology we used for optimization of farming systems applied a five-stage approach in assessment and optimization at the level of the watershed:

(1) Existing farming systems within the watershed are characterized and alternative more environmental friendly practices are designed. A GIS is utilized for spatial mapping. Farming systems are characterized on the basis of crop management (rotation cropping on a two years basis and fertilization) and farming outcomes (yield and gross margin) in a way to meet the dimensions of both time and space. Within the watershed, four existing farming systems are identified and five alternative farming systems defined by management options (related to N fertilization reduction and changes in rotation cropping) that avoid degrading water quality and soil nutrient levels without increasing the pollution of the cropping environment.

(2) Nitrogen leaching is assessed at the hydrologic unit (HRU) using the SWAT model. According to their location within the watershed (soil type + topography), Nitrogen leaching potential of the different farming systems are assessed using the Soil and Water Assessment Tool model (SWAT) which is a watershed scale model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in watersheds with varying soils, land use, and management conditions over long periods of time. SWAT model outcomes show that the level of nitrogen leaching potential depends significantly of the type of soil and farming system. The question which occurs then is where to perform the changes of farming systems to minimize Nitrogen loadings to groundwater at the level of the watershed while securing farmers profitability on the area.

(3) A GIS is utilized to generate new homogenous spatial units (by crossing cropping blocks and HRU)

As individual blocks (fields plots with a specific land use), management and soil scattered throughout the watershed are lumped together to form the HRU, optimization allows only to locate farming systems on soils of the watershed. Thus, if a type of soil is not entirely occupied by the same cropping system, then different mapping solutions are possible. Hence, for optimization, the map of individual cropping blocks pattern is crossed with the HRU to generate a new grid of uniform spatial units with only one crop on one soil.

(4) A goal programming model determines the optimal farming systems pattern

The application of mathematical programming and optimization techniques to spatial analysis offers significant decision support by producing solutions which optimize certain objectives defined
by users or decision makers. A goal programming (GP) optimization model is used to optimize the geographical distribution of existing and alternative farming systems within the watershed. Optimization of changes for the farming systems distribution is achieved at the watershed and at the sub-basin level. The goals to target are the reduction of Nitrogen loadings (with goals of different levels ranging from 10% to 40%) and no substantial reduction of farm incomes satisfying the economic sustainability of farms. Weights are introduced in the model to normalize the goals in order to overcome incommensurability but we do not consider weights to indicate preference of decision makers with respect to each goal. If reduction of Nitrogen leaching is easily understandable for environmental concerns, the affordable reduction of profit is although difficult and not straightforward (nor politically expedient) to specify.

As the model should incorporate the discrete and multi objective nature of farming systems allocation, the decision variable is a binary variable taking the value of 1 if the farming system is assigned to the spatial unit of the watershed and the value of 0 if it is not. Model is written as a MILP using GAMS (GAMS 20.7) and solved with CPLEX. Optimization is achieved at the sub basin level and at the watershed level.

(5) A GIS is again employed for mapping the optimal solutions into a detailed land use proposal.

Results
Optimization model outcomes show that almost all the existing wheat/maize farming systems are changed by other more environmental friendly farming systems. Crops changes affect mainly maize (reduction) and sunflower (large expansion). High fertilized maize area is reduced and changed partly by less fertilized maize and less fertilized wheat and sunflower. When the target of leaching reduction increases to 40 % cropping area changes totally to sunflower/less fertilized wheat systems. Grassland area is modified with increasing level of the leaching target but its modification (reduction) is bounded by a straight constraint in order first to conserve the existing forage systems and its replacement by cropping systems.

Optimization achieved at the whole water basin level leads to a specialization of production on each sub river basin which may be not optimal for farmers aiming at some diversification when producing commodities and for planners aiming at landscapes variety. In this case, changes affect particularly the sub basin which contributes mainly to Nitrogen leaching.

Optimization of changes allow a reduction of the total leaching at the watershed scale up to 36 % which seems to be the maximum level possible for leaching reduction. When optimization is achieved on a smaller area (sub-basin), the number of possible combinations is more limited and reduction of Nitrogen leaching is slightly lower (-1%) than in the case when optimization is achieved at the watershed level. Reduction of profit ranges from 3% to 57 % depending on the level of target for Nitrogen leaching and the level of optimization. Profit decrease is lower when optimization is achieved at the watershed level. Without weights to indicate preference with respect to each goal, target of leaching reduction is obtained but with a considerable fall of farm incomes.

Conclusion
Developments of this study should be achieved particularly by attaching different weighting factors to the goals and by adding other environmental goals (like those relating to pesticides). The implementation of sensitivity analysis by various weighting and ranking scenarios or changes in goal types may be needed to provide a number of solutions large enough for analysis. Further in formulating the goals and achievement function, such approaches could help decision makers to tackle environmental issues by targeting and locating programs of measures to protect the environment while maintaining the economic sustainability of farms.

References
TECHNOLOGY TRANSFER STRATEGIES BASED UPON FARMER LEARNING STYLES

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Introduction
Agriculture in NW-Europe and especially the EU-financially supported agriculture is changing fast. The farmer/entrepreneur has to face changes and consequently adapt his farm and cropping practices. The starch potato industry in the Ems-Dollard region (NE-Netherlands and NW-Germany) started 10 years ago the strategic research and extension program AGROBIOKON for sustainable innovation of the potato starch production chain. This program is a cooperation of the Dutch farmers board (HPA), the Landwirtschafts Kammer in Niedersachsen, Dutch Northern provinces (SNN) and the INTERREG program of the Ems-Dollard Region (EDR). The objective of AGROBIOKON is to improve economic and ecological performance of the potato cropping in order to increase potato yields, reduce losses, the environmental legislation on nutrient losses and crop protection agents. A major part of the program is dedicated to the development of dedicated DSS for topics in potato crop management. The most sophisticated DSS, TIPSTAR, applies genetic algorithms for non-linear multiple goal optimization by using a differential equations based simulation model. This system allows the farmer to optimize simultaneously ecological and economical targets for achieving sustainable yields. (in Jorna et al 2006)

Knowledge for crop management improvement is disseminated through a portfolio of approaches: individual coaching, farmer knowledge networks, magazines and newsletters, field demonstration days, field schools, courses, extended courses on specialized topics, seminars, bench marked crop registration systems, internet knowledge portals, and finally through several interactive decision support systems which are free available on www.kennisakker.nl. With all the knowledge available and the extension programs in place the profit of farms should increase when farmers adopt the developed technologies.

The practice however is that the extension program reaches only about 20% of the potato starch farmers and consequently the average starch potato yields increase only a small amount in the past few years. The focus of research is now redirected to the understanding of information retrieval, knowledge processes and innovation intentions by farmers with the objective to develop targeted technology transfer strategies which can reach about 80% of the farmers.

Methodology
The first step is to quantify the performance levels of potato cropping of the individual farmers by using the factory delivery data based upon truck load measurements. Data from about 2400 farmers for 3 different cropping seasons are used in a statistical cluster analysis. The next step was to send out an enquiry about the farm system, knowledge sources and preferred ways of knowledge retrieval. About 800 farmers returned the forms. The third step was to investigate personal differences between farmers regarding learning and personality attitudes. The learning questionnaire was inspired upon the MSLQ (Pintrich and de Groot, 1990) and adapted to a farming context. The personality questionnaire was inspired upon the Big Five. Almost 400 farmers returned the questionnaires. The last step until now was to apply the Theory of Planned Behavior to measure the innovation intention of farmers (Harrison et al, 1997). A questionnaire was adapted to farmer’s conditions. More then 300 farmers returned these enquiries.

Results
The statistical analysis of farmers deliveries to factories revealed four significant farmer clusters of respectively, top farmers, quantity farmers, quality farmers and normal farmers, see figure 1. These farmer clusters correspond with different farm types and the usage of different knowledge sources. Figure 2 shows the major statistical significant differences of the farmers clusters regarding learning motivation, learning skills and personality. The motivation scales “extrinsic value” and “self efficacy” and the skills scales “peer learning” and “help seeking” differ significantly between clusters. Hence top farmers perform best in study groups where they pose their questions and learn from their (top) peers. Consequently, knowledge diffusion from top farmers to other farmer
clusters is limited. The quality oriented farmers, seems to lack behind with respect to their learning skills especially on the scales of peer learning and help seeking.

![Graph showing learning styles and personality impact on DSS usage]

These farmers might perform better when their learning skills are addressed properly. The quantity farmers appear to hesitate and need perspective or the “strategic fit” between industry and farmer. The normal farmers, rank very high regarding extraversion and openness. This opens the possibility that these farmers are not highly interested in improving starch potato cultivation but have their interests in other aspects of their farm. Learning styles and personality have impact on the use of DSS, especially anxiety is one of the scales which appears to block the usage of DSS. The measured Innovation intention of farmers did not correlate with the farmer clusters or the learning styles.

**Conclusions**

Technology transfer strategies must take into account the different learning styles of individuals in order to increase its efficacy. Eventually it will result in a portfolio of strategies differing in methods and media but targeted to specific groups of knowledge users. Model-based intervention by applying DSS is hence only suited for users who possess the “right” learning skills and motivation, hence who are not anxious to apply DSS. The (apparent?) discrepancy between learning styles and innovation intention of the farmer’s clusters will be investigated further.

**References**


Introduction
Over the past decade, the South African Sugarcane Research Institute (SASRI) has invested substantially in the development and implementation of model-based decision support systems (DSS). Van den Berg and Smith (2005) presented an overview, and highlighted that little is known about their actual use and practical utility. The objectives of this paper are: (i) to investigate the users, use and perceived usefulness of three DSSs that have at their core the sugarcane growth model Canesim, a daily time step, point-based simulation model predominantly driven by water; and (ii) to draw up a tentative list of factors that contribute to DSS adoption, in order to support future development.

Methodology
The three DSS investigated are: (i) SQR-Canesim (Olivier, 2001), a desk-top version of the model allowing users to run their own simulations with downloaded weather data; (ii) the Canesim crop forecasting system (Bezuidenhout and Singels, 2007) which, since 2001, provides monthly estimates of sugarcane production at sub-regional level (48 climate zones); and (iii) an application of the MyCanesim system (Singels and Smith, 2006), which, starting in 2004, provides automatically generated daily irrigation advice and yield estimates for individual fields to small-scale growers (a pilot scheme with 39 farmers) by SMS, and more extensive information to the advisory support structure (SASRI extension, sugar mill, and water board) by FAX and internet.

Semi-structured interviews were conducted by a neutral interviewer, telephonically or personally, with registered users of the systems. In addition, written questionnaires were conducted anonymously with SASRI researchers and extension officers to probe their attitude towards SASRI DSS in general. Questions regarding the use, usefulness and ease of use of DSS were inspired by Davis’ Technology Acceptance Model (Davis, 1989) and a list of factors perceived to inhibit adoption, drawn from Stephens and Middleton (2002).

Results and discussion
Preliminary results indicate that uptake of SQR-Canesim is very low. Of the 19 (out of 38) registered users interviewed - mostly SASRI researchers and extension officers - only 5 indicated that they use this DSS frequently (almost every month or more). They find it quite useful for yield benchmarking, irrigation scheduling and/or as an aid for crop and soil water monitoring. Most of the others hadn’t used the program at all over the past 12 months, mainly because its use was considered too complicated or because of perceived shortcomings or it was found of little relevance to their job.

The crop forecasting system has a much higher uptake among a more diverse group, including researchers, advisers, farmers’ group representatives, sugar mill managers and marketers. Virtually all persons interviewed appreciate the industry-wide estimates provided by e-mail, but most of them disregard the comprehensive information at the subregional level available on the internet (http://sasri.sasa.org.za/cropest/). The production estimates are used for diverse purposes like benchmarking of regional yields, financial planning, planning of the milling season and future sugar sales. Several persons indicated that the system helps them to increase profits, but without giving (or willing to give) specific examples. Interestingly, persons in similar jobs often expressed contrasting views about the system and how to use it.

With regard to the irrigation advice from the MyCanesim system, 75% of the small-scale growers interviewed regard the system as very valuable and follow the advice whenever possible. Evidence
of tangible benefits includes higher yields and more efficient use of irrigation water. This system was conceived on the principles that users’ exposure to its complexity should be as limited as possible, while they should participate in system design and implementation. Interaction between users and developers of the system occurred through workshops and field visits. In addition to providing simple near-real-time irrigation advice directly to the growers, the more extensive reports generated are used by extension staff as a basis for discussion with growers during field visits, and to identify agronomic practices that limit yields. This has led to improved practices in several cases.

Results from the written questionnaires to SASRI researchers and extension officers clearly indicate a positive attitude towards computer based decision support. This contrasted with a low level of actual use of the DSS available. Rather than a lack of perceived usefulness, most of the reasons given for not using the systems pointed towards a lack of perceived ease of use (e.g. lack of documentation, poor internet access, lack of training opportunities) and poor dissemination and marketing.

Discussion and conclusions
The results of this study confirm the existing feeling that SASRI DSS are used below their potential. A factor that clearly appeared for the SQR-Canesim and Crop forecasting systems as well as SASRI DSS in general, is a lack of continued engagement between the custodians of the software and the target group: a fairly large portion of registered “users” had left their job and could not be traced back, while the systems are insufficiently promoted and explained to newcomers. The results also confirm findings elsewhere that more successful applications tend to have a high degree of interaction between model developers and (potential) users, but a low degree of exposure of users to the model itself. The question remains if systems developed in this way can be sustained over time and scaled-up to other regions. In the case of the MyCanesim irrigation advice, this would inevitably require gradual disengagement of researchers and developers, but the support structure of advisors remains in place. They would have to be the link for two-way communication between growers and developers.

Further introspection and consideration of the results led to the following tentative list of DSS success-factors that should be considered in future developments:

1. System should respond to imminent needs or pressure to change practices
2. System should provide ‘answers’ that are difficult to obtain without the DSS;
3. System developers must understand the requirements of different types of users and their capacity to absorb new technology; most users prefer targeted information rather than exploring options by themselves.
4. DSS must be tailored to user needs rather than developers’ fancy;
5. Broad institutional support is required for DSS oriented research, development, implementation and maintenance; well beyond the modelling group.
6. Post-development user support and marketing system must be in place.

References
Session 1.4:
Model-based intervention in land management practice and policy, part II

Session Convenors:
Peter Carberry, John Dimes and Maurits van den Berg
EVALUATING ECONOMIC SUSTAINABILITY OF FARMING SYSTEMS,
THE FARMING SYSTEM ANALYSIS AND DIAGNOSIS (FASAD),
A METHOD FOR REGIONAL ANALYSES

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Introduction

This paper proposes the Farming System Analysis and Diagnosis (FASAD) as a standard methodology to consolidate a variety of similar analytical procedures aimed at evaluating the economic sustainability of farming systems (FS) through a holistic approach. From a conceptual viewpoint, the FS practised in a given region define the mode of exploiting the eco-system by which farmers satisfy their own needs. This is characterised by four main elements: the environment, in the broadest acceptation, including the natural characteristics of the examined areas and all modifications related to human activities; history, as a ground to investigate the present-day conditions of variables to be taken into account; technology, i.e. technical means and methods used by farmers; society, which subsumes population, socio-economic relations, and institutions operating within the examined area, as well as the wider national and international context influencing relations and individual choices at the local level.

Methodology

Operatively, the FASAD procedure develops through seven principal steps: (1) Zoning consists in the geographical delimitation of the region (or regions) under examination and in the identification of the different sub-areas that can be considered homogeneous with respect to problems related to agricultural development. The aim is to identify the main variations in the land-use pattern (extensive/intensive field cropping, fruit-tree plantations, gardening, grazing, forestry, etc.) and the potentials and constraints of each sub-area. (2) The background analysis studies the FS evolution in relation with social dynamics and environmental modifications. It means to reconstruct the original characters of eco-systems, FS, local economy, and society, and (ii) recognise the main determinants of changes (e.g.: spread of new techniques, creation of infrastructures, demographic changes, social, economic and political events, etc.) and feed-backs among ecological, technical, and socio-economic transformations. The objective is to explain the progressive formation of present-day FS and the existing inequalities in farmers’ productivity, income, and living standards. (3) The farm analysis investigates the agricultural holdings with regard to technical, economic and social aspects of production organisation and generation of farm income. The inquiry is carried on by selecting representative samples of the different types of holdings existing in the region and by interviewing farmers and local experts. The analysis focuses on the farms’ structures (land, facilities, tools, machinery, livestock, workforce, landownership, crop patterns), the production techniques (work timetable, technical means and workforce used), the elements concurring to FS economic performances (yields of crops and livestock, prices of inputs and outputs, products for market and for family consumption, marketing systems, taxes, access to credit, farm gross income, add value and net income, etc.), and the social and economic aspects of farm households (composition, members involved into farm activities, off-farm incomes, living standards, etc.). (4) Farm typology. The farm analysis should highlight the distinctive features that differentiate the holdings by indicating the most significant criteria for a farm categorization. The purpose is to work out a comprehensive farm typology summarising the variety of region’s holdings and evaluate importance of each farm type. (5) FS modelling. A FS model is a standardised representation that reproduces the ordinary conditions – in terms of farm structure, techniques, products, yields, workforce, etc. – of the holdings belonging to the same farm type. A model is built basing on data collected through the farm analysis and shows the technical outcomes of the associated farm type. (6) FS economic analysis. The economic performance of each FS model is described using linear equations which indicate variations of outputs, costs, and net income (NI) per work unit (WU) as

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1 A. Segrè wrote the Introduction section; M. Canali wrote Methodology, Results, and Conclusions sections.
functions of a significant farm indicator; e.g. the utilised agricultural area (UAA) per WU, or the livestock units (LU) per WU. The NI per AWU obtainable from the different FS models is compared with an economic Reproduction Threshold (RT). The RT is the indicator of FS economic sustainability; it corresponds to the income assuring the minimum acceptable living standards to the farmers, and is deducted from data collected during both the background and the farm analyses. A FS is considered economically sustainable when it generates a NI per WU higher or equal to the RT. The difference between the NI per WU provided by a particular FS and the RT expresses the FS accumulation capacity. The greater is the difference, the higher is the capacity of farmers to maintain acceptable living standards and accumulate a surplus. When the difference is negative, farmers not only do not have possibility of surplus accumulation, but also their livelihood results insufficient. This procedure allows direct comparisons of the income levels attained by the different types of farms existing in the analysed region, and shows their degree of sustainability and accumulation capacity according to socio-economic criteria (i.e. the RT) expressed by farmers in the region. The final diagnosis defines the conditions of the various categories of farmers, taking into account all the analysed aspects (environmental, technical, and socio-economic), formulates hypotheses of the evolution of agriculture and FS in the region, establishes hierarchies of opportunities and constraints for the different farm types, and identify priorities and proposals for policy measures.

**Results**

The graph shows a simplified scheme of possible results of FASAD use in a regional analysis. The four FS lines represent the variation of the NI per WU (vertical axis) related to exploited UAA per WU (horizontal axis) of the farms associated to four different FS identified in the region. The RT is represented by the scattered line. The four FS have different technical potentials; the upper limit of a FS line correspond to the maximum UAA per WU exploitable by farms practising the corresponding FS. The income generation capacity of the four FS increases from FS1 to FS4. The maximum NI per WU of FS1 and FS2 does not attain the RT level: these FS are not economically sustainable. This entails that the holdings belonging to the corresponding farms types are not viable and need to improve their FS or will cease to produce. FS3 and FS4 can reach income levels above the RT: they have accumulation capacity if the UAA per WU is wider than the area corresponding to intersections between the FS lines and the RT line. One can easily imagine the effects of simulations in the graph: for example, if output prices decrease, the FS lines diminish slope and also FS3 and FS4 could fall below the RT and would become non sustainable. The same effect can be created by a general improvement of the socio-economic conditions in the region. In this case, the wish of farmers to ameliorate their living standards, as the other social categories, can bring to a displacement of the RT above the FS lines. Farmers will no longer be satisfied with their income and will be stimulated to upgrade their FS (or even to change job) in order to achieve better livelihood.

**Conclusions**

The FASAD can explain the origin of FS changes and how they can be related to various socio-economic phenomena: e.g. land abandonment, rural migration, ageing of farmers, etc. The use of FS models to represent real farms and the possibility to modify the models’ variables make this method suitable for scenario analyses and to evaluate agricultural policies and agricultural development projects. Some case studies worked out by the authors are listed in the references.

**References**

Introduction
This paper proposes the use of generic simulation models to realize innovation of entire value chains in agricultural domains. We illustrate this approach with two cases; an existing simulation model is used in the Dutch starch potato growth to support (i) crop management of starch potato farmers and (ii) capacity planning in starch processing factories.

Agriculture in NW-Europe and especially the EU-financially supported agricultural value chains is changing fast. Innovation in such agricultural value chains is necessary regarding farmers and processing factories. Interventions at the level of knowledge provide the leverage that is needed to adapt to the pressures these value chains experience. Such interventions operate at the level of individuals (Newell & Simon, 1972) and originate from the field of knowledge management. Knowledge management interventions operate through either social or technical paths. Organized carefully, knowledge management interventions enhance current knowledge about the agricultural section in which they operate, and the ability to generate new knowledge that enables continuous adaptation and innovation of farmers and processing factories (e.g. Jorna, 2006). Agricultural value chains consist of multiple individuals who perform various tasks, and require specific knowledge to perform these tasks (Schreiber et al., 1999). Scientific simulation models often lack the task specificity that is required to provide adequate support in such tasks. In utilizing a scientific simulation model as a DSS, the challenge is to connect the scientific models that form the foundation of these simulation models to the knowledge domains of the individuals who perform a task in the value chain; a knowledge engineering challenge (Schreiber et al., 1999).

Starch potato growth
The starch potato industry in the Ems-Dollard region (NE-Netherlands and NW-Germany) started the strategic research and extension program AGROBIOKON for sustainable innovation of the potato starch production chain 10 years ago. This program is a cooperation of the Dutch farmers board (HPA), the Landwirtschafts Kammer in Niedersachsen, Dutch Northern provinces (SNN) and the INTERREG program of the Ems-Dollard Region (EDR). The objective of AGROBIOKON is to improve economic and ecological performance of the potato cropping in order to increase potato yields, reduce losses, the environmental legislation on nutrient losses and crop protection agents.

A result from the AGROBIOKON program is TIPSTAR, a starch potato crop growth simulation model. The crop, soil, and climate are identified as the subsystems to be studied and understood, and that can be described using mathematical functions. Knowledge from the domains of soil-physics, soil-chemistry, crop ecology, eco-physiology, and meteorology is used. Crop management, daily weather, physical, and chemical soil data are inputs to the system. The soil-water system simulates the crop's daily availability of water, using the farmer's irrigation, precipitation, and groundwater data. The Soil-Organic Substance and Nitrogen system simulates the crop's daily availability of nutrients (nitrogen) for each separate layer of the soil, using the farmer's fertilizing data. TIPSTAR has been developed from a scientific standpoint, building the model as generic as possible, reducing everything relating to starch potato growth to simple units. The model simulates plant behavior in one point, which is used to estimate the behavior of plants growing on one hectare. Practical situations, as are encountered by farmers or other actors from the starch potato value chain, however are more complicated.

General architecture
A three-layered architecture is used to connect TIPSTAR to two tasks in the starch potato value chain. The three layers are (i) simulation, (ii) simulation management, and (iii) user interface. TIPSTAR resides at the simulation layer, which forms the base of the architecture. The simulation inputs are
received from and simulation outputs are forwarded to the simulation management layer. The simulation management layer has two main functions. First, it processes and stores all data that is received from and sent to the simulation and user interface layers. Second, it controls the starting and stopping of simulation. Last, the user interface receives user inputs, informs the user about his settings, and about the status of the simulation and simulation management layers. The three layers of the architecture together can be used to form a decision support system for several tasks in the starch potato value chain. Currently, the tasks (i) crop growth management, and (ii) capacity planning are supported.

Case 1: crop growth management
The crop growth management task concerns activities regarding crop growth, stretching from pre-growth plowing, to in-growth irrigation and fertilization, to harvesting at the end of the growth. TIPSTAR can support this task at operational (day-to-day management advice), tactical (investigating the consequences of alternative management strategies for a historic growth), and strategic (comparing management strategies and effects on soil composition for multiple growths regarding multiple years) levels. The current configuration of the user interface provides tactical support. It enables a user to define his fields, type of crops, location, soil composition, weather data/forecasts and other ecological and geographical data; it enables the creation of a virtual copy of a farmer’s field. From this point on, the user interface handles the input of operations on the field, like sowing, plowing, fertilizing, irrigating, etc. These operations can be actual operations, planned operations or experimental operations, depending on the objective of the usage of TIPSTAR. For instance, during a training course an improved irrigation method can be explained by the results of TIPSTAR or during the season, a farmer can predict the effect of a planned increase in compost depending on different weather scenarios. The user interface has been designed to match the farmer’s perception and knowledge of his domain and environment as closely as possible.

Case 2: capacity planning
Capacity planning concerns the construction of a production schedule for the processing of the total yield of all farmers in the region that is served by the factory. This schedule concerns factory machines and employees. The factory capacity planner requires a forecast of the expected starch potato yield in order to make the schedule. Thus far, a forecast was made using several field samples during the growth, which is costly and time-consuming, and often leads to unreliable forecasts. The prognosis user interface provides the factory capacity planner a portal to the TIPSTAR simulation model. In this instance of the architecture, the starch potato region is considered as one giant field consisting of the region’s complete soil data. The user interface has been designed to handle the input of parameters, like crop emergence dates and weather data, and the result of the simulation: the forecast. The forecast is presented in management summary and graphical charts.

Discussion
The chosen architecture is suitable to build various DSSs on top of the TIPSTAR simulation model. We plan to extend the amount of tasks in the starch potato value chain that is supported. The first task that will be added to the current portfolio will be crop growth management of seed potato growers and Furthermore, other functionality will be added to the current configuration of the DSS. First in line is GIS functionality to add geographical orientation to the user interface for crop growth management. In the current user interface, a farmer needs to specify the exact composition of the soil of his farm land. Using GIS functionality, soil maps can be used to automatically deduce farm land soil composition from a set of coordinates.

References
SCALING UP FARMSCAPE: A NATIONAL NETWORK DELIVERING SIMULATION TO SUPPORT FARM MANAGEMENT

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Introduction

The FARMSCAPE project employed Participatory Action Research (PAR) to investigate the value of simulation as an aid to farmers’ planning under climate risk. In a project that commenced in 1991 we found that once we demonstrated the credibility of the simulator and our commitment to farmers’ perceived problems, farmers became keen to explore a wide range of management issues. Participating farmers often attributed significant insights and management changes to their involvement in ‘What-if’ discussion sessions (Carberry et al. 2002). On the strength of this, we turned our attention to ‘scaling up’ the delivery of such interventions. This paper describes the efforts, frustrations, impacts and learning achieved through a number of approaches to scaling up FARMSCAPE.

Methodology

Snapp and Heong (2003) defined ‘Scaling up’ in four ways: 1. the scaling up of an intervention or technology to serve a wide geographic area, 2. extrapolating from a small field experiment to estimate the impact on a larger area such as a region, 3. the growth of a small-sized organization to a large-sized organization, and 4. expanding impact from a small to a large number of beneficiaries. While simulation is commonly utilised for spatial as well as temporal extrapolation of plot experiments (2nd way) this work was primarily concerned with expanding the number of beneficiaries and the geographic area covered (1st and 4th ways). Three scaling up efforts are described in this paper: 1. a training and accreditation program to enable consultants to incorporate the FARMSCAPE approach into their business, 2. Internet enabled ‘What-if’ discussions with remote farmer groups, 3. Yield Prophet® - an internet enabled support network providing farmers and consultants with direct access to simulation tools.

Training and Accreditation: Farm advisers were important participants in FARMSCAPE. It seemed logical that with the appropriate training they could replace researchers in the provision of crop and soil monitoring, simulation and facilitation of “what-if” discussions. We decided to establish a FARMSCAPE training and accreditation program. Two public sector advisers and 7 agronomists from 4 companies participated in the program.

Internet enabled ‘What-if’ discussions with remote farmer groups: In this investigation we explored the possibility of connecting farmers and their advisers with research scientists through Internet enabled online workshops. Workshops were mediated through low-cost, low bandwidth Internet video-conferencing. Fifteen online workshops featuring simulation aided discussions about alternative management practices were conducted with 6 groups of farmers in 4 states.

Yield Prophet®: Engagement with the Birchip Cropping Group (BCG) in the Internet enabled delivery program was a catalyst for the next step in scaling up FARMSCAPE. At one such meeting the group invited the researchers to re-evaluate prospects for the upcoming season on a monthly basis. From this invitation evolved Yield Prophet (www.yieldprophet.com.au), an Internet enabled user interface to the cropping system simulator APSIM. Yield Prophet consists of a network of farmers, consultants and researchers concerned with improved management of crops in Australia’s climatically variable environment. This network is managed by BCG with the support of the
APSRU/CSIRO research group. Subscribers enter their actual management information such as crop, variety, sowing date, nitrogen fertiliser rate and time of fertiliser application. They can then choose to generate a variety of reports that are made available to the individual farmer and their nominated agronomist. Reports provide information on the current status of the crop and of soil moisture and soil nitrate levels, as well as probabilistic forecasts of crop yields for current and alternative management scenarios.

Results
Training and Accreditation: A flexible, part time, and work based training program was designed and delivered. However, most participants experienced difficulties meeting the demands of training in competition with demands from their clients. Consequently, only four trainees including the two public sector trainees achieved full accreditation. The longer term impacts of the program on the two private sector companies that employed the accredited FARMSCAPE agronomists were evaluated. In July 2003 interviews of a sample of one company’s clients revealed varying impacts ranging from one client who clearly attributed a AUD 0.5M benefit to a single decision to others who were unaware of the opportunity to participate. At the time of writing the second agronomic consulting company had adapted the use of these tools to suit their consulting style and was using simulation and monitoring as a regular part of their consulting business. The company has also absorbed much of their learning from simulation into new heuristics that are used by all company agronomists.

Internet enabled ‘What-if’ discussions with remote farmer groups: Effective Internet interactions required good local and remote facilitation, common understandings about interpretation and meaning of shared representations and reliable functioning of the underlying communication technology. Replacing face to face FARMSCAPE workshops with Internet enabled online workshops proved to be cost effective and time efficient while delivering comparable measurable impacts on farmers’ management practice.

Yield Prophet®: In 2002 Yield Prophet started by reporting monthly on 3 paddocks to 500 BCG member families. It grew to 32 paddocks in 2003 when it was still a faxed sheet service. Expansion was enabled by providing an Internet based service in 2004. By 2006 there were >550 registered Yield Prophet paddocks in 5 states Australia-wide. The number of reports generated in 2006 exceeded 8300. Yield Prophet directly involved a networked community of grain growers supported by agronomic consultants State Government staff and 7 Farmer Groups. At the time of writing all indications were that these numbers will continue to grow in 2007. There are now many examples of farmers learning from their participation in the Yield Prophet network. In 2006 this was largely by early warning of the likelihood of unfavorable seasonal outcome that led to reduced expenditure on input resources and conservative marketing strategies.

Conclusions
This paper reports on a series of attempts to scale up FARMSCAPE. Due to the partial success of the training and accreditation approach there had not been a concerted attempt to upscale that program, despite requests from other companies for such training. The Internet enabled ‘What-if’ discussions achieved impacts at a distance but the need for ongoing intensive engagement by researchers and facilitators with relatively small numbers of farmers remained. The legacy of both these projects led to Yield Prophet. After four years of development and implementation Yield Prophet is a technically comprehensive system that encompasses many of the features of the prior efforts and provides users with a credible science based tool for investigating a wide range of tactically important management options for coping with climate variability. The remaining challenge is to better understand the barriers to reaching the majority of Australia’s grain growers.

References
The Potato Systems Planner: A Successful Decision Support Tool for Growers

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Introduction
Simulation models and Decision Support Systems (DSS) have become popular tools for transferring technology. However, as with more traditional approaches, use of these tools does not guarantee that the technology will actually be adopted. We developed a DSS called the “Potato Systems Planner” that has significantly aided in adoption of new cropping systems and management practices by potato growers. The objective of this paper is to provide information on the approaches and related factors that have contributed to its success.

Methods
Identifying customers’ priority research needs is one of the most critical steps in guiding development of technology with the highest relevance and adoption potential. Consequently, our laboratory initiated and co-organized a “Research Visioning Workshop” for the Maine potato industry to identify and prioritize their research needs. The number one research priority was finding and developing profitable crop rotations for potato. Responding to this research direction, a total of 14 different cropping systems were evaluated by an interdisciplinary team for their impacts on potato yield and quality, nutrient availability, plant diseases, soil microorganisms, potential profitability, economic risk, and other factors.

Cropping systems are highly complex, being composed of interrelated, mutually dependent components and processes. To reduce this complexity, simple phrases summarizing each research result were developed for scores of research observations. These research summaries were then organized into a format designed to look like a web site to promote ease of use. The Planner was designed so that different levels of scientific detail can be accessed by simply clicking on a research summary. As an example, the Sweet Corn-Potato cropping system contains the simple description “Lowest Economic Risk”. Clicking on this statement provides a graph showing that the probability of an economic loss from the Sweet Corn-Potato system is only 3%, while the Potato-Potato system is 37%. It then shows growers how growing sweet corn in rotation with potato can increase profitability by $160 US per hectare. Similar hypertext-linked research summaries are provided for up to 15 properties of each cropping system.

An “Economics Calculator” was designed to allow growers to estimate profit potential of each cropping system. Growers were given a choice of using default values for a range of economic parameters, or inputting their own values based on their experiences with the crops chosen. In addition, the Economics Calculator incorporated identical loan application information that is required by the USDA Farm Service Agency when growers apply for a crop loan. Also included is a “Disease Database” that provides pictures and management options for 19 of the most common potato diseases.

A trial version of the Potato Systems Planner was demonstrated to growers and then modified based on their input. Several initiatives were then launched for transferring the technology. This included developing a traveling presentation booth for demonstrating the Planner at numerous grower meetings, field days, technical conferences, workshops, and at potato industry meetings with local, regional, state, national, and international audiences. In each event, the Planner was demonstrated by a Technician with a farm background to promote acceptance of the technology by growers. The DSS was advertised in internationally distributed potato industry trade journals and local news.
media, with each article providing contact information for requesting a free Potato Systems Planner compact disk.

**Results**

Although it is always difficult to quantify the impact of Decision Support Systems or any other technology transfer tool, we know from many interactions with growers and industry officials that production practices have changed as a result of the Planner, with over 1100 copies requested by growers and scientists from 26 U.S. states, 8 Canadian provinces, and 28 countries since its release in 2005. For example, the Planner shows that growing canola before potato can reduce several soil-borne diseases by 20-50%. Phone calls and emails from across the United States and Canada show that growers have changed their small grain-potato rotations to canola-potato in order to reduce soil-borne diseases and improve potato quality. We know that in Maine alone, potato growers are now producing approximately 3000 ha of canola, where there once was none. This led the University of Maine to conduct a pilot study on producing biodiesel from canola, and the Houlton Band of Maliseet Native Americans now plans to build a large biodiesel facility in Maine projected to provide a market for approximately 30,000 ha of canola.

Several aspects of this Decision Support System contributed to its success. Perhaps the most important was the first step of identifying the customers’ technology needs in order to ensure greatest adoption potential. Designing the Potato Systems Planner to look like a web site and summarizing research observations into simple statements proved highly effective for communicating the main message without overwhelming the grower with detail. Providing customers with the option of obtaining more information by clicking on a research summary gives access to more detailed observations for those users wishing to further evaluate the research results. Providing an “Economics Calculator” allows growers to estimate potential profitability on a wide range of production systems before investing in those systems. Designing the “Economics Calculator” to reflect the same input required for crop loan applications allows growers to use the same information for deciding what crop to grow as they use when applying for a loan to grow it. Providing growers with the “Disease Database” allows them to identify and select management options for controlling 19 of the most common diseases of potato.

**Conclusions**

Decision Support Systems can be a valuable tool for transferring technology to aid growers in making the most informed decisions on choice of production systems and management practices. In our experience, several attributes of the Potato Systems Planner, in particular, contributed to its success. Namely, 1) the information needed by growers was first determined by the growers themselves; 2) research was designed to address those priority needs identified by growers; 3) the research was conducted by an interdisciplinary team in a manner reflecting the truly interdisciplinary nature of the systems evaluated; 4) the Decision Support System was designed for easy use by growers, recognizing that growers must in practice be the integrators across disciplines; 5) a trial version of the Planner was field-tested and modified based on grower feedback; 6) special emphasis was placed on the growers’ “bottom line”, i.e., the profitability and economic risk of each cropping system; and 7) significant efforts were made to advertise, demonstrate, and freely distribute the Planner at local to international scales. Incorporating such approaches and attributes into planning, development, and technology transfer using Decision Support Systems significantly contributes to their potential for positive impact.

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WHAT DETERMINES THE CHOICE OF MODELS FOR USE IN ENVIRONMENTAL REGULATION?

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Introduction

Various EU directives and UN conventions mean that agricultural losses of nitrate, ammonia and nitrous oxide are under scrutiny by national and international environmental authorities. This scrutiny emerges at the farm level through increasing restrictions on farm management, particularly when farmers wish to extend or intensify their operations. This means environmental authorities often need to assess the likely environmental impact of nitrogen losses following farm intensification and the measures that can be taken to reduce those impacts. This need exists principally in two locations; in the central administration (i.e. the ministries dealing with agriculture and environment) and with the local environmental regulators, who have to deal with the needs of individual farmers. The transformations and losses of nitrogen from agricultural systems are complex and involve a range of interactions between sources, so modeling is often used in supplying advice. The advice given to the central administration will frequently rely on in-house staff or a single outside contractor, where specialist staff use a single or limited number of models. The specialist staff develop an in-depth knowledge of the models and their strengths and weaknesses; they may indeed have developed the models themselves. In contrast, the local environmental regulators may have to manage a wide range of losses and emissions. Such staff demand a greater level of support from the modeling system, so in many ways, they can be considered classical decision support systems (DSSs), similar to those available to farmers and advisors. Here, I reflect on the development of DSSs for environmental regulation, based on an example of how this happened in practice.

Choosing the right model

Taking as a starting point an idealized traditional agricultural DSS, the features that can be expected are as follows:

- The information presented should be relevant to the users.
- The underlying model must be an acceptable reflection of reality; not all the interactions and processes known to science need be incorporated, just those that are most important.
- The model should be conservative; it is more important for it to be reasonably accurate all the time than to be very accurate most of the time and wildly inaccurate in a few instances.
- The quality and quantity of input data demanded must be reasonable in relation to the time and resources available to the user.
- The quality control of the programming must be good and the underlying model must be well documented.
- The operation of the model must be transparent to the users.
- There must be an adequate user interface.
- The user guidance must be understandable

Case study

The Danish government decided to abolish the 14 counties responsible for environmental regulation at the farm scale and pass the responsibility to the municipalities. At the same time, the number of municipalities was reduced from 275 to about 100. Simultaneously, the environmental legislation relating to agriculture was revised and consolidated. Development of a DSS was felt necessary, given the relative inexperience of many of the municipal regulators and the complexity of the new legislation. To facilitate the use of existing national databases, it
was decided that the system should be internet-based. Since the final form of the legislation only became apparent 6 months before implementation, this was the time frame for the development of the DSS. The imperatives for the system appear to have been a. to have an operational system available when the new legislation was came into force and b. to keep system functionality to a minimum, to avoid confusing the inexperienced users. The system was based on the use of a number of existing models, including part of the FARM-N model described elsewhere in the proceedings of this conference (see also www.farm-n.dk). Conceptually and with respect to their complexity, the models were quite compatible, which aided integration. However, the system could not be made available to users until two months after the target date, mainly due to technical difficulties. At the time of writing (6 months after the target date), the system is fully functional and is a mandatory part of the environmental impact assessment of farm intensification.

Discussion

The contrast between the criteria for an idealized DSS and those applied in the case study is notable. The question is whether this just an exception or whether the criteria and decision processes applied to the development of environmental DSSs differ significantly from those traditionally applied within agriculture. In my view, there is much overlap between the criteria but the decision processes often diverge. For traditional agricultural DSSs, the development process can as often be initiated by those in possession of the knowledge as by those who are perceived to need it. This leaves ample scope for a failure by the scientists, their managers or the funders of science to appreciate that matters that seem important to them may not be important to the ungrateful recipients. In the case of environmental regulation, the initiative for development more often comes from the regulators themselves and they have a strong incentive to ensure that only relevant information is presented.

The most successful amongst the traditional agricultural DSSs are arguably those that are focused on providing very limited information. This is, I think, because they demand few input data and the information provided can be used in a wide range of farming systems. An example would be systems that forecast weather or some related aspect (e.g. irrigation demand). Systems that deal with more complex matters demand more input data, so require more effort on the part of the user, and are more difficult to adapt to different farming systems, so the results are less relevant. Environmental legislation is normally based on the setting of targets or limits for indicators and/or the regulation of the behavior of the major actors. This means that there is an implied model underlying the legislation itself. Despite usually being complex, this implied model tends to constrain the nature and output of the model within the DSS. I suspect that in contrast to traditional agricultural DSSs, this also means that the development of DSSs to assist environmental regulation is less prone to ‘mission creep’ i.e. where the specification of system functionality changes significantly during product development.

Perhaps the main difference between traditional agricultural and environmental DSSs is that the latter are part of a political rather than a commercial process. This means that the development of the regulatory DSS is, like politics, the art of the possible. The aim is to achieve the best one can within the timetable and resources allowed by the political process. I believe that the chances of achieving a satisfactory outcome are greater if there is a good dialogue between the science and policy advisors during the legislative process. In this way, there is a greater chance that the implied model underlying the regulations maps onto an existing scientific model(s) that could form the basis of a DSS.

If the use of the DSS is mandatory, uptake cannot be used as an indicator of success. The verdict on the choice of model therefore becomes the absence of the indicators of failure; no awkward questions in parliament, nasty letters to the press or irate users on the telephone/email. It is too early to judge whether the case study described above can be considered a success – they may just be on their summer holidays.
THE ROLE OF MODELING IN THE DEVELOPMENT AND UPTAKE OF SMALL DOSE FERTILIZER TECHNOLOGY IN SOUTHERN AFRICA

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Introduction
Despite poor soil fertility and low or declining crop productivity in smallholder cropping systems in southern Africa, farmers consistently exhibit a reluctance to invest in soil fertility technologies. In the past, researchers have struggled to understand and find solutions to this problem, and fertility recommendations, particularly for fertiliser use, remain irrelevant to all but the wealthiest of farmers. As a consequence, productivity gains from fertilizer use remain grossly under-exploited in these farming systems. Contributing to the lack of progress in resolving this issue in the past has been an inadequate analysis of the impact of rainfall variability interacting with the resource and operational constraints of farmers, firstly on the relevance of current fertilizer recommendations and secondly in the assessment of market opportunities and risks associated with drier regions.

This paper summarizes the evolution of ICRISAT’s small dose fertilizer technology that resulted from linking crop simulation with participatory research and development in southern Africa. It describes the impact of modeling output on three aspects of development and uptake of the technology: (i) researcher learning on the pay-offs and risk reductions of sub-optimal fertility management under conditions of resource constraints and rainfall variability (ii) obtaining donor and development agency support for rapid scaling-out of the new technology, and (iii) attracting the support and investment of fertilizer companies in developing more appropriate fertilizer marketing strategies for resource-poor farmers in drier regions.

Methodology
ICRISAT’s applied simulation work in southern Africa uses the Agricultural Production Systems Simulator (APSIM). APSIM is a modelling environment that uses various component modules to simulate cropping systems (Keating et al., 2002) and is increasingly been used to simulate crop responses to fertility inputs in smallholder farming systems in the semi-arid tropics of Africa (Carberry et al., 2002, Ncube, 2007)

Results reported in this paper emanate from participatory research on fertilizer recommendations for smallholders in southern Africa over the period 1999 to 2006. One activity was to conduct modeling workshops wherein agricultural professionals (researchers, extension and agri-business) were given the task of managing a ‘virtual’ smallholder farm over a 10-20 years period based on specified resources (field numbers and size, soil type, labour and finances). The objective was to explore how systems simulation could be used to evaluate the type of resource allocation questions faced by resource poor farmers. The APSIM systems model (and climate data) was used to simulate the performance of each farming scenario as nominated by the participants.

Another activity included the application of APSIM in a more generic sense, to explore longer-term productivity and risk of alternative investment options on a site-specific as well as agro-ecological basis. Model outputs were summarized in research briefs, project capability documents and extension flyers. One key analysis was long-term simulation of maize productivity and seasonal variability for small and recommended fertilizer investments across agro-ecological regions.

Results
Researcher Learning
The first modeling workshop in September 1999 proved pivotal. It involved researchers focused on soil fertility management options for smallholder farmers in Zimbabwe and Malawi. In this workshop the biophysical and socio-economic scientists were forced to consider trade-offs between intensive and extensive allocations of fertilizer and weeding labor. Technically, the results emphasized the high potential return from small investments in N fertilizer in the lower potential
regions and the fertilizer equivalence of an extra weeding. More significantly, the workshop had a dramatic effect on researchers understanding of the reasons for apparently sub-optimal management by many farmers, as resource and operational constraints interacting with rainfall variability was confronted in the modeling exercise.

As a consequence of this workshop, field experimentation of a number of research projects was either dramatically modified or directly attributable to it. In Malawi, a field program focused on maize response to legume-based technologies was subjugated to treatments evaluating maize response to small doses of N and interaction with weeding. In Zimbabwe, farmer participatory trials were conducted by national research scientists and the regional Sorghum and Millet Improvement Project testing crop response to small doses of N. Subsequent workshops in 2000 involving extension agents encouraged the Zimbabwe national extension agency to create a Crop Modeling Unit in 2001 (although it was short-lived due to deteriorating economic conditions). Collectively, these activities initiated the "micro-dosing" research strategy conducted at ICRISAT and other institutions in the region with subsequent funding support from ACIAR, DFID and ECHO and in partnership with development agencies Care International and World Vision (Twomlow et al. 2006)

Scaling-out small N dose technology
For the 2003/04 cropping season in Zimbabwe, 170,000 farmers were supplied with small packets of fertilizer (10 and 25kg ammonium nitrate) in the drier regions by drought relief and recovery programs following the drought of 2002/03. From these, 1200 farmers participated in simple on-farm trials (+/- fertilizer). Results across a number of districts showed 25-80% average grain yield increases from the small applications of fertilizer. Significantly, output from simulation modeling had an impact in allocating the $8-10 Million drought relief in 2003. “Normally, most money goes to seed and any fertilizer is provided to the high potential areas. But modelling results, combined with on-farm trial data, indicated the highest payoffs would be through the application of small fertilizer doses in the lower potential zones. This contributed significantly to the decision to distribute 4,000t in small packets in the drier areas” (David Rohrbach, ICRISAT Project Leader on Food Relief Monitoring).

Fertilizer Marketing
A Project Capability Document in which a simulation analysis compared the relative productivity, monetary returns and risk of recommended and small N doses across agro-ecological regions in Zimbabwe and South Africa proved effective in demonstrating to fertilizer companies the market potential for fertilizer in the drier regions by overcoming previously held perceptions about the high risk of crop production in these areas. As a consequence, fertilizer companies in both countries have established pilot projects marketing small packs of fertilizer to complement small dose fertilizer options. In RSA, the fertilizer company has also co-invested in evaluating low dose N and P technology in on-farm trials.

Conclusions
Application of crop simulation modeling brings many potential benefits to cropping systems research. In the case of smallholder-farming systems in the semi-arid tropics, where resource-poor, risk-averse farmers operate under highly variable rainfall patterns, the results in this paper demonstrate that its application is highly positive in helping to make research and development more relevant to the needs of a wider cross-section of smallholder farmers.

References
AGRONOMIC INDICATORS FOR THE WHEAT QUALITY MANAGEMENT AT THE COUNTRY ELEVATOR LEVEL

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Introduction
The improvement of crop performance is generally reached through the design of new cropping systems at the field level. However, as cereal products are rarely sold at the field level but are often collected in grain batches, the grain quality can be managed through the farmers and country elevators coordination, defined as the Local Crop Supply system (Le Bail 2004, Le Bail and Makowski 2004). In this work, we tested several indicators that could be used for decision support of collectors to improve the grain quality of the batches.

Methodology
We conducted a survey at the scale of the largest crop collector in Beauce (S-W from Paris) to identify the main characteristics of the management of wheat quality implemented to satisfy the market requirement: strategic planning (genotypes choice, grading, storing and logistic strategies) and daily decisions during the harvest period. The survey consisted in interviews with the people in charge of country elevators, of technical and marketing advising, of collecting management, storage logistic and outlet markets. Moreover we participated to several meetings between several people of the collecting firm and observed the decisions taken by the person responsible of a country elevator during the harvest period.

Besides, experiments located in the studied area were carried out to assess the accuracy of five models predicting wheat grain yield and protein content (Jeuffroy et al, 2006). One model, based on chlorophyll-meter measurements at growth stage 71 on the Zadoks scale (Le Bail et al. 2005), combined good predictive results for yield and grain protein content and ease to get data. On three networks of farmers’ fields (2004 - 60 fields - cv Apache; 2005 - 64 fields: cv Apache, Andalou, Orvantis; 2006 – 58 fields: cv Apache, Andalou, Bastide) the area, the genotype, the SPAD values (Minolta SPAD-502 chlorophyll meter) on the flag leaf at GS71 in three representative areas of the field and the geographical coordinates were noted. We tested the performances of decision rules based on yield and protein content predictions in a crop collecting area with two silos (geographical coordinates (GPS); number and grain capacities of cells).

Results
We identified three levels for decision-making and translated the management choices into simple rules (table1): (i) the agency including 4 or 5 country elevators from which grain batches are directly sold to users, (ii) the temporary elevator: more numerous, they are closer to the farmers/fields and allow to reduce the cost of transport from field to collector; (iii) the cell: where it could be necessary to anticipate grading according to the grain protein content of the grain harvest, but some elevators have no near infrared instrument or cannot use it to grading when there are too much trucks together at delivery point.

<table>
<thead>
<tr>
<th>Level</th>
<th>Aim</th>
<th>Rule: Input variables for decision making…</th>
<th>and decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency</td>
<td>1</td>
<td>- If the harvest of this year has the same protein content to that of the last year - If not</td>
<td>- they do not change their outlet strategy - they try to take position as soon as possible on feedstuff or export market</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>- If there is no difference between genotypes - If there are differences</td>
<td>- they can be mixed in the same batch - they put apart the faintest genotype</td>
</tr>
<tr>
<td>Country elevator</td>
<td>3</td>
<td>minimize the sum of distances between fields and country elevators A or B</td>
<td>- choose the address of delivery A or B</td>
</tr>
<tr>
<td>Grain cell</td>
<td>4</td>
<td>- If the predicted value of the harvest delivered at the country elevator is higher than 11.5% - If not</td>
<td>- Allocate in “high protein” grade cell - Allocate in a “low protein” grade cell</td>
</tr>
</tbody>
</table>
At the agency level, the global protein content of each year simulated from the model applied on each field was systematically underestimated (between 0.6 and 1.2 %) and the mean yield was often overestimated (max 0.7 t). Differences between years were faint for protein but yields were better in 2004 as indicated by the model. In 2006 the model succeeded in identifying the best results of one of the genotypes, one point upper the other ones.

### Table 2: Comparison of Yield and Protein content for different genotypes and year (simulated / realised)

<table>
<thead>
<tr>
<th>Year</th>
<th>Apache</th>
<th>Andalou</th>
<th>Orvantis</th>
<th>Bastide</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>9</td>
<td>8.5</td>
<td>9**</td>
<td>8.5**</td>
<td>9**</td>
</tr>
<tr>
<td>P %</td>
<td>11.5</td>
<td>12.2</td>
<td>11.5</td>
<td>12.2</td>
<td>11.5**</td>
</tr>
<tr>
<td>2005</td>
<td>10.7</td>
<td>12.4</td>
<td>11.2</td>
<td>12.4</td>
<td>10.9</td>
</tr>
<tr>
<td>Y t</td>
<td>8.4(23)</td>
<td>7.8(22)</td>
<td>8^A</td>
<td>7.8(22)</td>
<td>8^A</td>
</tr>
<tr>
<td>P %</td>
<td>11.3</td>
<td>12.3</td>
<td>11.3</td>
<td>12.3</td>
<td>11.3</td>
</tr>
<tr>
<td>2006</td>
<td>10.9</td>
<td>12.1</td>
<td>11.9</td>
<td>12.1</td>
<td>11.9</td>
</tr>
<tr>
<td>Y t</td>
<td>8.4(18)</td>
<td>7.8^A</td>
<td>7.8^A</td>
<td>7.8^A</td>
<td>7.8(15)</td>
</tr>
<tr>
<td>P %</td>
<td>11.3</td>
<td>12.3</td>
<td>11.3</td>
<td>12.3</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Genotypes (letters by lines) year (signs two last columns) differences (95% confidence level (Newman-Keuls))

At the country elevator level, the choice of field allocation to silo 1 or 2 was made from the simulated values of yield and protein content and GPS data to minimize the sum of distances between the fields and the two silos. The result for 2005 is mapped in figure 1 and the weight and protein content are the measured ones. To dedicate two silos with significant differences in protein content, the distances are twice as far.

At the cells level, we simulated in 2006 the delivery of all the fields ten kilometres around the silo of the city of Civ. Since we had the simulation of yield and protein content (mid June) we could simulate a protein content grading, taking into account the capacities of the different cells foreseen for the milling outlet. The results showed a significant segmentation between both grades (figure not shown).

### Conclusions

In that work we showed that the early simulation of grain protein content and yield can serve the wheat collecting management to improve the global quality of the wheat batches to be sold. Each year we presented the results and discussed the potential use of those tools in the collecting firm, in the aim of improving the tools proposed. Results seem promising for the collecting firm, but the building of the database from the fields to be collected, for the simulation before harvest seems still too expensive for the firm.

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AGRONOMIC AND ENVIRONMENTAL EVALUATION OF COLLECTIVE MANURE MANAGEMENT FOR A GROUP OF FARMS

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Introduction
Collective Manure Management Plans (CMMPs), in which livestock farmers provide nutrients and organic matter to crop farmers, are gaining in importance. Such plans allow livestock farmers to comply with environmental regulations related to nutrient loads, while crop farmers gain from the cutback in mineral fertilizer use. However, the agronomic efficiency of these CMMPs and their environmental impacts have not been evaluated yet, due to the complexity of intertwined biophysical processes and farming management practices featuring these CMMPs.

A previous study showed that the dynamics of slurry storage influences the environmental performance of CMMPs, as it plays an important role in the emissions of ammonia and methane (Lopez-Ridaura et al., 2007). The objective of this paper is to present a model that simulates the logistics and main emissions of CMMPs for the evaluation of their agronomic and environmental performance: MagmAppro.

Methodology
MagmAppro is a hybrid model, including discrete and continuous variables, that simulates the dynamic interaction between material flows and human practices in manure management. The model, resulting from the integration of other stand-alone models, contains logistic and agronomic modules representing the collection, transportation and application of manure, and biophysical modules accounting for gaseous emissions (NH₃ and CH₄) during manure storage and application. MagmAppro is programmed in VENSIM and consists of five interconnected modules simulating: (i) the production of manure by livestock farmers and their individual spreading plans (i.e. on their own crop land) (MAGMA_1; Guerrin, 2001); (ii) the delivery of excess manure to a collective storage facility in the spreading area (APPROZUT, Guerrin, 2004); (iii) the application of excess manure from the collective storage facility to the land of the crop farmers (MAGMA_2, Guerrin, 2001); (iv) the emissions of NH₃ and CH₄ during manure storage (based on Loyon et al., 2005 and Pelletier et al. 2006), and (v) the emissions of NH₄ from manure during its application to crop land (STAL, Morvan and Leterme 2001). The model includes decision rules such as the priority of and spreading period for certain crops, the feasibility of carrying out a spreading operation based on rainfall and soil moisture, as well as stochastic variables representing unexpected events such as the breakdown of spreading or transport units.

The model has been parameterized to a real case study in Brittany, western France, where 11 pig farmers, producing a total of 160 tons of N per year in the form of slurry (ca. 40 000 m³), are planning to transfer ca. 40% of their slurry production to 22 crop farmers in a region 40 km away in order to comply with environmental regulations. A cooperative of agricultural machinery (CUMA) will be in charge of the logistics of the spreading plan. In consultation with representatives of the CUMA, we have set the parameters for transport and spreading rates, as well as an empirical rule where access to the fields is limited by present and cumulative effective rainfall: If present rainfall or average daily rainfall in the previous ten days < 2 mm, it is possible to spread; if ≥ 2 mm it is not.

Results
Figure 1 shows (A) the evolution of slurry stocks of the 11 pig farmers for 2001 and 2002 and (B) the emissions of CH₄ during storage as simulated by MagmAppro for the case study in Brittany, taking into account one spreading unit with an application rate of 40 m³ hr⁻¹. The difference in stocks between the two years, and therefore in CH₄ emissions, is due to the fact that 2001 was a wet year, limiting opportunities to enter the fields to spread during spring, when cereal crops require the application of slurry. Figure 2 shows, for spring 2001 and 2002, the effect of the rainfall-related decision rule applied to spreading; the dots below the axis represent the days when it was predicted to be possible to enter the fields for spreading.
The efficiency of CMMPs can be evaluated by the satisfaction of the crop nutrient demand. Table 1 presents the simulated performance of the slurry spreading plan in Brittany for 2001 and 2002 showing that the inability to spread in spring has an important effect on achieving an efficient transfer of nutrients.

**Conclusions**

Plans for collective slurry management such as the one analyzed in this paper are complex systems in which the synchronization of slurry deliveries from livestock producers and nutrient demands of crop farmers is difficult to achieve. In addition, biophysical and organizational aspects such as the weather-related spreading restrictions or the availability of transport and spreading units play a crucial role. MagmAppro is able to simulate such CMMPs and evaluate their agronomic and logistic efficiency as well as their gaseous emissions.

In relation to the Brittany case study, representatives of the CUMA acknowledged the value of MagmAppro to assess the vulnerability of the CMMP to changing conditions (like weather) and considered it a good tool to improve the robustness of the CMMP. Scenarios suggested by the CUMA will be evaluated in the future including different numbers of transport and spreading units available, different application techniques and different crops and cropping calendars.

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MODELLING SOIL EROSION AND LAND USE/LAND COVER UNDER WATERSHED MANAGEMENT APPROACH: A CASE STUDY AT ADULALA MICRO WATERSHED, CENTRAL RIFT VALLEY OF ETHIOPIA

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Introduction

Globally, a high-level concern has long been reflected in light of the currently manifested climate change, ecological degradation and loss of biodiversity as a function of anthropogenic factors through deforestation, soil erosion, and increased concentration of green house gases. Because these complex processes mostly take place at a large scale and expensive that impede studying them under hardware laboratory or controlled field experiments. On the other hand, models abstract such complex reality inexpensively, while at the same time providing deeper understanding of the changes, as well as, the corresponding management solutions through deconstructing the components and putting the parts back together as a whole, but with new understanding (Goodwin and Write (1991)).

In fact, models are by no means new tools and cannot be an absolute alternative to experimentation i.e., observations will always be closer to truth and must remain the most important component of the scientific investigation. In Ethiopia’s context however, experience in long-term experiments on natural resources rehabilitation is lacking therefore impact assessment and prediction of the ecosystem behaviour is quite difficult. In system modelling too, it is not possible to analyse the components all at once, hence; the divide and conquer principle which catalog the whole components into a chunk of solvable problems through hierarchies and boundaries is appropriate.

This paper discusses results of the soil erosion and land use/land cover modelling research conducted at one of the watersheds located in Ethiopia and that generates information that can be linked to the other modelling results in due course of risk management solutions. In context, watershed is proved an ideal spatial resolution for the purpose of planning and implementing conservation measures and optimal use of natural resources. Gullies due to soil erosion and therefore spiral of land degradation are common in Adulala Watershed, which in turn caused change in land use due to fragmentation and reduced farm and grazing land size.

The objective of this paper is therefore to develop a soil erosion model and land use/land cover models that contribute to development of the society and the environmental rehabilitation. In this particular study, the empirical Universal Soil Loss Equation (USLE) that represents the best estimate of the soil loss on annual time scale was used (Jager, 1994). For the land use/land cover analyses, ERDAs 8.2 software was used.

Materials and Methods

Adulala watershed covers an area of 2500 ha and is 3 km away from Melkassa Research Center (MARC) in the CRV. Agriculture constitutes the single most important sector of the watershed society, but it is carried out under full-blow impact of weather, soil erosion and other socio economic constraints. In particular, soil erosion is found to be a serious problem among all the complex processes leading to gully erosion, cutting the land by as deep as 13 m and as wide as 16 m.

Baseline area map was drawn using a 1:50000 scale topo-sheet. In order to determine annual water erosion, satellite imagery (LANDSAT TM acquired on Dec 5, 2000 with a spatial resolution of 28.5m² and band combination of 2, 3, and 4) were used in combination with the annual rainfall data of MARC and soil data of the watershed. DEM was generated from the contour map of the watershed in order to examine the elevation difference and to derive the input parameters for Universal Soil
Loss Equation including rainfall erosivity, soil erodibility, slope length, slope gradient and management factors. Eventually, annual soil erosion (t/ha/yr) was estimated using the multiplicative form of USLE that takes the form of:

\[ A = R \cdot K \cdot L \cdot S \cdot C; \]

Where: \( A \): Mean annual soil loss (t/ha); \( R \): Rainfall erosivity factor; \( K \): Soil erodibility factor; \( L \): Slope gradient factor; \( S \): Slope length factor and \( C \): Cover management factor.

Finally, the product mean annual soil loss was mapped using the overlay images of all factors. The land use system in Adulala watershed comprises cultivated land, grazing land, settlement, degraded hilly land, roads and small area of bush land. Teff, maize and beans are the dominant cultivated crops in the area although barley growing is practiced infrequently.

Results and Discussion

Fig 1 shows intensity of the annual soil loss from different portion each of the watershed. Results show that about 41 percent of the watershed loose soil at the rate of 5 t/ha/yr and above, which is above the tolerable limit. Despite the remaining 59 % of the area is estimated to experience lower soil loss, the prevailing heavy dissection due to gully erosion (map not shown), which USLE cannot capture easily assumes the prominent position. Land use analysis of the area reveals that 69.62 % of the total watershed is cultivated (Fig 2). The bushes and shrubs accounting for 26.58 % of the total area are at degraded stage due mainly to overgrazing. This emphasizes the need for sound management practices.

Fig 1: Annual soil loss at Adulala Watershed  
Fig 2: Land/Land cover at Adulala Watershed

Conclusion and recommendation

The paper emphasises that development can not be anticipated from one angle alone unless problems are solved elsewhere in the system such that solutions to these complex challenges could take multiple of alternative forms. Therefore, there is a pressing need to plan and implement sound natural resource management experiments for the long term prediction and improving the livelihood of the society.

References


Cumin (*Cuminum cyminum*), an annual herbaceous species grown in arid and semiarid Iran, has a wide range of uses including medicinal, cosmetic and food industry (Kafi et al, 2006). Variability in climatic factors plays an important role in crop production. Sowing takes place between December to March. The crop grows mainly on stored moisture which is progressively depleted with crop growth. The crop experiences drought stress from late vegetative stage until maturity. The intensity of drought stress varies from year to year, depending on the amount and distribution of rainfall and on spring and early summer temperatures. Thus, large responses in grain yield are expected when supplemental irrigations are applied. In wet years with high spring rainfall, damage due to fungal diseases is extremely high and crop yield may be reduced considerably (Israel et al., 2005; Tawfil and Allam, 2004, Hajian and Jafarpour, 1996). Therefore, water requirements of cumin should be scheduled in relation to these pathogens. Results using climatic models to evaluate alternate decisions by examining the interactions between environmental and phenological stages in increasing and stabilizing cumin production are presented.

**Methodology**

Agroclimatic models were developed using data from Mashhad. Daily climate data were obtained from Iran Meteorological department for 1961-2005 for Mashhad, Iran (Lat/Lon: 36.3° N 59.6° E. and Elevation: 989 m). Thermal time concept was used to quantify phenological stages of cumin. Based on data obtained from Kafi (1990) and Tatari (2003), three different phonological stages of cumin were defined as:

a) Phase 1: Sowing to emergence (when 85% of the seedling emerges)
b) Phase 2: Emergence to flowering (when 50% of plants flourished) and
c) Phase 3: Flowering to maturity (when the seeds matured and dried and the color of plant changes to brown).

Based on different base temperature (0, 1, 2, 3, 4, 5 °C) the degree days requirements for each phenological stages were calculated using formula 1.

\[
\text{GDD} = \left[\frac{(\text{Tmax + Tmin})}{2}\right] - T_b \quad \text{if} \quad \frac{(\text{Tmax + Tmin})}{2} \geq T_b
\]

Where GDD is the growing degree days, Tmax., and Tmin. are daily maximum and minimum air temperature, respectively, and \( T_b \) is the base temperature.

Based on the analysis, the base temperature of 4 °C was used in further calculation. The mean duration of phase 1 based on 45 years data for four sowing dates (1st January, 1st February, 1st March and 1st April) and in addition, the seasonal accumulated precipitation were calculated. The first of March was selected as the best sowing date. The duration of phases 2 and 3 using first of March sowing date were calculated. The seasonal accumulated precipitation and the average daily and weekly precipitation and evapotranspiration (Penman method) were used. Probability of receiving 2.5 mm precipitation per day or more and 5 and 10 mm per week or more were examined to assess how much evaporative demand are met by the rainfall.

**Results**

Information on base temperature of cumin is not well documented in the literature. Sadeghi (1992) stated that the minimum temperature for seedling emergence of cumin is between 2-5 °C. Our results showed that 4 °C is the best base temperature for cumin. Using these base temperature cumin needs 49.5, 488 and 876 thermal units for phase 1, 2, and 3, respectively. The average
number of days from sowing to emergence was 80, 50, 26 and 10 days, for 1\textsuperscript{st} January, 1\textsuperscript{st} February, 1\textsuperscript{st} March and 1\textsuperscript{st} April sowing dates. Because of cooler temperature during January and February seeds need longer time to achieve the amount of GDD needed to emergence and because of that seed damage would be high. For April 1 sowing although the seeds would emerge quicker compared with other sowing dates, the seedlings would face shortage of water because of less rain. The average seasonal precipitation was 105, 77, 46 and 18mm for 1\textsuperscript{st} January, 1\textsuperscript{st} February, 1\textsuperscript{st} March and 1\textsuperscript{st} April sowing dates, respectively. Therefore, the first of March was the best sowing date for cumin in Mashhad. In the first of March sowing date, the average number of days from sowing to emergence, emergence to flowering and flowering to seed maturing were 26, 58 and 51 days respectively.

**Model application:**
Model results in choosing appropriate planting dates match well with the common experience by the farmers and agronomists in the Mashhad region. This is particularly relevant in controlling fungal diseases, and choosing optimum time and amount for supplemental irrigation. Our results are in agreement with those of Israel et al. (2005), Tawfil and Allam (2004) who suggested that controlling fungal disease is one of the most important aspect to reduce crop failure mainly during rainy years. Kamkar (2005) suggested that sowing date could be one of the most important manageable options to decrease cumin grain yield gap. Alavi (1969) indicated that delaying planting date from December to March reduces the disease damage to cumin in some areas of Khorasan. The disease agent usually attacks the plant mainly during late March. Fungal infection generally occurs when the temperature rises and humidity increases as a result of more rain. By changing the planting date to the first of March, chances of fungal infection of cumin were minimized. Another impact of the model was in choosing supplemental irrigation to optimize cumin yield as a function of planting dates. The probability of receiving 10 mm or more precipitation per week in Mashhad for March 1 sowing date (50%, 15% and 1% at emergence, flowering and seed maturing) were used to demonstrate that supplemental irrigation (1 to 2) provided better farm yields.

**Conclusions**
Based on our results the first of March is best sowing date for cumin in Mashhad because of lower fungal infection associated with more reliable rainfall during emergence to flowering. The model showed promise for its use in farm decision-making in terms of resource allocation and we recommend further testing of the model with additional sites, and more interactions with the potential users.

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M. Kafi et al., Cumin (*Cuminum cyminum*): Production and Processing, 2006. Enfield, NH, USA: Science Publishers
SPATIAL AND TEMPORAL ANALYSIS OF SIMULATED RAINFED AND IRRIGATED WHEAT

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Introduction

The shortage of water in Mediterranean countries requires the application of crop management practices which allow a more sustainable use of water resources. Crop simulation models are able to simulate the effect of management practices on yield, profitability and resources use efficiency. Applicability of these models can be extended to much broader spatial scales by combining them with Geographic Information Systems (GIS) (Hartkamp et al., 1999).

In this paper we applied a crop model in Southern Italy, in order to support the different stakeholders in assessing the optimum irrigation strategy for durum wheat: the local authority for irrigation water allocation that would optimise the irrigation water use efficiency; the farmers, who aim to maximise economic return; the industrialists, interested in optimisation of product yield.

Methodology

The case-study is referred to an about 1000 km² area in Southern Italy. Pedological data from 481 soil samples were georeferenced, converted into polygons by the Thiessen method and then intersected with a soil map. Daily climatic data (from 1955 to 1999) were collected by eight agrometeorological stations and each polygon was assigned to the nearest weather station. These data were used as input in seasonal and spatial simulations of durum wheat continuous crop, performed by CERES-Wheat model (Jones et al., 2003), interfaced with a GIS, AEGIS/WIN. Three irrigation scenarios were simulated: no irrigation supply (Rainfed); one irrigation of 50 mm with sprinkler method at anthesis date, resulting from the long-term simulation of Rainfed scenario (IRR1); two irrigation supplies of 50 mm each, 15 days before and 15 days after anthesis (IRR2). The water use efficiency (WUE, kg m⁻³, grain dry matter/actual evapotranspiration) and irrigation use efficiency (IRRWUE, kg m⁻³, grain dry matter increment respect to Rainfed scenario/irrigation volume) were calculated. Net Return (NR, € ha⁻¹) was computed by the model using current (2006) prices and costs in Southern Italy.

Fig. 1 – Optimum irrigation scenario basing on MAXIRRWUE, MAXWUE and MINCV criteria mapped for the 481 soils and referred to the 44 crop cycles of simulation.

The optimum scenario based on net return (MAXNR), WUE (MAXWUE), IRRWUE (MAXIRRWUE), grain yield (MAXGY) and its temporal stability (MINCV) was then assessed and mapped for each polygon. Finally, a temporal analysis of grain yield was performed comparing the trend of this variable with that of rainfall occurred during the January to May period (PJan-May, mm).
Results
Average NR simulated for 44 years resulted higher in Rainfed scenario than in the irrigated ones in all the soil polygons. On the contrary, maximisation of grain yield was obtained by two irrigation applications in the whole area. Temporal analysis showed that irrigation provided benefits on grain yield in each of the 44 cropping cycles, but larger increase in IRR2 respect to the other strategies was observed in the years when PJan-May resulted lower than the mean of the period.
Application of the different option criteria had different effects on the outputs (Tab. 1). Profitability of durum wheat resulted the most susceptible variable to irrigation management. More in detail, MAXGy (prior target for industrialists) was the option criterion that mostly affected NR (prior target for farmers), reducing it respect to MAXNR. So, main conflicts occurred between these two criteria.

The map of optimum scenario based on MAXIRRWUE criterion suggests to water distribution authorities the areas where IRRWUE resulted higher with IRR1 or IRR2 strategy (Fig. 1).
Farmers option, oriented towards NR maximisation, brought the minimum need of water irrigation, thus resulting the more sustainable criterion from the environmental and energetic point of view, in addition to the economic point of view. On the contrary, MAXGy was the option criterion that involved the largest use of irrigation water.
The gain in WUE due to the application of MAXWUE criterion respect to the other ones was just slight, thus this physiological criterion might be considered of minor importance in decision making about the scenarios proposed in the study. However MAXWUE met quite well with the farmers need of NR maximization.
The decrease of the yearly variability of yield with irrigation was not generalized in the area. The application of MINCV criterion allowed to detect the areas where the different irrigation strategies improve temporal stability of yield (Fig. 1). Nevertheless, as observed for MAXWUE, this improvement due to MINCV was little respect to the other option criteria. MINCV met well with the prior aims of industrialists in most soils.

Table 1 – Averages of output variables of durum wheat simulated by CERES-Wheat model, referred to the 44 crop cycles of simulation and to the 481 soils, for different criteria of optimal scenario selecting.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Grain yield (t ha⁻¹)</th>
<th>WUE (kg m⁻³)</th>
<th>IRRWUE¹ (kg m⁻³)</th>
<th>Net return (€ ha⁻¹)</th>
<th>C.V. of grain yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXNR</td>
<td>3.20</td>
<td>1.06</td>
<td>-</td>
<td>133.8</td>
<td>40.1</td>
</tr>
<tr>
<td>MAXWUE</td>
<td>3.34</td>
<td>1.07</td>
<td>0.54</td>
<td>111.3</td>
<td>39.4</td>
</tr>
<tr>
<td>MAXIRRWUE</td>
<td>3.60</td>
<td>1.04</td>
<td>0.48</td>
<td>55.3</td>
<td>39.3</td>
</tr>
<tr>
<td>MAXGy</td>
<td>3.66</td>
<td>1.03</td>
<td>0.46</td>
<td>37.8</td>
<td>38.9</td>
</tr>
<tr>
<td>MINCV</td>
<td>3.52</td>
<td>1.05</td>
<td>0.51</td>
<td>76.7</td>
<td>37.9</td>
</tr>
</tbody>
</table>

¹Averaged in the soils where irrigation occurred.

Conclusions
Our study is an example of application of crop simulation models coupled with GIS as a tool to quickly compare different forms of crop management for a large number of “year/soil/climate” combinations. The resulting decision support system may be used to plan water distribution for agricultural use at a regional level. Results of simulations and the comments about the conflicts among different stakeholders may offer a starting base for a multicriterial analysis that, applied to each soil, can provide a tool for addressing general planning of irrigation water distribution. In this way the needs of the different stakeholders would be simultaneously considered; just priorities among them would be established, pursuing the general aim of a sustainable use of water resources.

Acknowledgements
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References
Land use models in complex societal problem solving;
Plug and play or networking?

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Introduction
The potential of computer-based models as a source of advice for tackling management problems was well established with the concept of the decision support system or DSS. This potential was also recognized within the land use systems research community. However, land use systems research addresses issues related to agricultural policy making, land use planning and integral water management, often involving multiple stakeholders. Several potential roles for models in multi-stakeholder situations have been identified, such as a heuristic (improving understanding), symbolic (putting the issue on the political agenda) and a relational (creating a community) (McIntosh et al., 2006; Van Daalen, 2002; Shackley & Wynne, 1995). The few reported examples of effective use of a tools in a multi-stakeholder context do not provide the theoretical and/or empirical material to understand how computer models get to perform their heuristic, symbolic and relational roles. Therefore, the aim of the work reported here is to build critical understanding regarding which kind of arrangements, conditions, model qualities, or other factors harness land use modelling to perform heuristic, symbolic and relational roles in multi-stakeholder contexts. Thereto, a conceptual framework of the interactions between scientist, model, and societal stakeholders is developed. Subsequently, this framework is used to analyse a number of case studies of linking land use modelling to problem solving in a multi-stakeholder context.

Results
A conceptual framework of the interactions between scientist, model, and societal stakeholders towards solving a problem
Solving a problem in a multi-stakeholder contexts is about interactions of actors with different backgrounds, interests and opportunities, and with sometimes completely different perspectives of both problems and solutions. To understand the roles of computer models in such context, actor network theorists argue, that the computer model, as a non-human entity, should not be excluded from the analysis of those interactions beforehand (e.g. Callon et al., 1986). The model presented in Figure 1 is an attempt to capture the actors and interactions. A science model can only perform a role in complex problem solving when it is enrolled in the interactions by one or more of the stakeholders. It then gets a different status, i.e., ‘accepted model’, because it becomes part of the interactions and its role(s) is being defined

Impact of land use models in societal problem solving
The conceptual framework was used to formulate three questions to further investigate in three case studies how computer models come to contribute to problem solving and get specific roles:
• What role(s) did the model play in the course of the interactions?
• How did the model become part of the interactions in the network?
• Which model qualities contributed to the accepted role(s) of the model?
The results are presented in the Table.

<table>
<thead>
<tr>
<th>GOAL (Van Latesteijn, 1995)</th>
<th>EURURALIS (Westhoek et al., 2006)</th>
<th>TOA (Stoovogel et al, 2004)</th>
</tr>
</thead>
</table>
Roles
heuristic, symbolic

Building of a network
-initiated and maintained by modelers
-communication was explicit component of project management

-privileged position of project leader

network -model enrolled and maintained in network

interventions were composed of broad range of stakeholders, i.e., different disciplinary backgrounds, and farming, intervention and research.

Qualities of model
-relates differing issues
-explores space for manoeuvre

-encapsulates different views on future developments

-exploration of management and technical alternatives

Discussion
The comparative analysis of the three case studies (see Table) suggest that land use models were accepted for particular model qualities as well as the ‘work on the network’. The land use models were not accepted in a network by chance. In all three cases, substantial investments were made to maintain relations with relevant stakeholders. Scientists as well as users enrolled the model in the network. All three studied models had a heuristic role and all three cases it were characteristic system research features, i.e., the study of interactions between components, and the integrative capacity, that were mentioned in relation to this role. Therefore, we suggest that other features typically associated with the use of land use models, such as the representation of uncertainties in computer models, the ease of use of graphical user interfaces, and transparency are qualities that are not key to the heuristic capacity of land use models but rather are facilitating in a particular network setting of scientists, societal stakeholders, and the land use model. In two of the three cases, a land use model contributed directly to the creation of communities around the land use issue at stake. This is a capacity of land use models, which has rarely been attended to in literature till date. However, we deem it a highly relevant issue for further research while the linking of social and ecological systems and the capacities of communities to manage natural resources in a sustainable way are major issues in natural resource management research these days (Fabricius et al., 2007; Reynolds et al., 2007).

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Paddy Based Farming Systems in Southern Karnataka, India –Optimization Model for Land Management

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Introduction

The ever increasing demand for crucial inputs like fertilizers, irrigation, credit, labour and farm mechanization has to be viewed in the long-term perspective of its consequence on sustainability of agriculture. On the one hand, country needs to be self-sufficient in food, fibre, meat, fish and livestock production through intensive agriculture and biochemical farming. On the other, the natural resource base of the country, which is being gradually eroded by the modern methods of farming, must be protected from irreversible degradation. In this direction, the adoption of appropriate farming system technologies deserves special emphasis. With the limited possibility of expansion of land for cultivation in most of the Asian countries, integration of enterprises like crop, livestock, poultry and farm forestry helps achieve economic improvement and sustainability in farming. Integrating crop and animal husbandry systems in farming promotes efficient use of resources. Indian agriculture is characterized by mixed farming, involving a system of combining crop production with one or more of the livestock enterprises, viz., rearing of cattle, sheep, goat, pigs, poultry, fishery, beekeeping, sericulture etc.

A farming system is a complex, interrelated matrix of soils, plants, animals, power, implements, labour, capital and other inputs controlled in the past by farming families and influenced to varying degrees by political, economical, institutional and social forces that operate at any levels (ICARDA, 1979). Research with a farming systems perspective has various objectives ranging from increasing the body of knowledge about farming systems to solving problems in different farming systems.

Objectives

The paper attempts to explore the existing paddy based farming systems, assess the costs and returns and evolve optimum paddy based farm modules in Mandya District located in Southern part of Karnataka state, India. While doing so, the study also aims to identify the critical gaps in techno-economic, socio-political and institutional framework governing major farming systems prevalent in the study area.

The clients of the research output of this study are varied- agricultural scientists to develop and implement research addressing low cost complementarity of different farming systems; policy makers to evolve and implement suitable policy interventions towards overall sustainability of agriculture through promoting Integrated Farming Systems approach in the Karnataka State.

Methodology

The objectives of the study could be achieved by using the primary data collected through personal socio-economic surveys from 120 farm households of Mandya district practicing major paddy based farming systems. Data were processed using tabular, benefit-cost analysis and Linear Programming Techniques to arrive at meaningful results.

Results

In the study area, in general, four major paddy based farming systems (FS) were predominantly practised, namely, Crop+Poultry (FS-I), Crop+Sericulture (FS-II), Crop+Dairy (FS-
and Crop (FS-IV) enterprises. FS-II was most popular in the study area in terms of farmers followed by FS-III, FS-IV and FS-I.

The net farm income was higher under FS-I (Crop+Poultry) as compared to other farming systems considered ranging from Rs.171,934 to Rs.187,555 followed by FS-3(Rs.83658 to Rs.106867), FS-4 (Rs.57740 to Rs.85920) and FS-2 (Rs.54721 to Rs.62331) across different farm size categories.

For optimization of returns, three different linear programming models, viz., existing resource base (Model-I), reallocation of resources within the existing budget (Model-II) and relaxation of labour and capital, if necessary, beyond budget limitations (Model-III) were considered.

The estimated Linear Programming Models revealed that the farmers were operating closer to optimality under existing resource levels as indicated by marginal increases in their net farm incomes. However, with the reallocation of resources (Model-II) and relaxation of labour and capital (Model-III), the net farm incomes would increase by an extent of 0.33 to 48.15 per cent and 13.78 to 48.81 per cent, respectively, over existing plan (Model-I) across different farming systems. With the provision of liberal credit at reasonable interest rates, there could be some scope for relaxation of resource constraints, particularly labour and capital. Thus, the farmers’ net incomes could be increased to the tune of nearly 48 per cent through optimization of farm resources in the study area.

Conclusions

Among the paddy based farming systems, in general, there was ample scope for increasing the net farm income through introduction of poultry as an enterprise by the farmers under all farming systems, while in FS-I, mere reallocation of resources would enhance the farmers’ net income considerably. The net farm income was higher in the case of FS-I as poultry required less additional labour and maintenance. Hence farmers of other farming systems could have taken advantage of complementary nature of crop and livestock enterprises. In order to stabilize the incomes, there was an urgent need to take up poultry enterprise with breeds, practices and facilities suitable to the agro-climatic settings. By mere reallocation of resources (Model-II) farmers’ net incomes could be increased by the order of 0.33 to 48.15 per cent while by relaxation of resource constraints (Model-III) the net farm returns could be increased by the order of 13.78 to 48.81 per cent per cent over the existing net incomes (Model-I), across the major paddy based farming systems practised in the study area.

References


USE OF A MATHEMATICAL MODEL WITH HOURLY WEATHER DATA FOR EARLY WARNING OF DOWNY MILDEW IN VINEYARDS

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Introduction
Downy Mildew (Plasmopara viticola) is known as one of the most important vineyard diseases in the Western Cape, because it has the capability to develop and spread very quickly (Emmett et al., 1992), and so cause large crop losses in certain years according to the weather conditions. Farmers must make decisions as whether or not to spray for downy mildew (Magarey et al., 1994) and also how frequently to spray and which agrochemicals to use. Obviously they want to limit the number of times they spray to reduce costs and environmental pollution, but they also want to minimize the risk of crop failure due to infection by downy mildew disease. In 1992 an Austrian researcher developed the Metos automatic weather station and associated software, to predict the occurrence of primary and secondary infection of downy mildew. The overseas model was however not sensitive enough to accurately calculate infections, and furthermore it only gave a “Yes/No” warning of possible primary and/or secondary infections. The Metos software model (Pessl, 2000) was adapted for South African conditions in 1995 and again during 2006 to make it more accurate and user-friendly and named Donsige Skimmel Vroeg-Waarskuwingsmodel (DSVW) (Afrikaans for “Downy Mildew Early Warning Model”) (Haasbroek, 2006). DSVW model output now provides a graphical representation of the past weather variables (up to three weeks), and an indication (3 different colours - high, medium and low chance) of possible favourable periods for both primary and secondary infection occurrence.

Methodology
Automatic weather stations collect hourly data of different weather elements in downy mildew disease prone areas. At 5 o’clock each morning modems in a central operation room (OPS room at ARC - ISCW - Pretoria) download hourly as well as daily data from each weather station. Operators in the OPS room then check what data is downloaded and thus available for the disease reports. The raw data (no correction of errors) is then stored in both hourly and daily databanks. The DSVW model is then run to generate primary and secondary downy mildew disease reports from the hourly raw databank for each of the stations in the grape growing areas of the South Western Cape Province of South Africa. Software is being developed to do quality control on the data. This will increase the reliability and accuracy of the disease reports.

Results
About a third of the users have a weather station on their own farm (less than 5 km from the vineyards) while others use weather data from a neighbour’s farm or from one of the ARC-ISCW automatic weather stations. The DSVW model uses the hourly rainfall, temperature and relative humidity measurements to make the decisions about the favourable weather conditions for infection by the downy mildew disease. Leaf wetness is now calculated from the relative humidity and the air temperature as the leaf wetness sensors proved to be unreliable. For the primary infections period, the critical conditions include receiving a 24-h cumulated rainfall of more than 10 mm and having leaves wet
for 3 hours when the air temperature was above 10°C. For secondary infection to be predicted, the conditions must have included 4 continuous hours when the relative humidity was above 92% with at least 2 or more of them having wet leaves as well as a mean air temperature above 13°C during these hours. These favourable conditions are then marked on a diagramme together with a graph of the weather conditions over the last 3 weeks. The DSVW model also gives 4 risk classes (0%; 1-34%; 35-74% and above 75%) for both primary and secondary infection by downy mildew disease.

Each morning the primary and secondary predictions infection reports, as predicted by the DSVW model for the respective weather stations, are send via e-mail or fax directly to vineyard producers in the Western Cape. Internet and SMS messages are being investigated for future distribution of the predicted disease results. Seventy percent of the producers have been receiving these outputs for the past 5-10 years. Producers use the information about the periods of favourable weather conditions for downy mildew infections given by DSVW to better manage their preventive spray programs and to minimize crop damage. About 50% of them stated in a survey, that they normally work on a regular repetitive spray programme spaying each part of the vineyard every two weeks. Each of these spray actions cost them about US$60 per hectare although it does vary according to the chemicals used and with time through the season. The DSVW output helps 38% of them to make the decision about whether to spray with systemic or contact chemicals and which chemicals to use. Another 19% responded that they use the DSVW output to help them to decide whether to do an additional spray when the DSVW model indicates that the weather conditions have been highly favourable for infection with downy mildew.

Conclusions
The producers and their advisors have therefore been using the output from the DSVW model to make decisions about when to spray to combat downy mildew on the grapes for the last 10 years. In the near future the GPRS technology will be introduced to receive data much quicker than currently and then have more time available to do better data quality control, before sending out the disease reports to the producers.

References
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P.A. Magarey et al., A computer based simulator for rational grapevine downy mildew (plasmopara viticola) on grape leaves, 1994. Phytopathology 78, 1316-1321
Session 1.5:
Multipurpose farming systems

Session Convenors:
Olaf Christen, Jerry Hatfield and Holger Meinke
MODELLING FIELD AND FIELD MARGIN MANAGEMENT EFFECT ON **PRIMULA VULGARIS** POPULATION AT THE LANDSCAPE SCALE.

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Introduction
Landscape must now be multifunctional and production is not agriculture’s sole objective. For example, biodiversity management needs to take into account field and field margin management at both farm and regional scales.

Field margin’s role in sustaining plant and animal communities is well-known especially for a patrimonial species like *Primula vulgaris* characteristic of “undisturbed” flora and which can be found only on field margins. The objective of this work is to study the effect of crop and field margin management on population viability at the landscape level. We have developed a network model of dynamic field and field margin management at the landscape level integrating a population dynamics model.

Methodology
This model explores the interactions between the plant lifecycle and the timing of farming operations that determine habitat quality for population survival.

The demographic part of the model simulates the impact of different cropping techniques and border management on *P. vulgaris* life cycle, discretized in key stages.

Each month the population changes on each pixel independently according to *Primula* biology (Endels, 2004) and management techniques in the neighbouring field and field border, using Leslie matrices of population dynamics (Caswell, 2001) and management techniques impact, each being dependent on the month they are made, the border type and adjacent crop and the stages on which they act.

\[
\text{Pop}_{t+1} = \text{EffectCT}_{x,t+1} \times \text{EffectCT}_{2,t+1} \times \ldots \times \text{EffectCT}_{11,t+1} \times \text{EffectCT}_{12,t+1} \times \text{Biology}_{t+1} \times \text{Pop}_t
\]

Where, \(\text{EffectCT}_{x,t+1}\) is the matrix of the effect of cropping technique \(x\) on the different *Primula* stages at the month \(t+1\); \(\text{Biology}_{t+1}\) is the matrix of population dynamics on month \(t+1\) and \(\text{Pop}_t\) is the matrix of the number of individuals of each stage on month \(t\).

Exchanges between pixels occur once a year, during seeding, according to survival and dispersal rates. *P. vulgaris* seed dispersal is done by ants and small mammals according to Valverde and Silvertown (1997). Small mammals in the Brittany region are mainly grain eaters but ants of several species can lose some of the grains on their way to the anthill. Model estimation is that 90% of the seeds taken by ants are dispersed to less than 4 meters and stay on the pixel (4x4 m²) while the last 10% go to a neighbouring pixel. This is higher than what can be found in the literature (Gomez and Espalader, 1998; Gorb and Gorb, 1999) but was thought necessary to see an effect of seed dispersal on population survival.

Results
3 types of borders conventional in the Brittany region are considered with associated management: i) embankment with low fence, no grazing on the border and mainly chemical management of the border; ii) embankment with grazing and trampling possible when neighbouring field is in pasture and chemical treatment or mowing on the border (includes road borders, farmer may “outgrow” in the border when tilling); iii) flat margin with grazing and no trampling when neighbouring field is in pasture, chemical management otherwise. 3 successions are classical in the region: Maize/Wheat; Maize/Wheat /4 years Ray Grass and permanent pastures.

First simulations on a pixel alone showed that crop succession, rather than annual crop management, is a major factor for the fate of *Primula* as phases of harsh conditions may be counterbalanced by more favourable phases and that the techniques (herbicide on the
crop….) may reinforce deleterious trends in population dynamics. Management implications are that crop diversity (in space) and time (long rotation including sown grassland) buffer the deleterious effects of some practices as herbicide use or annual ploughing. For other techniques (mowing) the timing of the operation affects the effects on populations.

Simulations were then done on a field pattern based on a real one (Figure with the 3 types of borders). The first part (year 1-18) of the simulation reproduced the past management based on a 10 years survey of this region. The second part (year 19-36) simulated present management on this region (intensification of crops and herbicide use). The third part (year 37-54) tried to see if a return to less aggressive techniques could save *Primula* populations.

![Field pattern with 3 types of borders](image)

<table>
<thead>
<tr>
<th>Margin Type</th>
<th>Embankment low fence</th>
<th>Road</th>
<th>Embankment no fence</th>
<th>Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past management</td>
<td>195.6</td>
<td>195.5</td>
<td>195.6</td>
<td>195.6</td>
</tr>
<tr>
<td>Present management</td>
<td>216.3</td>
<td>6.4</td>
<td>147.4</td>
<td>83.9</td>
</tr>
<tr>
<td>Saving populations</td>
<td>230.4</td>
<td>6.2</td>
<td>143.7</td>
<td>81.6</td>
</tr>
<tr>
<td>Year 1</td>
<td>5.2</td>
<td>3.4</td>
<td>124.8</td>
<td>34.8</td>
</tr>
<tr>
<td>Year 18</td>
<td>5.0</td>
<td>3.3</td>
<td>120.8</td>
<td>33.2</td>
</tr>
<tr>
<td>Year 36</td>
<td>4.7</td>
<td>3.2</td>
<td>124.4</td>
<td>18.5</td>
</tr>
</tbody>
</table>

Model simulations results were partially evaluated by a comparison to field data collected over 10 years in France and by experts.

**Conclusion**

These simulations show that *Primula* population are decreasing over the region and that even stopping aggressive management techniques cannot stop this decrease. The low colonisation rate is such that saved population cannot migrate on other borders. This model and its simulations reproduce the effect of changing crop succession and management techniques on field margin flora seen in the region (unpublished data). Simply changing management techniques is not enough to save the metapopulation, a change in crop succession may be necessary to enable population survival, introducing several years of pasture to redevelop populations.

However, this first version of the model does not take into account dispersal by cows in pasture borders and small mammals’ dispersal, as no data on seed survival after ingestion was available. Anthills’ number and location in the landscape may also have an impact on seed dispersal. This has an impact on long distance dispersal in our simulations. The model structure is easily adaptable to other plant species if the survival/succession matrix and the effect of management technique on the plant is known. The next objectives are: the validation of the model with Bayesian calibration and field data and the use of this model to simulate different networks and crop management and their impact on plant metapopulation.

**References**


ECONOMIC PRODUCTIVITY OF A MULTIPURPOSE PRODUCTION SYSTEM

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Introduction
The resource poor farmers in the southeastern zone of Nigeria depend on multipurpose farming. For instance they cultivate a minimum of four food crops (cassava, maize, fluted pumpkin and melon) with okra, pepper (Ikeorgu et al, 1989) as well as few stands of plantain, oil palm or other tree crops in the same plot. This can be seen from one farm to another and from community to community. This level of farmers cultivate a maximum of 0.3 – 0.5 hectare and depend on rain-fed farming. The farmers also keep one or two goats, a sheep and few birds on free range and even raise snails as sources of savings. Collection of non-timber forest products (NTFPs) like mushroom, herbs, spices, tree legume seeds, fodder and fuelwood constitute other sources of income in the farming systems. To assess a multipurpose production system of this nature, it became necessary to determine plant population combination, input and labour cost, grain and fresh tuber yields and income productivity of a four crop component of cassava, maize, cowpea and melon, which is a typical crop combination in the farming systems.

Methodology
A three year on-farm study was undertaken using a split-plot arrangement replicated three times in a randomized complete block design to analyze a four crop component of cassava (Manihot esculenta, Crantz), TMS 30572, maize (Zea mays, L), TZSR-W, cowpea (Vigna unguiculata, L Walp), IT 82D-716 and melon (Colocynthis vulgaris L.), ‘Ikon’ local. Cassava at 10 x 10^3, maize at 20 x 10^3, cowpea at 20, 33 and 50 x 10^3 with melon at 5, 10 and 15 x 10^3 plants ha^-1 were intercropped to determine crop yields, income and economic productivity of the four crop component. The sole crop plots of cowpea and melon at each of the respective populations and sole crop plots of cassava and maize as well as cassava/maize intercrop were randomized along with other treatments for purposes of standardization.

At planting a compound fertilizer N:P:K (15-15-15) was applied to all plots between rows at soil recommendation of 300kg ha^-1 and weeds controlled by hand hoeing. Crops were harvested manually at maturity, 70 days for cowpea, 91 for melon, 115 for maize and 350 for cassava. Grain yields of cowpea, maize and seed yield of melon were adjusted to 12, 12 and 15% moisture content, respectively. The fresh tuber weight of cassava was also recorded. Data were assessed by analysis of variance (ANOVA) and means were compared by the use of least significant difference (LSD). Production costs for the various cropping components consisted of land preparation, sowing, fertilizer application, hoe weeding, harvesting for the four crops and processing for cowpea and melon. Net income was sensitive to changes in production costs, crop yields and commodity prices. Farmgate prices for cassava, maize, cowpea and melon were 10.00, 15.00, 20.00 and 5.00 N (Nigerian currency) kg^-1 for 2000, 2001 and 2002 respectively.

Results and Discussion
Yield of sole cropped cassava was significantly higher than yield of cassava in the crop component as shown in Table 1. Generally, yield of cassava intercropped with maize, cowpea and melon was higher when cowpea and melon were planted at low population (20 x 10^3 and 5 x 10^3 plants ha^-1 than at 33 or 50 x 10^3 and at 10 or 15 x 10^3 plants ha^-1 of cowpea and melon respectively) as shown in Table 1. The cowpea effect on maize indicates competition between cowpea and maize for light and for uptake of nutrients, and soil moisture, with cowpea probably taking up a higher level of the resources and at a faster rate thereby suppressing maize. Grain yield of maize as affected by the varying cowpea and melon population is shown in Table 2.
Sole cowpea or intercropped cowpea with cassava, maize and melon and cowpea/melon interaction affect cowpea grain yield. This implies that cowpea at the three levels can be conveniently cultivated with melon and the base crops, cassava and maize. With the increase in cowpea prices, which could provide higher income and with the supply of protein needs to farm families, increase in cowpea population with base crops could be highly beneficial to low-resource farmers (Table 3).

Cowpea and melon population and cowpea/melon interaction all significantly affected melon seed yield in all the years. However, seed yield of melon increased with increase in melon population particularly with sole-cropped melon (Table 4). Though the sole cropped melon showed a higher and significant seed yield than intercropped melon, adopting the sole cropping system may not be profitable with the small-holder farmer because of the size of farm and because of the supplementary and complementary family food needs that cannot be derived from sole cropping. Intercropping melon with cassava, maize and cowpea is therefore a profitable and a sustainable practice.
MULTIPLE FUNCTIONS OF BUFFER STRIPS IN THE AGRICULTURAL TERRITORY

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Introduction
Buffer strips are strips interposed between the fields and the streams that intercept and treat the waters coming from cropland, becoming an useful tool to reduce the agricultural diffused pollution in the lowlands. In addition, if properly vegetated and managed, they can produce wood for burning, act as sinks of atmospheric CO₂ and improve the landscape beauty. They are hence typical elements of multi functionality in the farming systems. In this paper, data on buffer strips performance in these functions are provided and discussed, with a multicriteria economic analysis.

Methodology
Core data refer to a long term experiment on buffer strips running at the at Padua University Experimental Farm (45°12’ N, 11°58’ E, 6 m a.s.l.) since 1998 (Borin et al., 2004). The study site is located on a flat plain in North-East Italy, with median annual rainfall of 830 mm and sub-humid climate. The experimental site is a rectangular field, with a 35 m long 1.8% slope downwards to a ditch. The following four types of BS, interposed between field and ditch, are studied, in comparison with absence of BS (N): 3 m wide, with only grass cover (Festuca arundinacea L.) (3F); 3 m wide, composed of one row of regularly alternating trees (Platanus hybrida Brot.) and shrubs (Viburnum opulus L.) (31S); 6 m wide, composed of a 3 m strip of grass and a row of trees/shrubs (61S); 6 m wide, composed of two rows of trees/shrubs. Runoff volumes were measured every day when runoff occurred and water samples were collected to determine suspended solids (s.s.), nitrogen (Total N, NO₃-N) and phosphorus (Total P and PO₄-P) concentrations in order to calculate the losses.

In autumn 2003 platanus plants were cut to harvest the wood and soil samples were taken to determine the accumulation of organic C. In addition, the production values of older platanus hedgerows, grown in the same farm and harvested in autumn 2002 were also taken.

In another experiment (Borin and Bigon, 2002), the effectiveness of buffer strips in abating the agricultural pollutants in a shallow water table was also studied.

Data on the role of buffer strips in ameliorating the landscape quality were taken by Tempesta and Thiene (2004) and have been utilized in a Multiple Criteria Decision Making model (MOP) to assess how different environmental policies can be implemented on the basis of the maximization of three objectives (farm income, landscape improvement and N losses reduction) (Thiene et al. 2007).

Results
Pollutants losses control. In the main experiment, in presence of BS, the combination of lower runoff and pollutants concentration significantly reduced losses with respect to those without a BS, the only exception being 31S (table 1). In the other experiment, BS were able to reduce the concentration of NO₃-N by 90% respect to the value measured in the field.

Table 1 – Pollutants losses in runoff water with the various BS and without (cumulative values, 2004-2006). Different letters indicate significant differences at 0.05 p

<table>
<thead>
<tr>
<th>Pollutant and m.u.</th>
<th>N</th>
<th>3F</th>
<th>31S</th>
<th>61S</th>
<th>62S</th>
</tr>
</thead>
<tbody>
<tr>
<td>s.s. (kg ha⁻¹)</td>
<td>794 a</td>
<td>53 b</td>
<td>1245 a</td>
<td>163 b</td>
<td>71 b</td>
</tr>
<tr>
<td>tot N (kg ha⁻¹)</td>
<td>7.9 b</td>
<td>2.6 c</td>
<td>12.4 a</td>
<td>1.8 c</td>
<td>1.6 c</td>
</tr>
<tr>
<td>NO₃-N (kg ha⁻¹)</td>
<td>1.4 b</td>
<td>0.8 c</td>
<td>2.1 a</td>
<td>0.5 c</td>
<td>0.5 c</td>
</tr>
<tr>
<td>tot P (kg ha⁻¹)</td>
<td>2.7 b</td>
<td>0.4 c</td>
<td>6.1 a</td>
<td>1.1 c</td>
<td>0.7 c</td>
</tr>
<tr>
<td>PO₄-P (kg ha⁻¹)</td>
<td>0.5 b</td>
<td>0.2 bc</td>
<td>2.7 a</td>
<td>0.5 b</td>
<td>0.2 bc</td>
</tr>
</tbody>
</table>
Timber production. A single platanus plant at the first cycle of utilisation produced 49 kg of d.m.; at maturity his production reached 160 kg. Considering one hectare of hedgerow 5 m wide, with a single line of plants at 2 m between each other, the production achieves 49 and 160 tons respectively.

CO₂ sequestration. In the first growing cycle, the C immobilized in the wood was 104 kg per single plant; at maturity, the amount was three times higher. Moreover, the soil under hedgerows accumulated C respect to an arable land with values increasing from 0.8 to 1.9 in the first 10 cm and from 1.0 to 1.6 in the layer 10-30 cm (Borin and Maccatrozzo, 2005). Consequently, the yearly total C sequestration ranges from 20 tons in the young hedgerow to 50 in the older one. These values correspond to the emissions of 7-18 cars of medium power travelling 15000 km per year. The trading value in the world market of CO₂ is rather variable (e.g. from 16 to 29 € per ton, depending on time and reference market, Pettenella and Ciccarese, 2007), but it can offer interesting opportunity for the farmer income.

Landscape. Hedgerows are among the elements which more influence positively a well perceived landscape. Their height influences differently landscape perception: the higher the hedgerows, the largest the effect.

MÖP. Results provide estimates of the opportunity cost that must be supported by the farmer in term of income losses to achieve increases in landscape quality and to reduce the nitrogen releases. in example, in a typical farm of the Veneto plain, a loss of about 50 €/hectare allows an improvement of quality landscape by 22% and a reduction of N losses by 28%. Moreover, the same landscape quality improvement associated with a double reduction in terms of N losses can be reached by the farmer facing a double cost.

Conclusions
The results demonstrated the importance and the multifunctionality of buffer strips in the rural territory of Veneto Plain. The modern agriculture is called to offer two main functions to the collectivity: primary production and positive externalities. Buffer strips offer a good opportunity to satisfy both these targets.

Within the multifunctional role of agriculture, some aspects of hedgerows (e.g. timber production) turn out to have a straight monetary value, some others, instead belong properly to the public sector. In this frame, decision makers need more information. The results show that estimated opportunity costs can support the public decision maker in determining the subsidies to be paid to farmers to encourage them to peruse higher levels environmental quality.

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EXPLORING THE POTENTIAL ROLE OF STRAW TO ENHANCE CARBON STORAGE IN AGRICULTURAL SYSTEMS

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Carbon (C) sequestration is one of the most important ecosystem services that agricultural systems can provide to human society. Until now, much emphasis has been placed on C sequestration on agricultural soils, but the are inherent difficulties in accounting for both C sequestered and CO₂ emitted in response to a specific land use management practice. The Kyoto protocol, signed in December 1997, introduced the concept of credit for C sinks, and recognized credits for afforestation and reforestation but not for other agricultural land use. Indeed, the article 3.4 of the protocol mentioned the possibility of future inclusion for other agricultural activities, under conditions of transparency and verifiability. The protocol was subsequently revised in Bonn in July 2001, and comprised two clauses relevant to land use: 1) country are allowed to subtract from their C industrial emission increases in C sequestered in sinks as forest and soils; 2) C sinks are recognized provided that the rate of SOC sequestration can be verified by standard procedure. Nevertheless, as Lal (2004-a) pointed out, monitoring and verification of the rate of soil C sequestration in transparent, cost-effective and credible manner is one the main obstacle to developing a C trading with agricultural systems. In addition, Schlesinger (1999) argued that many of the techniques recommended to increase C sequestration in soils contain hidden carbon “costs” in terms of greater emissions of CO₂ into the atmosphere. Therefore, major challenges for C sequestration in agricultural systems are: i) to achieve a C sink in a quick, transparent and verifiable manner; ii) to capture C in products with low nitrogen (N) content, since N is a valuable commodity, associated with hidden C costs.

The objective of this paper is to explore the possibility of increasing C sink of agricultural systems by storage of cereal straw and corn stover.

Figure 1. Whether a unit of CO₂ is not emitted, is immobilized into straw bales (displaced from other uses) or it is taken up by a growing forest, the C offset is the same. But then a question arises: will the C stay there? The permanence of stored carbon, for both straw bales and forests, is a matter of liability. (Modified from Marland et al. 2001).

Although straw bales are quite bulky, they offer good opportunities for C storage. One cylindrical bale (1.5 x1.2 m) has a weight of about 250 kg, 87 % of DM and 44 % of C, thus contains about 96 kg C. Therefore, about 80 kg C m⁻² could be stored by just one bale (96 kg /1.2 =79.8). It is worth noting that such amount is, surprisingly, about tenfold the C stored in the soil organic matter (SOM) of agricultural soil which is, on average, 7-11 kg C/m² (Wood et al., 2000). Yet, since straw bales can be easily piled up, considerable amount of C can be stored per unit area (figure 2). When crop residues are returned to the soil, either directly or indirectly via farmyard manure, only 2-20% is transformed into stable organic C, whilst the rest is emitted in the atmosphere (Lal, 2004-b). We do not contend that maintaining or increasing SOM is a key strategy for sustainable land use. Therefore, a crucial question arises: what is the fraction of crop residues that could be collected from the field without depleting SOM and increasing soil erosion? Graham et al. (2006)
referring to corn stover production in Iowa/Minnesota, concluded that about two-thirds could be collected without detrimental effects.

Figure 2. The hay-loft shown in the picture on the right contains piles of 5 bales, ordered in 8 rows and 11 columns, corresponding to 42 tons of C. That is equivalent to about half of the C stored in one hectare of agricultural soil.

We underline that setting aside cereal straw is a potential avenue to store C in farming systems with several associated advantages:

(i) all the C captured by the crop in the inedible aboveground biomass (about 50%) could be exploited for C storage whilst food production is not displaced;
(ii) C is stored in a transparent and cost-effective manner, that allows accurate measurement at farm level (i.e. the verifiability issue is satisfied);
(iii) stored C is associated to very low N content (C/N=88), thus the hidden C costs are negligible.

As an example, Italy produces about 22 Mtons of cereal straw every year, equivalent to 36 Mtons of CO\textsubscript{2}, corresponding to 6.2% of the 582.5 Mtons of CO\textsubscript{2}eq national greenhouse gas emissions for the year 2004 (European Environment Agency, 2006). Setting aside even a half of the straw produced would then be a substantial help in achieving the national Kyoto target (457 Mtons) by 2012.

A market based cap-and-trade system, compared to taxation applied on CO\textsubscript{2} emissions, provide more assurance that the environmental target will be met by a certain date (Chameides and Oppenheimer, 2007). Under cap-and-trade system, farmers could rent emission credits for sequestering a given (verifiable) amount of C in form of straw. A rental contract for emission credits would establish continuous responsibility for the storage of C. In other words, credit would be emitted when C is stored, and debits would accrue in case straw is either sold, used for manure, returned to the soil or destroyed by fire. Interestingly, Spreng et al. (2007) defined carbon capture and storage as a “Faustian Bargain”: on the one side it offers the temptation to extend the fossil fuel era over time, an easy way out of drastic political choices; on the other side it implies the commitment to long term vigilance in managing the captured carbon.

Challenges ahead

It remains to be seen what is the level of C price necessary to achieve a target participation rate by the farmers. Under a scenario of $ 50 per ton of C, frequently hypothesized in recent literature, it is likely that many farmers would be willing to keep straw stored.

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NITROGEN BALANCES AS A MEANS TO ESTABLISH COMPENSATION PAYMENTS - AN EXAMPLE FROM A CATCHMENT AREA IN GERMANY.

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Introduction
Water quality is a central indicator for the impact of farming practices on the abiotic environment. This is especially important in the case of water catchments with limitations or thresholds for nitrate pollution. Very often such thresholds are only achieved by strict regulations of agricultural practices with inevitable yield penalties. Since 2002 the German State „Saxony“ established a legislation, which enforces water companies to pay compensation payments to farmers if any restrictions with yield decreases due to changes on husbandry are necessary. Therefore the water company Kommunale Wasserwerke Leipzig (KWL) was looking for a goal orientated systems to reduce nitrate pollution and also to manage compensation payments for farming enterprises in a water catchment area near Leipzig.

The water catchment near Leipzig is dominated by agricultural land use and the production system on the farms therefore directly affects the ground water quality in the area. In cooperation with different partner institutions such a compensation system was established in order to minimize nitrate pollution but also to manage compensation payments based on scientifically sound calculations.

A goal oriented compensation payment will be granted to an agricultural enterprise based on a specific contribution to water quality. The target is in this example to achieve a specific nitrogen balance, which is than used to calculate the potential nitrate leaching. The nitrogen balance as an indicator was chosen, because it has a close relation to the nitrate pollution of the ground water, however, due to the hydrological situation in the catchment area a time lack of often several years exists.

Materials and Methods
The introduced concept uses the nitrogen balance on the farm level as a means for compensation payments, however, all calculations were done on the field and than aggregated on the farm level using the environmental management system REPRO (HÜLSBERGEN 2003). From an agricultural point of view it is important to mention that the calculations of the nitrogen balances are based on all relevant nitrogen flows on the farm and on the field level in order to calculate sound and comprehensive nitrogen cycles, which have relevance to agricultural production and thus decisions by the farm manager. Therefore all information in relation to crop production and all details of animal production are included in the system. This incorporates crop yields, nitrogen contents of all products and by-products, mineral and organic nitrogen fertilizer applications as well as all information on crop rotation, crop protection and tillage. Because animal feeding and the efficient storage and use of organic fertilizers are important for the calculation of the nitrogen balances, animal production is also included in the calculation.

An important aspect is the amount of time to manage such a system. REPRO uses all available data from electronic field books and is also based on a great deal of date in master files so that farm managers must not supply data separately to different systems.
Based on calculations with the REPRO system all nitrogen balances were calculated including possible changes in the nitrogen pool in the soil organic substance. Also possible losses via denitrification, ammonium volatilization are taken into account. Those parameters mentioned are calculated with information on soil and climate parameters according to HERMSMEYER and VAN DER PLOEG 1996, FELDWISCH 1998. Detailed soil information is available from soil mapping in the state of Saxony (ARBEITSGRUPPE BODEN, 2005). Water movement in the profile was calculated using the software „ABIMO“ (GLUGLA and FÜRTIG, 1997). The amount of nitrate potentially susceptible to leaching was than calculated according to ABRAHAM (2003). This allowed a standardized comparison between different husbandry treatments within and between farms. The nitrogen balance as an indicator was selected because of its great relevance for nitrate leaching in the ground water and also its sensitivity to changes in agricultural management. As a consequence the farmers were able to adjust their husbandry in accordance with the overall target to reduce the nitrate pollution.

Results
Measurements of nitrate by the water company KWL over the years, knowledge of the hydrological characteristics of the catchment area and detailed information of the husbandry on the relevant farms have been used to calculate nitrogen balances and compensations payments to the farmers. The nitrate threshold is 25 mg/l for the drinking water. Given the fact that further nitrate reductions occur after the water has left the rooting depth, KWL requires a threshold of 40 mg/l of nitrate right below the rooting depth, which is 10 mg/l lower than the current threshold for drinking water in Germany.

With the use of the above described methods it was now possible to calculate various scenarios on the field and on the farm level and give direct advice to the farm managers for adjustments in husbandry in order to minimize potential nitrate leaching on their specific situations. Those changes in crop rotation, nitrogen fertilisation, plant protection, tillage or even animal feeding are very specific and might vary from farm to farm. This is different to the classic approach in the cooperation between water companies and agricultural production, when normally the water companies only pay for changes in husbandry regardless of the specific situation on a particular farm and also without detailed knowledge of the results under specific conditions.

Based on these results, realistic scenarios for compensation payments were established and have lead to a substantially reduced potential for nitrate pollution in the catchment. Another important result from this approach is based on discussion with the farm managers.

References
Exploring trade-offs between multiple functions in agricultural landscapes

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Introduction
The performance of farming systems is increasingly evaluated for new functions or services in addition to the primary function of producing food and fibres. The most important issues are efficiency of energy and carbon conversion, mitigation of nutrient emissions and contribution to ecosystem functioning. Exploratory modelling approaches can play a role in further strengthening multifunctionality of agriculture by providing goals and possible futures and by establishing trajectories of desired changes to reach desired futures. The challenge for modelling approaches aiming to contribute to multifunctional agriculture is to clarify the interactions between functions, and to contribute to further development and strengthening of functions exhibiting synergy.

We have developed Landscape IMAGES, a multi-objective optimization approach, which simultaneously optimizes productive and environmental functions (Groot et al., 2007). The method employs a Pareto-based evolutionary strategy, thereby avoiding weighted summation of objectives. The methodology yields a set of Pareto-optimal solutions, i.e. trade-offs among objectives or functions. Each solution represents a spatial configuration of land-use including management practices which determines the performance of the functions. The development and application of the method have been conducted in close cooperation with an NGO dealing with landscape management. In this paper we present two applications of the method to farming system and landscape design problems for an agri-ecological zone in the Netherlands, where economical, ecological and culture-historical aspects were considered.

Methodology
The exploration of the trade-offs between functions or objectives can be formulated as a multi-objective design problem, which can be generally stated as follows.

\[
\text{Max } F(x) = \left( F_1(x), ..., F_k(x) \right)^T \quad (1)
\]

\[
x = (x_1, ..., x_n)^T \quad (2)
\]

Subject to \( i \) constraints:

\[
g_i(x) \leq h_i \quad (3)
\]

Where, \( F_1(x), ..., F_k(x) \) are the objective functions that are simultaneously maximized or minimized, and \( (x_1, ..., x_n) \) are the decision variables that represent the activities allocated to the \( n \) spatial units. To solve this problem we use a heuristic technique: the evolutionary strategy of Differential Evolution (DE, Storn and Price, 1995). This technique yields a set of solutions, each representing a spatial configuration of farming activities and landscape management practices which determines the performance of environmental functions, and thus the quality of the solution. The solution set is randomly initialized and iteratively improved by generating a competitor for each solution in the set with evolutionary operators of mutation, uniform cross-over and selection. The selection process uses the Pareto concept. A set of Pareto optimal solutions consists of solutions that are not dominated by other solutions, when all objectives \( F_1(x), ..., F_k(x) \) are considered.

We have applied the Landscape IMAGES methodology to case studies in an agri-ecological zone of ca. 850 ha in an intensively managed agricultural landscape in the Northern Friesian Woodlands (The Netherlands). This region is characterized by a small scale landscape on predominantly sandy soils with dairy farming as the prevailing land-use activity. On some farms a limited proportion of up to 5% of the area is used for forage maize production, while the rest of the area is occupied by permanent grassland, rotationally grazed and mown. The fields with an average size of 2 ha are often surrounded by hedgerows.

Case study A focussed on the interactions between agricultural production from fields and environmental benefits from fields and field borders in a 232 ha sub-region (Groot et al., 2007). Productivity of dairy farming was expressed in economic terms as the gross margin, whereas the other functions were represented by indicators for nature value (plant species diversity in fields and...
borders), landscape quality (variation in plant species diversity and half-openness of the landscape) and environmental health (avoidance of nitrogen emissions). Case study B aimed at supporting a landscape management NGO in designing an improved hedgerow structure in the complete agri-ecological zone, taking into account the objectives of increasing the ecological quality (connectivity of the hedgerow structure) and landscape identity (maintenance of half-openness and historical hedgerow configuration) and of decreasing maintenance costs for farmers for removal, planting and recurrent maintenance of hedgerows.

Results
For illustration the relation between selected objectives are presented in Fig. 1. In Fig. 1a the estimated solution space for case study A is described in terms of gross margin and nature value. Solution sets in both applications cover a large range of possible landscape configurations in terms of land-use on fields and the placement of hedges on field borders. In Fig. 1b this is illustrated for total hedgerow length in the solution space of case study B, which was found to be strongly but not fully correlated with landscape connectivity, a measure of ecological quality at the landscape scale. By plotting the solution space with the 2005 landscape and the restructured 2007 landscape it became clear that the decision rules employed by the NGO impacted positively on connectivity. The results made clear that further improvements would have been feasible without increasing the length (and therefore costs) of hedgerows in the landscape (Fig. 1b). Co-development with the NGO led to a strong interest and invitation to participate in new projects.

Fig. 1. (a) Solution space (○) and Pareto-optimal frontier (●) for the relation between gross margin and nature value at landscape scale in case study A, and (b) the relation between total hedgerow length and connectivity in case study B. Original landscape (●) and landscape replanted by NGO (●) are indicated by the red symbols at the end of the arrows in (b).

Conclusions
By exploring trade-offs among objectives, the Landscape IMAGES modelling instrument aims to reveal the ‘manoeuvring space’ of decision makers on land use issues, thus contributing to solutions that do justice to interests of broad groups of stakeholders. This methodology is applicable to any design problem characterized by multiple scale spatial interactions.

References
MULTIFUNCTIONAL AGRICULTURE: INDICATORS SYSTEMS FOR SOCIAL AND ECONOMIC PERFORMANCES EVALUATION

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Introduction
The present research introduces an evaluation model for enterprise performances so as to consider in a wider sphere the entrepreneurial behavior – when these can be translated into monetary outcomes and also when they imply the production of goods without a direct market values.

The basic idea is that an evaluation system should be able to interpret several kind of outcomes produced by farms and at the same time to schematize them.

The proposed outline is articulated in an organized system of indicators, properly selected to cover all the aspects in which, only theoretically, the enterprise activity can be divided. This system enables to quantify - on the base of the evaluation that the same entrepreneur makes of his/her own performances - the traditional economic results; but also aspects concerning how the entrepreneur interacts with the socio-economic and institutional system in which he/she works.

Methodology
The methodology for the definition of indicators system for sustainability under the socio-economic aspect is articulated in various phases:

• definition of four thematic macro-areas related to the attitude of the enterprise which, pursuing the objective to produce income, carries out, with its activity, positive effects in terms of added value to advantage of the society,
• construction of a set of indicators, defined synthetic. This map of indicators allows a synthetic reading, but exhaustive enough to understand the multidimensional impact that the choices of the entrepreneur have in the reference context. Each synthetic indicator is declined in several detailed indicators, which describe better a specific aspect of the sustainability that agrees to put in relevance.

The information survey for the construction of the indicators can be synthetic - the data are supplied directly from the entrepreneur - or analytics with information found through punctual surveying.

The selected indicators can be measured in a punctual way - just finding the presence/absence of the searched variable - or in a graded way: scoring the indicator in a range from 1 to 5, according to the level of sustainability that it satisfies. The definition of scoring derives from the evaluation:

• qualitatively estimated: the score from 1 to 5 is established on the base of the knowledge that the researcher has about the observed phenomenon,
• quantitatively compared: the score from 1 to 5 is attributed using as a reference parameter available in the socio-economic literature.

Results
The selected indicators have been properly organized in the four thematic areas in order to describe in detail a specific aspect of sustainability:

1. Area of efficiency, profitability and economic-financial management: these themes evaluate, through the analysis of the economic and financial management of enterprise, the ability to pursue a lasting economic balance. This group of indicators aimed to describe the economic sustainability of enterprise - its ability to produce incomes which remunerate all the factors of production included entrepreneur or incomes considered sufficient by the farmer. The indicators are declined considering:
   • the financial balance between monetary incomes and expenditures related to the process of income and capital growing.
• the balance between investments and funding.

2. Area of employment and relations with the "world of jobs": the area describes the complex management of human resources under the quasi-qualitative aspect. It expresses attitude of farms towards the professional increase of workers, to assure their continuing employment and suitable economic, social and professional conditions. It expresses the will to support stability of manpower, to promote a participative management of human resources, to assure adequate safety conditions in the working environment.

Although temporary employments have not a rewarding value, it is necessary to consider that:
• these indicators are often tested on small dimension farms,
• in some situations a temporary job can also find the agreement of workers (students, people with specific problems).

Moreover, in the social aspect relationships between employer and employee – even in the short-time – are considered sustainable. At the same time is estimated positively the attitude of the entrepreneur who conceive the farm like an open system toward society and institutions, promotes the social and professional inclusion of people with some specific differences.

3. Area of supply chain relationships: it is the area that evaluates the ability of enterprises to define lasting and mutually satisfying relationships with customers and suppliers. The loyalty with the other supply chain subjects is considered positively as it is an indication of:
• the ability of enterprise to supply goods and services with modality and times which meet customer’s satisfaction,
• the possibility to plan the production cycle, to reach the sought market outlets, to comply with economic-financial management criteria proper to the going on entrepreneurial activity.

4. Area of connection with the local context: it is the area that indicates the ability of enterprise, also in its limited dimension, of being proactive towards the local socio-economic system. This kind of interchange between enterprise and territory can find:
• in the valorisation of local resources: by an appropriate selection of the sale markets of final products and by offering services inside the territory to local communities and not,
• in the development of the specific “abilities to make” - not only in agricultural field - still not completely developed.

In order to pursue own goals effectively, the enterprise can collaborate - in permanent way or for casual opportunities - with other subjects of the same territory: agencies that pursue institutional purposes and/or other economic subjects. The idea of sustainability declined by the indicators of this area is that in some contexts, more than in others, the will of the enterprise to involve in the realization of some activities subjects working in the same context creates consent and social approval . For these reasons, this opening attitude promotes, more or less indirectly, reaching advantages also in incomes and competition.

Conclusions
The work represents an attempt to characterize an evaluation method of farm outcomes which considers the new societal demand toward agriculture. The basic idea of this research is that more and more the agricultural enterprises are calls to carry out functions useful for society, whose value can not always be translated in monetary terms. Therefore it becomes important to evaluate in a wider way the multidimensional impact that the choices of the economic subject have in the context in which the enterprise realizes its productive activity: In the proposed evaluation outline, an organized system of indicators allows to interpret the multiple outcomes connected to the enterprise activity. In particular, it is an evaluation system that allows to quantify - on the base of the scoring system - entrepreneur's behaviour.

References
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A MULTIFUNCTIONAL ORGANIC FARM - CASE STUDY IN OGAWA, SAITAMA PREFECTURE, JAPAN

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Introduction

Idealistically, organic farm is not just one for producing organic products for consumers and for income of farmers, but is one for sustaining provisions, enhancing internal cycling of nutrients of a farm or local area.

Methodology

A farm in Ogawa, Saitama prefecture, Japan has been cultivated organically for 35 y. There are no major weed, disease and insect pest problems at the farm. The organic farm consists of rice, wheat, soybean, 60 kinds of vegetables, egg, and milk productions in 2.9 ha farmland. Provisions for the farm members are mostly sustained, and organic produce is sold directly to 30 households and local food processors and at farmers’ market. Major inputs to the farm include yard trimmings, unmarketable wheat grain, rice bran, tofu refuse and fallen leaves. Unmarketable vegetables and farm surpluses were fed to 200 chickens, 100 hybrid ducks and 3 cows. Chicken litter is fertilized to vegetables and wheat as top dressing. Human excreta are unaerobically fermented in a biogas plant and the resulting biogas is used for heating and the resulting effluent as a quick-release fertilizer for vegetables (Fig.).

Mass flows of the farm were obtained from interviews and farm records. N flows of the farm were calculated with mass flows and their N concentrations, that was mostly obtained from textbooks and handbooks.

Results

Table indicates 70 % of N input was accounted for by outputs (grain, vegetables and daily products). This figure is surprisingly high, most likely due to very functional internal cycling: excreta, unmarketable vegetables and residues such as straws are used for other subsystems of the farm.

Conclusions

I conclude organic farms that produce provisions (consisting of subsystems) like this case study could cause high internal N cyclings and output/input ratio. The results need to be confirmed at other organic farms.
Table. Summary of N flows. (kg/ha/y)

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>N fixation</td>
<td>17 Cereals</td>
<td>26</td>
</tr>
<tr>
<td>Yard trimming</td>
<td>54 Vegetables</td>
<td>46</td>
</tr>
<tr>
<td>Feed</td>
<td>51 Dairy</td>
<td>15</td>
</tr>
<tr>
<td>Purchase</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>124</strong></td>
<td><strong>87</strong></td>
</tr>
</tbody>
</table>

Outputs

/Inputs 0.70

Balance 37

Fig. N flow (kg/farm) of an organic farm, in Ogawa, Saitama, Japan in ca. 2000. The farm is 4.6 ha including hilly forest
MULTIPURPOSE AGRICULTURE: DOES INTRODUCTION OF BIOENERGY CROPS CONTRIBUTE TO GROUNDWATER PROTECTION?

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Introduction
Conventional agriculture bears the risk of nitrate leaching into groundwater. In the context of bioenergy promotion, the question rises whether the introduction of annual energy crops in crop rotations or the production of perennial energy crops are adequate options compared to conventional food crops to reduce the risk of nitrate leaching as well as to reduce fossil energy demand, global warming potential and other environmental impacts.

The project is funded by the innovation fund of badenova ag, Freiburg (D)

Methodology
The following crop production systems are analysed for the South upper Rhine Valley:

- **Reference crop rotation (5 years):** winter wheat followed by turnip rape, corn followed by corn, summer barley, rape seed followed by spontaneous greening.
- **Energy crop rotation (5 years):** triticale followed by turnip rape, silage corn followed by mustard, silage corn followed by mustard, summer barley, rapeseed followed by spontaneous greening.
- **Perennial crops (20 years each):** miscanthus; willow (short rotation coppice); permanent meadow.

The crop rotations are balanced over 5 years and correspond to typical production scenarios for the investigated region. The life span of the perennial crops is 20 years and the results are converted to 5 years for comparison. The system boundary includes the production of all inputs (mineral fertilisers, machines, pesticides) and all activities on the fields from cultivation to harvest and transport to the farm. Application of farmyard manure was not included since most of the farms in the region do not have animal husbandry. The fermented biogas substrate was partly recycled in the system. Regional specifications were considered in the production inventories. For the impact assessment the Swiss Agricultural Life Cycle Assessment methodology (SALCA) was used. It includes the environmental inventories of agricultural inputs, taken from [1 & 2], methods developed by the Agroscope Reckenholz-Tänikon Research Station (ART) for the estimation of direct field emissions (more details: http://www.art.admin.ch/themen/00617/00785/index.html?lang=en) and impact assessment methods listed in [1] (see Table 1).

Results
The impact assessment shows major differences between both crop rotations and the perennial crops. An overview of the results is given in Table 1. Compared to crop rotations, perennial crops have lower energy demand, global warming potential and ozone formation per hectare. Besides fewer field operations, the main reason is that they do not need as much mineral fertiliser as crop rotations. The production of mineral fertiliser needs a considerable quantity of non-renewable energy [3] and generates emissions like carbon dioxide, ammonia and nitrous oxide. Miscanthus and willow show better results in acidification and eutrophication due to lower fertilisation and permanent soil coverage that reduces nitrate leaching (see Table 1). The same applies to the eutrophication of permanent meadow whereas its acidification potential is the highest together with the energy crop rotation. This is primarily due to emissions of ammonia caused by the application of the fermented biogas substrate recycled in the system. No pesticide use in the permanent meadow and low pesticide use in willow and miscanthus result in lower human and ecotoxicology potentials in comparison to those of crop rotations.
The energy crop rotation shows a higher impact on ozone formation due to more field operations (field cultivation, harvesting and transport of harvest) if compared with the reference crop rotation. Intensive field operations combined with less input of mineral fertiliser result in a similar energy use and global warming potential per hectare of the two crop rotations (see Table 1). The acidification and eutrophication potential of the energy crop rotation is higher because of the use of fermented biogas substrate as manure. In all other impact categories, both crop rotations show similar results per hectare. Considering the functional unit kg organic dry matter (oDM), the energy crop rotation has a considerably lower energy demand and a lower eutrophication potential because of the higher yield.

Table 1: Environmental impacts of the energy crop rotation (CR) and the perennial crops Miscanthus, willow and permanent meadow in percent of the impacts of the reference crop rotation given per hectare times 5 years (ha*5a).

<table>
<thead>
<tr>
<th>Impact category</th>
<th>unit/(ha*5a)</th>
<th>CR reference</th>
<th>CR energy</th>
<th>Miscanthus</th>
<th>Willow</th>
<th>Permanent meadow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy demand</td>
<td>MJ-eq</td>
<td>103,757</td>
<td>107%</td>
<td>49%</td>
<td>27%</td>
<td>42%</td>
</tr>
<tr>
<td>Global warming pot.</td>
<td>kg CO2-eq</td>
<td>18,080</td>
<td>95%</td>
<td>36%</td>
<td>19%</td>
<td>32%</td>
</tr>
<tr>
<td>Ozone formation</td>
<td>kg Ethylene-eq</td>
<td>3.57</td>
<td>125%</td>
<td>53%</td>
<td>36%</td>
<td>52%</td>
</tr>
<tr>
<td>Acidification</td>
<td>kg SO2-eq</td>
<td>92.8</td>
<td>464%</td>
<td>48%</td>
<td>20%</td>
<td>504%</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>kg N-eq</td>
<td>344</td>
<td>158%</td>
<td>44%</td>
<td>29%</td>
<td>72%</td>
</tr>
<tr>
<td>Terrestrial ecotox.</td>
<td>Tox. points</td>
<td>1809</td>
<td>79%</td>
<td>49%</td>
<td>26%</td>
<td>8%</td>
</tr>
<tr>
<td>Aquatic ecotox.</td>
<td>Tox. points</td>
<td>13,834</td>
<td>96%</td>
<td>9%</td>
<td>7%</td>
<td>13%</td>
</tr>
<tr>
<td>Human toxicity</td>
<td>Tox. points</td>
<td>288</td>
<td>102%</td>
<td>48%</td>
<td>29%</td>
<td>46%</td>
</tr>
</tbody>
</table>

Direct nitrate leaching kg N 229 122% 41% 26% 0%

Conclusions
Regarding ground water protection, the cultivation of perennial crops for energy production is a significant improvement compared to crop rotations with more intensive tillage and fertilising being responsible for high potentials of nitrate leaching. Contrary to the hypothesis, the analysed energy crop rotation is not suited for ground water protection. To achieve reduced nitrate leaching, it would need further optimisation in the selection and cultivation process of the crops (extensification of field processes, application form and time for of fertilisers, crop rotation design).

Disregarding the differences of the products, the energy crops miscanthus and willow represent an ecological alternative to conventional food production on arable land. Permanent meadow for energy production could also be a good option, although the acidification potential is quite high and the yield in oDM remains rather low. Considering also the overall energy production, perennial crops show lower impacts than energy crop rotations [4]. Political support of energy crops should therefore mainly focus on perennial energy crops.

References
ANALYSING FARMERS PRACTICES TO DESIGN A CONCEPTUAL MODEL OF A FARMING SYSTEM
APPLICATION TO THE CRAU HAY SYSTEM

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Introduction
The conceptualisation of a cropping system requires identifying and representing the key decision process of the farmer on its fields and resources. This study is carried out on the Crau region (South of France) where intensive border irrigation allows the development of agricultural systems based on hay production. Due to environmental impacts, conventional water management practices must be modified in order to ensure both higher water productivity while keeping hay production and quality, and lower environmental impacts.

Material and methods
The survey: The survey is based on a stratified sampling of the farms (Capillon, 1993). Three criteria were used: i) geographical localisation; ii) proportion of grassland area in the farm; iii) complementarities between the hay production system and other production system mostly sheep breeding. Semi-directive interviews were structured around five topics: history of the farm, plot design, grassland cropping system, water management, interaction grassland – sheep breeding.

The conceptual model: The conceptual model is based on the concept of ‘model for action’ (Aubry et al., 1998). When applied to the irrigation management, it gives 5 components: the various decision-making rules for irrigation and production decision, the descriptive variables of the planning schedules (Aubry et al., 1998), the main constraints for irrigation, the description of the equipment and water resource context (Bergez et al., 2001). This model for irrigation was used to analyse the results of the interviews in each farm and it is designed to answer two questions: when irrigating and how much (Bergez et al., 2002) considering environmental impacts, water use and hay production?

Results
Description of the farming system
Spatial entities relevant for irrigation and hay decision making: The whole irrigated area is divided into smaller sub-areas linked to a given water resource. The water resource may have a discrete or continuous water flow and is then associated to a water path that irrigates a given number of fields. Fields are then divided into irrigation borders. Irrigation decisions are taken at the irrigation border level and water path level while decisions for hay production are taken at the field and farm level. Distances between borders and fields are important in the decision making process.

Temporal units for decision making in the hay production system: The different agricultural practices are scheduled on a strategical temporal axis. This planning (fig.1) is modified by the farmer when competition between operations for different fields occurs especially for irrigation and mowing. Irrigation practices were identified as the priority in the farm.

Interaction between grassland cropping system and sheep breeding system: Only few temporal interactions were identified between hay and breeding systems (fig.1). These two activities are complementary in space and time and we only stressed a short-time effect: fields are grazed in a chosen spatial order that induces a spreading of the maturity of hay among the fields. Fields are then cut for hay in the same spatial order all along the three mowings.
Decision rules related to grassland irrigation practices: Five rules allowed describing irrigation management in the cropping system: the beginning and the end of irrigation season, the spatial distribution of water in the farm, the management of irrigation during mowing period and the adaptation of irrigation to rainfall events (Bergez et al., 2001).

Constraints and degree of freedom related to irrigation practices: In addition to pedoclimatic constraints, water constraints are important. The main irrigation constraint is due to the characteristic of the water resource. The available water amount on each water resource is totally fixed by the flow and the distribution calendar. Then the water distribution into the farm, spatially organized can not be changed easily as well as labour management. The degree of freedom to modify farmer organisation is quite limited.

Development of the conceptual model
The conceptual model was built on these results to describe irrigation management during a production season. Two operations were modelled in interaction with irrigation management: grazing and mowing. Five important constraints for irrigation were identified and integrated in the model for action. There were external constraints such as water flow constraints and internal constraints such as mowing, labour, grazing, spatial disposition of the borders and preferential schemes for water distribution. Associated with four timers, the decision-making rules were written in a formal “If Indicator Then Action1 Else Action2”. The model is made of 5 decisional chains each composed of a set of rules that are successively tested: at the beginning of the irrigation season, (i) a chain for the verification of water access and (ii) the verification of significant water deficit for irrigation, (iii) the decision chain to end the season, and during the season the decision chains (iv) for the fields to mow and (v) the borders to irrigate. Priorities between irrigation and mowing change depending on the period of the year.

Conclusion
This conceptual model has been used to build a Decision Support System DSS linked at a grass growth model and at a hydrological model. This DSS should allow testing different water guidelines and practices taking into account the complex interactions between the cropping system and the environment.

Introduction

Agroforestry systems are an element of the existing Swiss cultural landscapes. However, in the last decades, there has been a dramatic decrease of trees on the Swiss landscapes (Fig 1), either due to intensification of agriculture or to globalization driven loss of economic power of extensible managed tree products (Eichhorn et al., 2005).

Recent research indicates that modern agroforestry can be competitive with conventional agriculture and may also yield more environmental benefits regarding soil erosion, nitrogen leaching and biodiversity (Cabanettes et al., 1998; Graves et al., 2007; Palma et al., 2007a; Palma et al., 2007b).

In the Swiss context, modern agroforestry systems can fit on the present agricultural environmental quality framework. Under the project “Tree Gardens”, farmer’s innovations in using trees are documented and incorporated with new potential uses of trees (i.e. energy) to evaluate possible scenarios of agroforestry systems. To help maximizing effects of implementation, this geographical study at national scale focuses on where these systems can be introduced, considering their environmental and economic potential.

Methodology

The whole assessment is processed within a geographical information system to locate “Target Areas” (Fig 2). Datasets of land-use delineate the farmland where trees can be introduced, while national edafo-climatic datasets and expert driven economic tree growth criteria define the potential distribution areas of wild cherry (Prunus avium), black walnut hybrids (Juglans hybr.), chestnut (Castanea sativa), poplar (Populus spp), willow (Salix spp), mountain ash (Sorbus aucuparia), beech (Fagus sylvatica) and oak (Quercus robur).

Mitigation of environmental problems which can be achieved with the implementation of trees in the landscape are addressed. National datasets of erosion, nitrogen leaching and loss of biodiversity were gathered or generated and classified with thresholds of severity to delineate areas of potential mitigation with agroforestry.
Results

Target areas for new modern agroforestry systems were derived. The spatially explicit areas are mainly located in the direction south-west/north-east somehow expected due to the farmland area distribution. Nevertheless, interesting areas where modern agroforestry can be economically interesting and environmental functional were found. These focus mainly in mitigating soil erosion, nitrogen leaching and loss of biodiversity while ensuring reasonable profitability from the trees.

Conclusions

The assessment shows that modern agroforestry is not a solution for a large part of Switzerland in terms of environmental protection. However, this can be partially accomplished by the implementation of these systems on well defined areas.

The achieved spatially explicit areas can help decision makers to maximize efforts in locating priority regions for an eventual support for farmers.

References

FOREST: RESOURCE FOR DROUGHT COPING AND LIVELIHOOD SECURITY IN THE UNFAVOURABLE RICE FARMING SYSTEM

S. Taunk, R. Lakpale, G. Shrivastava

Introduction

The forests of the state fall under two major forest types, i.e., Tropical Moist Deciduous Forest and the Tropical Dry Deciduous Forest. Ecologically sal and miscellaneous forest are the major forest types Sal (Shorea robusta), Saja (Terminalia tomentosa), Teak (Tectona grandis) are the three major tree species in the state. Other notable overwood species are Bija (Pterocarpus marsupium), Dhawra (Anogeissus latifolia), Mahua (Madhuca indica), Tendu (Diospyros melanoxylon) etc. Amla (Emblica officinalis), Karra (Cleistanthus Collinus) and bamboo (Dendrocalamus strictus) constitute a significant chunk of middle canopy of the state's forests. In the ground flora, a number of herbs and shrubs is profusely present. The present investigation is a part of the IRRI-IGAU collaborative project on “Economic cost of drought and farmer coping mechanism” were conducted in Kanker district of Chhattisgarh, India from 2000-2005. Investigation was done to find out the farmers coping mechanism for their livelihood and food security in the unfavourable rice farming systems but with abundant forest area rich in minor forest produce, medicinal and aeromatic plants.

Methodology

The study was conducted in selected four villages of Kanker district. 100 farmers of different holdings were interview using structured interview schedule. The data were collected in the drought year and is purely relied according to the farming community which includes landless, marginal, small, medium and large households.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Forest division</th>
<th>Reserved forest (Sq km)</th>
<th>Protected forest area (Sq km)</th>
<th>Non protected area of forest (Sq km)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>KANKER</td>
<td>832.785</td>
<td>1032.299</td>
<td>423.647</td>
<td>2287.731</td>
</tr>
</tbody>
</table>

Kanker, Kondagaon, Narayanpur and Bahanupratappur total four district forest produce co-operative unions are working in this circle. There are 140 forest produce societies in that union.

<table>
<thead>
<tr>
<th>Year</th>
<th>Name of forest</th>
<th>Collection target</th>
<th>Collection rate</th>
<th>Collected quantity</th>
<th>Received revenue (in Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>KANKER</td>
<td>85000</td>
<td>300/- per</td>
<td>80785</td>
<td>44722985</td>
</tr>
<tr>
<td>2001</td>
<td>KANKER</td>
<td>85000</td>
<td>300/- per</td>
<td>67203</td>
<td>50723225</td>
</tr>
<tr>
<td>2002</td>
<td>KANKER</td>
<td>77000</td>
<td>300/- per</td>
<td>99759</td>
<td>24056930</td>
</tr>
</tbody>
</table>
The annual timber and bamboo production trends in the Kanker District are

<table>
<thead>
<tr>
<th>Forest Produce</th>
<th>Unit</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber</td>
<td>Thousand Cmt</td>
<td>21-24</td>
</tr>
<tr>
<td>Fuel Wood</td>
<td>Lakh Stacks</td>
<td>.25 to .30</td>
</tr>
<tr>
<td>Industrial Bamboo</td>
<td>Thousand N.T.</td>
<td>14</td>
</tr>
<tr>
<td>Commercial Bamboo</td>
<td>Thousand N.T.</td>
<td>10</td>
</tr>
</tbody>
</table>

Results
The forest of the Kanker district is rich in minor forest produces. The principal minor forest produces are Tendu Patta, Sal Seeds, Mohua, Harra, Amal, Achar, Gums, Lacs, etc and many other medicinal plants. The above tables and detail findings reveals that the Non Wood Forest Produce (NWFP) continuously played an important role for the food security and nutrition among the farmers, specially marginal and small farmers. Livelihood security of tribes and forest dependent communities were found to be managed through various forest species because it not provide the fruits as food but also its wood were sold in the market for gaining some income to fulfill the felt need of these communities. Since farming of medicinal plants and other NWFP is a very high income generating activity many farmers are willing to take up inter-cropping / cultivation of various such species. Generate income for the household budgets or as bartering goods the contribution of NWFP directly to fulfill basic needs is thereof particularly important for the poorest household and even fodder and medicines or livestock. Where agricultural yields are more uncertain and they therefore rely to high degree on NWFS which provides employment to 85% of almost 60% of the state forest revenues and 80% of the export are from forest produce.

Conclusion- In normal and drought year the MFP etc are the primary source of income and employment. Secondary is the crops etc. especially in drought years the food security -livelihood and economy of farmers was not effected due to abundant bio diversity alternate income from NWFP’s medicinal, tuber and aromatic plants supported the farmer income with this delicious taste and rich nutritive value and also fulfill the fodder need of the live stock. The astonishing finding was that there is no migration in extreme drought year.
A BIO-ECONOMIC MODEL FOR TROPICAL AGROFORESTRY: DESIGN AND FIRST IMPLEMENTATIONS

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Introduction

In February 2007 agroforestry trials of enriched fallow were set up in participation with indigenous farmers in the Venezuelan Guyana shield region. To compare ex ante the economic sustainability of these trials with each other and vis-à-vis the traditional system on a one-hectare scale level, a bio-economic agroforestry model was developed in Excel.

To clarify why and how a proper model was developed, we review existing agroforestry models. Four types of models are identified. Bio-physical models, like Simile, HyPAR, SCUAF and WaNuLCAS, simulate yields by mechanistic equations. Economic models use existing or simulated yield data from bio-physical models to simulate profitability. Examples are BEAM, the Agroforestry Calculator, ARBUSTRA and the Agroforestry Estate Model. Bio-economic models, like NUTMON and Plot- and FarmSAFE, are a combination of the two previous ones. Finally, large-scale models like FALLOW, simulate the impact of land use decisions in the tropics.

Methodology

Our model consists of two interacting biological and economic sub-models. In the biological sub-model the calculation of biomass production in kilogram per hectare per year is governed by the following equation, adapted from PlotSAFE (Van der Werf et al., 2007): \( \frac{dB}{dt} = \frac{365 \times I \times f \times \varepsilon \times NI}{1000} - a \times B \), with \( I \) mean daily radiation per year in MJ/m²; \( f \) the radiation intercepted [%]; \( \varepsilon \) the radiation use efficiency in g/MJ; \( NI \) a nitrogen stress factor (see below); \( a \) the percentage biomass needed for respiration; and \( B \) biomass in year t. The intercepted radiation is determined by the canopy structure, the position in the canopy and the modelled leaf area index, and limited by shadow effects. The biomass is divided over fruit and wood production (both economic benefits), and litter and pruning production (both inputs in soil nitrogen module) by multiplying the total biomass produced with the respective harvest indices.

The nitrogen stress factor is calculated following the NUTMON model. The main equation dealing with changes in soil nitrogen content per hectare per year in the upper soil layer ((dS/dt)h) is (Van den Bosch et al., 1998): \( \frac{dS}{dt} = F + N_{atm} + N_{nonsymb} + N_{litter} + N_{pruning} - U_{c,c} - U_{c,T} - Leach \). Inputs of nitrogen into the soil are fertilizers (F); atmospheric nitrogen fixation (N_{atm}) and non-symbiotic nitrogen fixation (N_{nonsymb}) (both determined by mean annual precipitation); and nitrogen additions from litter fall (N_{litter}) and pruning (N_{pruning}). Nitrogen fluxes leaving the soil are determined by leaching (Leach) (dependent on the clay content of the soil, precipitation, soil depth, fertilizer input, soil nitrogen content and nitrogen uptake by all crops), uptake of nitrogen by annuals (U_{c,c}) and uptake of nitrogen by (semi-)perennials (U_{c,T}). Once soil nitrogen (S_{t-1}) becomes lower than the crops’ requirements, the nitrogen stress factor reduces the potential biomass growth proportional with the lack of nitrogen.

The inputs used in agroforestry systems are fertilizers, insecticides and seeds, creating variable costs. Fixed costs can be entered as well. The total labour input into the system is converted into costs per hectare per year by multiplying with the opportunity cost of labour and an inflation factor. Currently the model does not account for potential economies of scale. Finally, the model calculates the net present value (NPV = \( \sum (B_t - C_t)/(1 + r)^t \)), the infinite NPV (=NPV * (1 + r)^n/(-1 + (1 + r)^n)), the equivalent annual value (EAV = infinite NPV * r) and the benefit cost ratios, with r the rent, n the duration of the cycle and B and C the benefits and costs realized in year t. The model is calibrated using literature data.
Results
The traditional system consists of a cropping phase of four years, in which the farmer cultivates corn (*Zea mays* L.) and yucca (*Manihot esculenta* Crantz), and a fallow (of at least 15 years) to restore soil fertility. The main economic species growing in the fallow are ice-cream-bean (*Inga edulis* Mart.), peach-palm (*Bactris gasipaes* Kunth) and cocura (*Pourouma cecropifolia* Mart.) (Villarreal, 2002). The fallow crops are not actively pruned or maintained. Experimental design 1 consists of a combination of copoazu (*Theobroma grandiflorum* (Willd. Ex Spreng.) Schumm.), cacao (*Theobroma cacao* L.) and ice-cream-bean. Experimental design 2 consists of a complex system of ice-cream-bean, copoazu, seje (*Oenocarpus bataua* Mart.), peach palm, manaca (*Euterpe oleracea* Mart.), cacao and temare (*Pouteria caimito* (Ruiz & Pav.) Radkl.). In the experimental systems yucca and corn are intercropped on the traditional way in the first four years. All three systems are profitable; however, in the traditional system soil fertility is in continuous decline. Only experimental system 2 outperforms the traditional system from an economic point of view. However, if we reduce the discount rate from 20% to 5% experimental system 1 becomes almost as profitable as the traditional system. Moreover, in the experimental systems soil fertility stabilizes at a certain level due to the pruning practice and the planting of a relative high density of the nitrogen fixating Inga. This means that if the shading effect is not too strong, farmers could continue yucca cultivation for more than four years.

<table>
<thead>
<tr>
<th>System</th>
<th>NPV (US$)</th>
<th>Infinite NPV (US$)</th>
<th>EAV (US$)</th>
<th>B/C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>7,344.85</td>
<td>7,582.173</td>
<td>1,516.435</td>
<td>5.53</td>
</tr>
<tr>
<td>1</td>
<td>12,661*</td>
<td>20,954.33</td>
<td>1,047.716</td>
<td>4.1</td>
</tr>
<tr>
<td>2</td>
<td>4,771.79</td>
<td>4,925.977</td>
<td>985.1955</td>
<td>4.344</td>
</tr>
<tr>
<td>8,782.715</td>
<td>14,534.52</td>
<td>726.7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>10,222.38</td>
<td>10,552.69</td>
<td>2,110.538</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>33,295</td>
<td>55,100</td>
<td>2,755</td>
<td>5.6</td>
<td></td>
</tr>
</tbody>
</table>

* numbers in italic discount rate of 5%; others discount rate of 20%

Conclusions
The simulated net present values and benefit cost ratios are high, though comparable to results of other agroforestry trials in Latin America (Current et al., 1995). The high values are explained by the extensive nature of both traditional and experimental plots, and the hypothesis that everything is sold at market value, leading to high benefits. The outcome is sensitive to the discount rate. A high discount rate is realistic, as short term benefits are valued by the indigenous, hence advantaging the traditional system over the agroforestry trials. To be complete the model should be extended to account for water limiting effects. The model will also be used to evaluate the agroforestry trials in two other project areas in Brazil and Suriname. Therefore, a stock module should be included, as the traditional system in Brazil is stock breeding. Finally the model will be extended to account for an energetic analysis of the systems, i.e., accounting for in- and outputs in energy units instead of monetary units.

References
CHANGES IN SOIL AGGREGATION IN A PLANTAIN CROPPING SYSTEM

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2International Institute of Tropical Agriculture (IITA)
3Crop Research Institute Accra Ghana.

Introduction
Soil aggregate stability is a crucial soil property affecting soil sustainability and crop production (Amezketa, 1998). The resource degradation of agricultural regions through soil erosion, compaction and other types of degradation caused by improper land use and farming practices, threatens not only the productive capacity of agriculture but also the health of humans and wildlife (Lipiec, undated). Soil aggregate stability is a major parameter of soils’ capacity to resist degradation. As such, systems that build highly stable soil aggregates might be more sustainable than those that do not. Plantain is a major cash food crop in the West and Central African humid forest zone, yet little is known about soil physical changes in plantain systems. This study was carried out to evaluate the effects of different plantain systems on aggregate stability.

Methodology
The study was carried out in Mfou, Nkometou and Ngoumou in southern Cameroon. In each village, two land use systems (LUS): bush fallow dominated by Chromolaena odorata and a secondary forest were used to test in a 4x4 factorial randomised complete block design the factors plantain sole, plantain with pepper, with Flemingia macrophylla or with Pueraria phaseoloides and the plantain cultivar and sucker types at four levels (plantain untreated, boiling-water treated, or from macro-propagation and a hybrid from macro-propagation). Treatments were 3 times replicated. Soil samples were collected in 2002, before planting, then 24 and 56 months later. Aggregate stability was determined according to Angers and Mehuys, (1993). Proportions of water stable aggregates and mean weight diameter (MWD) were calculated according to Whalen, et al., (2003). The geometric mean diameter was calculated according to Gardner, (1956). Macroaggregates were the sum of the proportion of water stable aggregates retained in the 4.0 and 2.0 mm sieves, mesoaggregates were the proportion of water stable aggregates in the 1.0 and 0.25 mm sieves and microaggregates were the sum of the proportion of water stable aggregates in the 0.125 mm sieve added to those which have past through this sieve. The annual rates of change of these parameters between 0 and 56 month after planting (MAP) were calculated as:
Rate of change 1 = 12 months x (the value at 24 MAP – the value at 0 MAP)/ 24 months.
Rate of change 2 = 12 months x (the value at 56 MAP – the value at 24 MAP)/ 32 months.

Results
Between 0 and 56 MAP, soil macroaggregates, MWD and GMD increased, while mesoaggregates and microaggregates decreased.

Table 1. Changes in MWD (0-10 cm) from 0 to 56 MAP in the cropping systems at Nkometou

<table>
<thead>
<tr>
<th>LUS</th>
<th>F. macrophylla</th>
<th>Pepper</th>
<th>P. phaseoloides</th>
<th>Natural regrowth</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bush 0 MAP</td>
<td>4.67b</td>
<td>4.42c</td>
<td>4.96b</td>
<td>4.60b</td>
<td>72</td>
</tr>
<tr>
<td>24 MAP</td>
<td>5.28b</td>
<td>5.54b</td>
<td>4.76b</td>
<td>5.90a</td>
<td>72</td>
</tr>
<tr>
<td>56 MAP</td>
<td>6.39a</td>
<td>6.33a</td>
<td>6.20a</td>
<td>6.57a</td>
<td>72</td>
</tr>
<tr>
<td>Forest 0 MAP</td>
<td>3.74c</td>
<td>4.11b</td>
<td>3.78b</td>
<td>3.66b</td>
<td>72</td>
</tr>
<tr>
<td>24 MAP</td>
<td>4.58b</td>
<td>4.78ab</td>
<td>4.46ab</td>
<td>4.34b</td>
<td>72</td>
</tr>
<tr>
<td>56 MAP</td>
<td>5.56a</td>
<td>5.00a</td>
<td>4.59a</td>
<td>5.40a</td>
<td>72</td>
</tr>
</tbody>
</table>

Land use systems x year <0.0001
LUS x cropping system x year = 0.34

Values in the same columns for a LUS with different letters are significantly different at P<0.05 using pdiff.

The rate of change of water stable aggregates expressed as MWD in the bush fallow in all villages was highest in sole plantain (0.32 mm yr⁻¹), intermediate in F. macrophylla (0.24 mm yr⁻¹) and pepper intercrop (0.23 mm yr⁻¹), and lowest in P. phaseoloides intercrop (0.15 mm yr⁻¹). There was
no significant cropping systems X village interaction in the rate of change of water stable aggregates. Rates of chance of all parameters were significantly higher at Nkometou than at

<table>
<thead>
<tr>
<th>LUS</th>
<th>Village</th>
<th>Macroaggregates (g/g)</th>
<th>Mesoaggregates (g/g)</th>
<th>Microaggregates (g/g)</th>
<th>MWD (mm)</th>
<th>GMD (mm)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mfou</td>
<td>Mfou</td>
<td>0.78a</td>
<td>0.129b</td>
<td>0.095a</td>
<td>5.15a</td>
<td>1.68a</td>
<td>72</td>
</tr>
<tr>
<td>Bush</td>
<td>Ngoumou</td>
<td>0.70b</td>
<td>0.201a</td>
<td>0.095a</td>
<td>4.77b</td>
<td>1.59b</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Nkometou</td>
<td>0.93a</td>
<td>0.036c</td>
<td>0.038b</td>
<td>6.37a</td>
<td>2.06a</td>
<td>72</td>
</tr>
<tr>
<td>Mfou</td>
<td>Mfou</td>
<td>0.77a</td>
<td>0.151b</td>
<td>0.077a</td>
<td>4.94a</td>
<td>1.68a</td>
<td>72</td>
</tr>
<tr>
<td>Bush</td>
<td>Ngoumou</td>
<td>0.71b</td>
<td>0.206a</td>
<td>0.087a</td>
<td>4.82a</td>
<td>1.62a</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Nkometou</td>
<td>0.75ab</td>
<td>0.172ab</td>
<td>0.075a</td>
<td>5.14a</td>
<td>1.68a</td>
<td>72</td>
</tr>
</tbody>
</table>

Values in the same columns for a LUS with different letters are significantly different at P<0.05 using pdiff.

Ngoumou and Mfou. The rate of aggregate formation was lower (p<0.01) during the first 24 months of the experiment than during the following 32 months. There was a close (p<0.0001) and positive relationship with the amount of sand, silt, Ca, Mg, pH water and macroaggregates, MWD and GMD, conversely for mesoaggregates and microaggregates where the correlation is negative (p<0.01). Clay and P content were positively related to the mesoaggregates (r=0.52, p<0.0001 and r=0.3, p<0.01 respectively), yet not to the macroaggregates, MWD and GMD. The 5 parameters were not related to the amount of K, total C, total N, C/N and bulk density.

Correlations show that Ca, Mg, sand, silt, clay, are some aggregating agents in this topical soil as shown by Salako and Hauser, 2001. The higher proportion of stable aggregates at Nkometou (table 2) may be attributed to a higher concentrations of Ca and Mg in the soil and higher decomposition rates of organic matter and thus the release of more aggregating agents, (Banful, 2006). In addition, the activity of termites was intense at Nkometou and Mfou, which may have contributed a certain amount of stable aggregates. The higher rate of change of stable aggregates in sole plantain in bush fallow is probably caused by the dominance of C. odorata, which is high in Ca and Mg compared to dominant species in the other systems and which decomposed faster than F. macrophylla, and P. phaseoloides. Moreover, the network of the actively growing woody root systems of C. odorata and F. macrophylla might have exerted pressure on non-aggregated soil material, such that the soil material was trapped and compressed into aggregates.

Conclusions

Plantain production, specifically sole plantain with the natural weeds re-growing does not have a negative impact on soil aggregate stability. The fact that intercropping pepper and the use of planted fallows (F. macrophylla and P. phaseoloides) did not improve aggregate stability at the same rate is surprising yet could be connected to the absence of weeds. The improved soil aggregate stability at 56 MAP might suggest that after intercropping of pepper, and in the planted fallows, more time is required to attain similar structural stability as in sole (weedy) plantain.

References

INTRODUCTION

Plantain is for most smallholder farmers in the West and Central African humid forest zone a major food cash crop. However, after 2-3 years of cropping the yield of plantain declines sharply, with its attendant economic consequences. Maize on the contrary is more of a staple food used to increase food security, (anonymous 1, undated) in this zone. Labour shortage to clear land and sometimes land shortage force farmers to use land for a longer period or crop after reduced length of the fallow period. Yet there remains the requirement to maintain soil fertility under intensified cropping (Verinumbe et al., 1992). The changes in soil properties that lead to sharp declines in crop production are still not well understood on southern Cameroonian Ultisols. This study was carried out to evaluate the effect of land history and tillage on the changes of soil physical properties in a maize cropping system.

MATERIALS AND METHODS

The study was carried out on an Ultisols at Mfou in the southern Cameroon, after the manual clearing of a 4 year-old plantain cropping system which had been set in a former 4-5 year-old bush dominated by Chromolaena odorata. The plantain cropping system had been established in a 4x4 factorial randomised complete block design with the factors plantain sole, plantain with pepper, with Flemingia macrophylla or with Pueraria phaseoloides and plantain sucker treatment and cultivar at four levels (plantain untreated, boiling-water treated, or from macro-propagation and a hybrid from macro-propagation). Treatments were 3 times replicated. Former plots were divided in 4 sub-plots, two of these, were left untilled (zero tillage) and two were either hand hoe tilled or tilled with the small three-wheel tractor. Beside these original plots, new plots were established as the control after the slashing of a bush fallow. Maize was sown in 0.50 x 0.50 m spacing. Soil compaction was measured in June 2006 using the hand penetrometer. Available water capacity (AWC) was calculated as in Nyobe (1998). Aggregates stability was determined according to Angers and Mehuys, (1993). The proportions of water stable aggregates and mean weight diameter (MWD) were calculated according to Whalen, et al., (2003). The geometric mean diameter was calculated according to Gardner, (1956). Macroaggregates were the sum of the proportion of water stable aggregates retained in the 4.0 and 2.0 mm sieves and microaggregates were the sum of the proportion of water stable aggregates in the 0.125 mm sieve added to those which have past through this sieve.

RESULTS AND DISCUSSION

Bulk density was not affected by tillage, except at 10-15 cm depth, in the natural regrowth, with 1.24 Mg m⁻³ (p<0.1) after tractor tillage, intermediate with no-tillage (1.17 Mg m⁻³) and lowest when hand tilled (1.10 Mg m⁻³). The water holding capacity of the soil whatever the soil depth and the former cropping system, at field capacity (FC: 172.6 g kg⁻¹) or at permanent wilting point (PWP: 113.5 g kg⁻¹) was significantly lower after tractor tillage, than after hand tillage, (FC: 229.0 g kg⁻¹ and PWP: 174.8 g kg⁻¹).

<table>
<thead>
<tr>
<th>Tillage</th>
<th>F. macrophylla</th>
<th>Pepper</th>
<th>P. phaseoloides</th>
<th>Natural regrowth</th>
<th>Uncropped Control</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>No tillage</td>
<td>1.27a</td>
<td>1.16ab</td>
<td>1.00b</td>
<td>1.09ab</td>
<td>0.97b</td>
<td>24</td>
</tr>
<tr>
<td>Hand hoe tillage</td>
<td>1.22b</td>
<td>1.12b</td>
<td>1.21*</td>
<td>1.51*a</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td>Tractor tillage</td>
<td>1.42a</td>
<td>1.21ab</td>
<td>0.96c</td>
<td>1.12bc</td>
<td>1.09bc</td>
<td>24</td>
</tr>
</tbody>
</table>

Values within lines, followed by different letters are significantly different at p<0.10 using pdiff.

* within columns significantly larger than all other values at p<0.10 using pdiff.

Table 1: Variations in AWC (cm) in the 0-5 cm depth with the former coping system and tillage level.
In no-tilled plots, across all depths, the log10 transformed penetration resistance in the former plantain pepper intercrop were significantly \((p<0.10)\) higher (2.91 kPa) than in the \(F\). macrophylla (2.68 kPa). The penetrometer resistance in \(P\). phaseoloides (2.75) and the previously uncropped control (2.84kPa) were intermediate. The plantain in natural regrowth had a strong gradient with soil depth (2.63; 2.76; 2.80 and 2.84 at 0-5, 5-10, 10-15 and 15-20 cm, respectively).

Table 2. Penetrometer resistance after different tillage in 4 former plantain sucker treatments, 0-10 cm (kPa)

<table>
<thead>
<tr>
<th>Plantain sucker treatment</th>
<th>Essong PIF</th>
<th>Essong boiled</th>
<th>Essong traditional</th>
<th>Pita 14</th>
<th>Uncropped Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero tillage</td>
<td>2.79(^a)</td>
<td>2.73(^b)</td>
<td>2.77(^{ab})</td>
<td>2.73(^b)</td>
<td>2.84(^a)</td>
</tr>
<tr>
<td>Hand hoe tillage</td>
<td>2.65(^b)</td>
<td>2.82(^a)</td>
<td>2.74(^{ab})</td>
<td>2.73(^b)</td>
<td>-</td>
</tr>
<tr>
<td>Tractor tillage</td>
<td>2.78(^{a})</td>
<td>2.84(^{a})</td>
<td>2.80(^{a})</td>
<td>2.82(^{a})</td>
<td>2.83(^{a})</td>
</tr>
</tbody>
</table>

\(P = 0.10\)

Tillage = 0.03 Plantain sucker treatments = 0.27 Tillage x plantain sucker treatment = 0.07

Values within lines, followed by different letters are significantly different at \(p<0.10\) using pdiff.

* within columns significantly larger than all other values at \(p<0.10\) using pdiff.

MWD is given in table 3; difference in GMD followed the same trend. A higher soil macroaggregate proportion was found in the uncropped control at zero-tillage (71.4%) than in the former plantain pepper intercrop (65.4%) and plantain \(F\). macrophylla (59.4%). Macroaggregate proportion was intermediate in plantain \(P\). phaseoloides (61.6%) and the natural regrowth (65.9%). The proportion of soil microaggregates increased significantly with the intensity of tillage: 22% in tractor tillage, 14.6% in hand tillage and 12.9% in the zero-tillage.

Table 3: MWD (mm) in 0-10 cm after different tillage in 4 former cropping systems

<table>
<thead>
<tr>
<th>Tillage</th>
<th>(F). macrophylla</th>
<th>Pepper</th>
<th>(P). phaseoloides</th>
<th>Natural regrowth</th>
<th>Uncropped Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero tillage</td>
<td>3.83(^b)</td>
<td>3.66(^{b})</td>
<td>4.44(^a)</td>
<td>4.26(^{ab})</td>
<td>4.75(^a)</td>
</tr>
<tr>
<td>Hand hoe tillage</td>
<td>3.94</td>
<td>4.56</td>
<td>3.74</td>
<td>4.39</td>
<td>-</td>
</tr>
<tr>
<td>Tractor tillage</td>
<td>3.84</td>
<td>4.62(^{**})</td>
<td>3.98</td>
<td>4.12</td>
<td>4.31(^{a})</td>
</tr>
</tbody>
</table>

\(^{**}\) within columns significantly larger than * at \(p<0.0\) using pdiff.

Values within lines, followed by different letters are significantly different at \(p<0.10\) using pdiff.

Conclusion

Soil physical properties were different after different land history and the cropping system used. Tractor tillage deteriorates soil water holding capacity, increased soil compaction and decreased soil aggregate stability under wet sieving conditions. In general, soil physical properties were closest to those in zero tillage when the soil was hand hoe tilled, with the positive effect that soil water-holding capacity was improved with hand hoe tillage.

References

Anonymous 1, [http://www.africancrops.net/crops/maize/index.htm](http://www.africancrops.net/crops/maize/index.htm)


MULTIFUNCTIONAL FARMING SYSTEMS CONTRIBUTING TOWARDS THE QUALITY OF RURAL AND URBAN AREAS IN NOORD-BRABANT IN THE NETHERLANDS

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Introduction

The agriculture sector in the Netherlands is changing its course: from the production of food to the combined production of food and public goods. Intensively used agricultural land may be turned into extensive farming practices where an additional income is made by delivering social services for nearby urban areas: health care, education, flood protection, leisure, et cetera. No longer can ‘traditional farming practices’ provide enough income for farmers. Furthermore, the demands of society are shifting. How are we to know what decisions to take in order to ride on top of this wave? Farmers and entrepreneurs in Noord-Brabant are learning by doing.

Noord-Brabant is one of the wealthier provinces of the Netherlands. With 500,000 hectares and 2.4 million inhabitants, Noord-Brabant belongs to the most densely populated areas of Europe. The urban cluster around Brabant’s major cities is home to 60 percent of the population and provides 70 percent of the 1.1 million jobs. Industry has developed here into an important stronghold hosting well-known multinational companies. However, agriculture remains a significant economic sector and is related to about 50 percent of the available space. Most surprisingly yet, the landscape of Noord-Brabant is green and has a traditionally small scale character. A large part (130,000 ha) is taken up by nature areas, some standing out because of their international fame and beauty.

Agriculture has always had an important socio-economic influence in Noord-Brabant. Undoubtedly this influence will remain substantial in the future, even though the number of farms is decreasing. New social functions are to be fulfilled. For instance, over the past few years the agricultural sector has been recognised as one of the most important stewards of our Brabant’s landscape. Presently a strong agro-industrial complex works alongside more than 14,500 farmers (table 1). In what direction will the agricultural sector develop and will the economic benefits contribute towards a productive balance with social and ecological values? Three directions are dominant in the development of the sector. Farmers tend to choose for sustainable development and scaling-up, multifunctional agriculture, or for stepping out of business altogether.

Table 1: Company structure - Number of farms in Noord-Brabant

<table>
<thead>
<tr>
<th></th>
<th>1996</th>
<th>2002</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable farming</td>
<td>2,173</td>
<td>2,189</td>
<td>2,159</td>
</tr>
<tr>
<td>Horticulture</td>
<td>3,098</td>
<td>2,645</td>
<td>2,487</td>
</tr>
<tr>
<td>Cattle &amp; dairy farms</td>
<td>7,682</td>
<td>6,305</td>
<td>5,795</td>
</tr>
<tr>
<td>Pigs &amp; chicken</td>
<td>4,010</td>
<td>2,782</td>
<td>2,333</td>
</tr>
<tr>
<td>Others</td>
<td>2,640</td>
<td>1,967</td>
<td>1,747</td>
</tr>
<tr>
<td>Total</td>
<td>19,063</td>
<td>15,888</td>
<td>14,521</td>
</tr>
</tbody>
</table>

1. Sustainable development and scaling-up production

The agro-food complex will further develop emphasizing the need for sustainable production of food. Within this context agricultural and horticultural production sites will be part of food production chains that may spread around the globe. Because of global competition in these production chains there is a need for products with more value-added. The income generated by the sector will grow, even though the number of farmers involved may actually decrease.

2. Multifunctional agriculture and diversifying production

A growing number of farmers play an important role in the sustainable management of an attractive regional countryside. In Noord-Brabant the pressures on the natural environment and underground water resources are high. More land, especially near urban areas, will become available for extensive types of agricultural production. However, from the perspective of the farmer’s income...
the figures are not impressive. The economic perspective for multi-functional agriculture needs to improve. Financing mechanisms are not yet in place, but are needed urgently to safeguard a sustainable future and to provide proper payments for the green and blue services.

3. Stepping out
More farmers will quit farming; especially those who do not have a son or daughter ready to take over the family business. The land will be sold to farmers who will develop in the other 2 directions.

Methodology
The first direction of development has been en vogue during the last decades and will probably prosper over the next 10 years as well. But the second direction is new and stakes out an unknown territory, where the agriculture sector and society meet in different and novel ways (some 25% of the farms in Noord-Brabant generate additional income from multi-functional farming, this adds up to 5% of the total farming income in the province Noord-Brabant). In Noord-Brabant we explore this new territory in pilot projects and practical learning situations involving different actors. The Steering Committee for Agricultural Innovation actively supports experiments involving different social services, evaluating their impact on individual farmers and society. Examples of revenues for society may be preventing pollution, saving biodiversity, and the quality of the landscape; revenues for farmers may be the developing of robust farming systems with better yields and fewer costs for fertilizer, pesticides, et cetera. Three examples will be presented. In these pilot projects the contribution of change is quantified at the level of farmers, integrated farming systems, and society.

Results
Active buffer farming
A first generation of projects had 650 participating farmers and created 1,250 km of water buffer zones. Farmers are paid by water boards, provincial authorities, and national government (€0.10 - €0.50 per meter) because of their contribution to the quality of surface water (less pesticides and fertiliser). The second generation (period 2007-2012) will have more than 1,000 participating farmers and create 2,800 km of water buffer zones, contributing to biodiversity and landscape. Ten million euros is available to pay for the second generation, but the challenge is to generate structural funding for this type of activity after this pilot period.

Lifescape – Your landscape
A European funded project for interregional cooperation and societal learning (INTERREG-IIIB NWE), aimed at creating new relationships between people and organisations based on a common interest: maintaining and enhancing the beauty and identity of their regional landscape. LIFESCAPE combines “livelihood” and “landscape”, the individual benefits and the common good, in one concept. Regional identity and social networks, rather than regional borders, are taken as a frame of reference. A variety of twenty trans-national actions are implemented, concerned with business development, branding processes for regional produce, stakeholder involvement, education, and financial mechanisms. The focus is on regional pride, responsibility, and solidarity. Personal, social, and economic benefits are generated for the partners and regions involved.

Farmers and biodiversity
About 100 farmers (dairy and arable farms) are stimulated to incorporate a wide variety of cattle, crops, or soils in their farming system which will bring them additional benefits. Traditionally, farmers use only a few races of cattle and grow monocultures. This pilot is implemented in the period 2007-2010 and costs 2.4 million euros. It will also contribute towards the biodiversity of the regional landscape. Mutual gains are expected for farmers and for society at a regional level.

Conclusions
Different examples indicate the importance of experiments as an instrument for innovation. They help to explore sustainable food production chains, as well as the development of multifunctional agriculture practices. A more realistic view of revenues and costs, both for farmer and society, is the outcome of learning by doing. Furthermore we conclude that there still is a long way to go considering the economics of the development of a multifunctional agriculture.
Landscape as designed by farming systems: a challenge for landscape agronomists in Europe

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Summary:

As agronomists, we are concerned by the landscapes seen as a result of human decisions. So, landscape is for us human-made and the main driving forces of landscape design processes are farming systems. In this way, landscape is designed by the farming systems in a complex relationship with the land. Just like ecologists twenty years ago developed a trend of ecology focusing on landscape ecology, we propose to create a new trend in agronomic research: landscape agronomy.

The origin of landscape is very interesting for our purpose: The word landscape is from the Dutch word landschap, from land (land, patch, area) and the suffix -schap, corresponding to the English suffix "-ship". The Dutch word landschap had earlier meant simply "region, tract of land". Landscape, first recorded in 1598, was borrowed as a painters' term from Dutch during the 16th century, when Dutch artists were on the verge of becoming masters of the landscape genre. (http://www.answers.com/topic/landscape). As agronomists (Agro from 'agros'= field, -nomy from 'nomos'= system of rules, laws), we propose a new scientific object for agronomy: the landscapes, as cropping and farming systems have been for ages.

So, the main scientific tasks to consider within the perspective of landscape agronomy are:
- to identify the rules and laws within the landscape linking environmental processes and farming systems,
- to create and/or refine modelling approaches to build scenarios for partners “if you change … then landscape changes …”,
- to build bridges between agronomists, geographers and ecologists on a common scientific object: landscapes in the respect of our each “point de vue”. For us, as agronomists landscape is created by farmer practices in complex rural societies, and we have to describe and to model the driving forces of landscape changes.

In this paper, we develop two main topics: (i) examples of recent European agronomic studies on landscape design modelling and multi-purpose farming systems to illustrate how we can integrate the landscape perspective in agronomy, (ii) and consequently
which are some main challenges that arise for landscape agronomy. The chosen examples are:

- Agricultural intensification, landscape changes and runoff in Kraichgau (Germany),
- Landscape changes and runoff, in Rhin watershed-Central Europe and in Danube watershed (Germany),
- Land degradation due to the changes in the management of the hydraulic-agrarian system in Monte Pisano (Italy),
- Landscape changes and types of farming systems in the Vosges mountains (France),
- Management of farmyard manure in open field landscapes and groundwater pollution in Lorraine (France).

The main challenges landscape agronomy has to face are:

- The landscape is characterized by a large range of environmental issues (e.g. water resource management, biodiversity evolution, aesthetic value for settlement, etc.). Farming systems have the capacity to adapt the way the landscapes evolve to multi-purpose objectives which are not always equally important. So how do we take this constraints into account in landscape design modelling?
- In accord with Bateson works, we want to focus on the mutual relationship between land and farming practices: on one hand, the current state of the land is a result of farming practices and changes in landscapes could not be decided without farmers participation, but on the other hand, the choice and location of cropping and grassland systems by farmers all over the world takes into account their own land characteristics. How to model the complex relationships between land and cropping/farming systems in landscape design modelling?
- Landscapes are changing with diverse speeds, either with long lag periods or with rapid turnover. So, how can we manage these diverse change dynamics in our modelling processes?

To conclude, we think that landscape designing is a relevant concept for agronomists and can be useful:

- It will help research on agriculture/environment relations by providing types of land use that convey the farmer’s strategy, independently of year to year changes that characterise crop rotations; these types of land use are stable over several years and can be related, on one side to field characteristics and constraints, and on the other side to environmental effects.
- It will facilitate discussions between farmers and other actors of rural territories by setting a common language and allowing an objective description of agricultural land use types.
- The concept of landscape designing, by considering the middle-term strategy of the farmer, frees itself from the infinite diversity of actual crop successions and facilitates the comparison between fields similarly managed in different farms, and hence facilitates the extension of cropping system research to the territorial and multi-year scales, which are relevant to environmental questions.

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1 This is as well the role of landscape concept as proposed by the European landscape convention “to establish procedures for the participation of the general public, local and regional authorities, and other parties with an interest in the definition and implementation of the landscape policies”. It wishes “to provide a new instrument devoted exclusively to the protection, management and planning of all landscapes in Europe”
Session 1.6:
Integrated assessment of agricultural systems: environmental and socio-economic trade-offs, part II

Session Convenors:
John Antle, James Ascough and Jon Hanson
Introduction

There is a demand by policy decision makers in the United States and around the world for timely information to support policy decision making. Currently, policy decision makers in USDA and other federal agencies and Congress are seeking information regarding policies that could encourage alternative sources of energy, particularly to reduce dependence on oil, motivated by trade, national security and environmental concerns. A key element in this strategy appears to be biofuels, particularly the use of corn to produce ethanol to blend with or replace gasoline. There is also interest in the potential for alternative crops such as switchgrass which could be used for ethanol production and which would have a more positive impact on net greenhouse gas emissions than corn-based ethanol.

This paper uses a new minimum-data (MD) modeling approach to assess the economic potential for incorporation of switchgrass into farming systems in the northern plains region of the United States for biofuel production. The MD approach incorporates the mean and spatial variability in productivity and cost of production of management alternatives to simulate farmers’ willingness to adopt alternative management practices. The MD approach can also incorporate payments for the provision of ecosystem services such as carbon sequestration, enhancing wildlife habitat enhancement, or water quality protection. In this preliminary analysis, we use secondary data from USDA statistics and cost-of-production surveys for the wheat-based cropping system typical of the northern plains region, and incorporate switchgrass into the system. The analysis evaluates the potential adoption of switchgrass in relation to key economic and technical parameters including crop prices, the demand for switchgrass for biofuel production, the technical potential for carbon sequestration, and the price of carbon.

Methodology

The methodology is based on the minimum-data approach to the analysis of ecosystem services developed by Antle and Valdivia (2006). The analysis is based on the assumption that farmers’ choice between alternative practices can be based on the opportunity cost of changing practices and the net benefits obtained from ecosystem services provided. In contrast to conventional “representative farm” analysis, the opportunity cost of changing practices is assumed to be spatially variable. The key to the MD approach is the fact that under plausible assumptions, the spatial distribution of opportunity cost can be approximated with a small number of parameters that can be estimated with the kinds of data that are generally available from secondary sources. The spatial distribution is simulated by agro-ecozones to determine the proportion of land units that would switch from a baseline practice (e.g., wheat) to an alternative practice (e.g., switchgrass), given crop prices and the price for the ecosystem service being provided (e.g., soil carbon sequestration).

Results

In this preliminary analysis, data were obtained from existing sources to estimate the mean crop yields as well as yield variability (NASS, 2007; Berdahl et al. 2005; Vogel et al. 2005), and mean costs of production (Swenson and Haugen, 2006), for agro-ecozones in North Dakota. The rate of adoption of switchgrass was simulated as a function of the price of switchgrass, taking as given the price of wheat and the price that farmers could receive for sequestering soil carbon, receiving
credit for 0.33 MgC/ha/season. Figure 1 presents results of the analysis, showing switchgrass adoption curves over a range of zero to $40/ton, with each curve simulated assuming an alternative carbon price (zero, $50/MgC, and $100/MgC). These prices represent the payments farmers would need to receive at the farm gate. The figure shows that switchgrass adoption is likely to be highly sensitive to the price, and that a positive price for carbon sequestration also would substantially encourage conversion of wheat to switchgrass. While it is not clear what price would be paid for use of switchgrass for ethanol production, the U.S. department of energy has identified a target feedstock cost of $30 per dry ton delivered to a biorefinery (INEEL, 2003). With transportation costs from the farm of $5-15 per ton, this results in a farm-gate price of $15-25 per ton. Figure 1 shows that in that price range, the supply response would be highly elastic. Without payments for carbon, a $30 price would generate substantial switching out of grain production into switchgrass. At a lower price such as $20/ton, the willingness to produce switchgrass would be quite low without carbon credits, but would increase substantially in response to a positive carbon price, particularly if it were in the range of $50/MgC or higher (a price similar to what is being paid currently for carbon credits in the European Union, where the price is currently about $15 per metric ton of CO$_2$).

**Conclusions**

A minimum-data analysis of the potential adoption of switchgrass for biofuel production was carried out for the North Dakota wheat production system. The analysis shows a positive economic potential for adoption of switchgrass, however, this potential depends critically on the price of switchgrass as well as additional incentives that could be provided by a positive price for carbon sequestration associated with the change from wheat to switchgrass. Future research will extend the analysis by considering other production systems in the region, and by investigating in more detail issues such as the dynamics of the crop rotation systems.

**References**


North Dakota State University Extension Service, Fargo, ND.

UNTANGLING THE MULTI-DIMENSIONAL NATURE OF SUSTAINABILITY – A SIMULATION APPROACH
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Introduction
In the low-income countries of the West-Asia North-Africa (WANA) region, food demand is increasing at a high rate. Agriculturally productive soils and renewable water resources are scarce in the region; this scarcity is aggravated by human-induced degradation. The expansion of irrigated agriculture to boost crop yields and buffer the risks associated with highly variable rainfall has led to rapidly declining groundwater tables. Based on a goal-oriented concept of sustainability (von Wirén-Lehr 2001), the goals for crop production in WANA are to design productive and profitable cropping systems which substantially ease the pressure on groundwater resources and minimise soil degradation. Assessment of whether consequences of agricultural practices are to move towards or away from a sustainable state requires a dynamic approach enabling changes and trade-offs to be quantified. At the field scale, cropping systems simulation allows the prediction of likely effects of alternative management practices on diagnostic variables (i.e. sustainability indicators). In this study, the Agricultural Production Systems Simulator (APSIM) (Keating et al. 2003) was applied to assess the sustainability of three alternative tillage practices in a wheat-chickpea rotation in a semi-arid environment of Syria. Two of the three tillage systems are operational in WANA: the first system, conventional tillage, includes deep ploughing; the second includes burning of wheat stubble prior to conventional tillage. The third strategy, no-tillage, is not operational in WANA. The sustainability indicators for the above mentioned goals were crop yield, water use efficiency (WUE; grain yield per unit evapotranspiration from sowing to harvest), percentage soil organic matter (SOM), and the gross revenue (GR) from grain and straw sales.

Methodology
Simulations with APSIM v4.2 were run for each season in the historical weather record (1979-2005) for a clay soil (256 mm plant available water) at Tel Hadya (340 mm rainfall), Syria. Details on the model parameterisation and testing are given in Moeller et al. (2007). Scenario simulations included five N fertiliser rates applied to wheat (0 to 100 kg N/ha), and three tillage systems (Table 1) in a wheat-chickpea rotation. Wheat was sown between 1-25 November and chickpea between 1-20 December, with sowing being triggered by adequate moisture in the seedling layer. With conventional (CT) and burn-conventional (BCT) tillage, surface residues were incorporated at 25 cm and 10 cm depth during primary and secondary tillage, respectively. Straw residues remained on the soil surface in the no-tillage system (NT). With BCT, all straw residues were removed from the soil surface after the harvest of wheat (i.e. “burned”).

Table 1. Specification of the residue management in the three simulated tillage systems.

<table>
<thead>
<tr>
<th>Tillage system</th>
<th>Residues removed at harvest of</th>
<th>Residues incorporated during</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>wheat</td>
<td>chickpea</td>
</tr>
<tr>
<td>Conventional</td>
<td>75%</td>
<td>50%</td>
</tr>
<tr>
<td>Burn-conventional</td>
<td>100%</td>
<td>50%</td>
</tr>
<tr>
<td>No-tillage</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Results
In the simulations, NT outperformed both CT and BCT in all sustainability indicators (Figure 1). This was a consequence of greater water availability due to reduced soil evaporation with residue retention. On 1-November, the average increase of surface residues with NT compared to CT was 3.7 to 10 t/ha at 0 to 100 kg N/ha applied to wheat (not shown). The consequent average reduction in soil evaporation from sowing to crop harvest ranged from 50 to 120 mm. The revenue gains related to soil water conservation with NT were higher than the losses incurred from not selling the
straw. At a N rate of 50 kg/ha, the total average revenue was EUR 168.- higher with NT compared to CT, while the losses from not selling the straw would have been EUR 94.- (Table 2).

Figure 1. Indicator values (broken line) with (a) burn-conventional tillage and (b) no-tillage relative to conventional tillage (set 100%) in a wheat (W) – chickpea (CP) rotation: average yield, water use efficiency (WUE), and gross revenue (GR); difference in soil organic matter (SOM) between the end and the start of the rotation. Wheat received 50 kg N/ha in all three management systems.

Stubble burning after wheat (BCT) reduced the total average revenue of wheat by EUR 40.- (fertiliser rate: 0 kg N/ha) to EUR 120.- (fertiliser rate: 100 kg N/ha) compared to CT because there was no revenue from straw sales. The average yield and WUE of wheat and chickpea were similar in the CT and BCT system (Table 2) indicating that stubble burning had only a small effect on crop productivity. In terms of SOM, only in the unfertilised BCT treatment SOM in 0-30 cm depth was simulated to decline by 0.02% over 25 seasons. In general, SOM increased with the amount of applied N fertiliser and the retained straw residues. Over the simulated timeframe, the increase in SOM was highest in the NT system with 100 kg N/ha applied to wheat (0.39% in 0-30 cm depth).

Table 2. Simulated average grain yield, water use efficiency (WUE), and gross revenue (GR) from grain and straw sales of wheat and chickpea grown in rotation at Tel Hadya. Results are presented for three tillage systems: conventional tillage (CT), burn-conventional tillage (BCT), and no-tillage (NT). Wheat received 50 kg N/ha in all systems. The standard deviation is given in parentheses.

<table>
<thead>
<tr>
<th></th>
<th>Wheat</th>
<th>Chickpea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CT</td>
<td>BCT</td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td>1.86  (1.04)</td>
<td>1.87  (1.04)</td>
</tr>
<tr>
<td>WUE (kg/ha.mm)</td>
<td>6.1   (2.9)</td>
<td>6.1   (2.9)</td>
</tr>
<tr>
<td>GR grain (EUR)</td>
<td>470   (263)</td>
<td>475   (264)</td>
</tr>
<tr>
<td>GR straw (EUR)</td>
<td>94    (35)</td>
<td>0</td>
</tr>
</tbody>
</table>

**Conclusions**

APSIM was capable of quantifying the likely long-term effects of alternative tillage practices on the sustainability of a wheat-chickpea rotation at Tel Hadya. The simulation results indicated that no-tillage has the potential to address important sustainability goals in the WANA region; chiefly to increase productivity and preserve the agricultural resource base. No-tillage outperformed conventional tillage in all simulated indicators, despite a trade-off between stubble retention for soil water conservation and stubble removal for acquiring additional revenue from straw sales. The sustainability of the system was reduced when wheat stubble was burned. However, the capabilities of the model predefine the choice of the sustainability indicators. Weeds, pests and diseases, for example, are not simulated. Their effective management will be critical for any ecological and economic benefits from no-tillage to be realised at the study site.

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THE GREEN REVOLUTION AND THE WATER CRISIS IN INDIA:  
AN ECONOMIC ANALYSIS  

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Introduction

India has attracted world attention recently as economic expansion began accelerating by producing superior IT engineers. According to media reports, however, India's agriculture sector is suffering from grave woes. Thanks to the green revolution (GR), the degree of self-sufficiency in food is 100% in India, which helps prevent starvation. GR implies an innovation in agriculture, e.g., the invention of new seedlings for crops such as wheat or rice. With huge population numbers, it was feared during 1960’s and 70’s that India might suffer from starvation due to food shortage. In spite of this great achievement, the farmers do not appear to have the benefit of GR in India. This paper conducts an economic analysis on GR, with a focus on its effect on profit. Particularly, GR is examined in terms of general equilibrium theory to determine if GR always makes it possible for the users of this innovation to obtain greater profit.

Methodology

This paper is based on comparative statics in the general equilibrium theory. Traditionally, assuming both producers and consumers, the theory computes market prices from the interaction between them. GR implies the modification of the production structure (parameters in the production function) which causes variation of the farmer’s profit. When the computation of market prices is difficult, the simulation approach is adopted by specifying the parameters in production and utility functions. Nash type non-cooperative game theory is also adopted in examining the interaction between the farmers.

Results

First, the Basic Model is constructed. As for the supply side, it is assumed that the two identical competitive firms (farmers) aiming at profit maximization produce rice, utilizing labor and water. Their identical production function is assumed as the Cobb-Douglas type, which is called a Type I production function (where water input is fixed). As for the demand side, suppose that there is one (aggregate) household and it maximizes utility under income constraint. This household consumes rice, providing labor. The utility function is also assumed as the Cobb-Douglas type. Two firms are owned by the (aggregate) household. From the equilibrium conditions on the commodity (rice) market and labor market, the general equilibrium rice price is actually computed with the wage rate fixed as one. When an innovation such as GR emerges, the production function shifts upward. The effect of this shift is the reduction of the rice price with increased rice production. The final result of the production function shift is the constancy of the profit. Thus, GR has no effect on the profit in the case of Cobb-Douglas type. It is shown that the utility level rises when GR emerges.

Next, a somewhat sophisticated aspect is introduced into the Basic Model. In the Basic Model, it is implicitly assumed that the availability of a seedling is fixed. In the actual world, a profit-maximizing firm would provide the seedling, especially when the new seedling is invented by crossbreeding. While farmers can change the amount of seedling input, the seedling itself must be purchased. It is assumed that the household possesses the seedling producing firm. In this section, parameters on the production and utility functions are specified in computing equilibrium rice and seedling prices. The conclusion of the production function shift is almost the same as the one listed above: the farmers' profit is independent of GR, while the utility level of the (aggregate) household rises.

The production function is then replaced by the CES (constant elasticity of substitution between seedling and labor) type. We examine the CES type with negative elasticity, which is called the Type II production function. The conclusion of the production function shift is different from the one above
where the farmers’ profit rises when GR emerges, while the utility level of the (aggregate) household rises. We also examine the CES type with positive elasticity, which is called the Type III production function. It can be ascertained that general equilibrium exists and is stable in the Type III case. The conclusion of the production function shift is different from the one where the farmers’ profit falls when GR emerges, while the utility level of the (aggregate) household rises.

Finally, we return to the Basic Model, where the seedling producing firm is out of consideration and water input is not constant. According to NHK, a Japanese media source, excessive well construction leads to dried wells which cause the loss of farms. As is well known, water input is crucial for GR. In this example, two farmers are regarded as game players in a Nash non-cooperative game with the same strategy sets where strategies for the $i^{th}$ farmer are the present water input, $w_p^i$, and the expanded water input, $w_e^i$, $(i=1,2)$. The pay-off in this game for the two players are profits.

Type I production function case: By specifying the parameters, the pay-off matrix for the two farmers is computed below. The solution of the Nash game is $\{w_e^1, w_e^2\}$. By expanding the water input the players have the same profit; however, this solution may lead to dried wells when the water resource is limited.

<table>
<thead>
<tr>
<th>farm 1</th>
<th>farm 2</th>
<th>$w_p^2$</th>
<th>$w_e^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_p^1$</td>
<td>{3, 3}</td>
<td>{1.90208, 4.09792}</td>
<td></td>
</tr>
<tr>
<td>$w_e^1$</td>
<td>{4.09792, 1.90208}</td>
<td>{3, 3}</td>
<td></td>
</tr>
</tbody>
</table>

Type II production function case: The solution of the Nash game is $\{w_e^1, w_e^2\}$. By expanding the water input the players have the greater profit, thus, the farmers are better off. This solution, however, may lead to dried wells.

<table>
<thead>
<tr>
<th>farm 1</th>
<th>farm 2</th>
<th>$w_p^2$</th>
<th>$w_e^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_p^1$</td>
<td>{3, 3}</td>
<td>{2.13949, 5.47744}</td>
<td></td>
</tr>
<tr>
<td>$w_e^1$</td>
<td>{5.47744, 2.13949}</td>
<td>{4.24951, 4.24951}</td>
<td></td>
</tr>
</tbody>
</table>

Type III production function case: The solution of the Nash game is $\{w_e^1, w_e^2\}$. By expanding the water input the players have smaller profit and this solution may lead to dried wells. Furthermore, this is the prisoners’ dilemma solution.

<table>
<thead>
<tr>
<th>farm 1</th>
<th>farm 2</th>
<th>$w_p^2$</th>
<th>$w_e^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_p^1$</td>
<td>{3, 3}</td>
<td>{1.77001, 3.30651}</td>
<td></td>
</tr>
<tr>
<td>$w_e^1$</td>
<td>{3.30651, 1.77001}</td>
<td>{2.32051, 2.32051}</td>
<td></td>
</tr>
</tbody>
</table>

Thus, independently of the assumptions on the production functions, the farmer’s plan is to expand the water input, which may lead to the dried wells when the water resource is scarce.

**Conclusions**

From the above examination, we may conclude that theoretically GR cannot always guarantee the greater profit for the farmers, while it always makes consumers better off. Furthermore, it was shown that theoretically GR leads to the excessive utilization of a scarce resource through Nash-type game playing. In addition, the dried wells may lead to increased monopolization by wealthy farmers.

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NHK, Water Crisis (Part 2), 2006, August 27.
TOWARDS THE EFFECTIVE REPRESENTATION OF FARMER ADAPTATION TO
CLIMATE CHANGE

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Introduction

Farm and catchment level models are often used to address questions relating to the impact of climate change on agriculture. We believe that, following the approach of Lambin et al. (2000), models should be spatially-explicit, integrated and multi-scale. While the term multi-scale is usually used in the sense of spatially multi-scale, we further emphasise that models need to be temporally multi-scale. Also largely neglected in previous approaches are temporal dynamics and explicit consideration of farmer decision making – particularly in multi-scale models, where investment in farm resources subsequently affects future decision making.

Any agricultural model or modelling framework should therefore take account of the following points.

1. Farms are the level at which management decisions are made;
2. Farmers make decisions using information available to them;
3. Adaptation is not always instant, it may be gradual, there are degrees of adaptation and previous adaptations will influence what the farmer does currently;
4. Some farm-level investment decisions are costly and provide a flow of resources over multiple years (e.g. building a reservoir);
5. At the catchment- or regional-level there may be interactions among farms (e.g. renting land);
6. Different farmers will make different decisions using the same available data;
7. An average farm will not sufficiently represent the diversity among farms; and
8. Mean outcome, driven by mean inputs, will not sufficiently represent the diversity of possible outcomes.

We outline a modelling approach that addresses these points.

Methodology

We have implemented a model framework that runs a group of farms simultaneously, sequentially and continuously over a period where climate change occurs. Each farm is represented by a separate MIP (mixed integer programming) problem based on an existing model, Farm-adapt (Ramsden et al. 1999; Gibbons et al. 2006). The individual farm models are integrated into a larger model running on a yearly time-step. At each step there is: i) a planning stage, representing farmer decision making for that year and ii) a resolution stage where discrepancies between the farm plan and actual outcomes are addressed (e.g. planning to apply more irrigation water than is available). Farmer decision making is a function of crop yields and irrigation availability in previous years. Decisions for the next year are constrained by the actual outcome from the previous year's resolution stage. Investment decisions carry over to subsequent years.

We illustrate the model with 29 farms in the Nar catchment in the east of England for over 93 years (1987-2079) for three periods of climate i) baseline, ii) 2020’s, and iii) 2050’s. The catchment is of interest because of predicted increases in irrigation demand and patchy distribution of abstraction licenses. For each climate period, 50 years of synthetic crop yields were generated using the UKCIP (Hulme et al. 2002) climate scenarios and the ACCESS-II crop model. Sampling from these data was used to construct 100 93-year sequences for model runs. Running the model over each
of these sequences allowed estimation of the uncertainty of outcomes. For the example farmer, expected yields were the mean of the yields for the previous four years. The example emphasises availability and utilisation of irrigation water with two irrigated crops, potatoes and sugar beet. Sub-optimal irrigation of these crops is modelled to simulate irrigation shortfall. Available adaptations are changes in crop area and investment in reservoir capacity. We examine the effect on catchment level abstraction by allowing the farms to trade abstraction licenses. By examining the range of possible outcomes over the 100 sequences, we also explore the likelihood of the adoption of an exotic crop, sunflowers.

Results

Modelled mean crop yields for the non-irrigated crops increased from the baseline to the 2020’s and from the 2020’s to the 2050’s. For the irrigated crops, with full irrigation, yields also increased. However, irrigation demand also increased and sub-optimally irrigated yields declined. Farmer expected yields varied more between sequences than the actual yields. For the Nar catchment example, allowing trading of abstraction license substantially increased abstraction at the catchment level in the 2020 (an increase of 10% of total abstraction capacity) and 2050 (21%) periods. Hence, farm-level constraints (distribution of abstraction licenses) limit adaptation at the catchment level and modelling the catchment without farm-level constraints would have over-estimated adaptation. Under the model assumptions, longer term investment in winter abstraction capacity (reservoirs) was not justified. Due to their high value, irrigation levels were maintained on potatoes, resulting in relatively stable crop areas over time; in contrast, the lower value sugar beet yields and areas were more variable due to their dependence on surplus water availability. Even in the driest sequences modelled there was no major shift from native cropping to exotic crops (oilseed rape to sunflowers) in either the 2020’s or 2050’s.

Conclusions

Farmer decision making and farm structure constrain adaptation to climate change at the regional level. If these constraints are not incorporated into models that estimate climate change impacts adaptations are likely to be over-estimated and impacts are likely to be underestimated. In addition, temporal and spatial variability and uncertainties make predictions of climate change impacts and adaptation uncertain. We have presented a modelling framework that includes farm structure, models farmer decision making and explicitly includes variability and uncertainty. This framework improves understanding of the important components of adaptation at the catchment level. While the results presented are specific to a single catchment the framework can easily be adapted to model other land use problems at the regional scale; or to incorporate other sources of uncertainty such as variability in output prices.

References

Lambin, E.F. et al., 2000. Are agricultural land-use models able to predict changes in land-use intensity? Agriculture, Ecosystems & Environment 82, 321-331.
EXPLORING THE ENVIRONMENTAL CONSEQUENCES OF STRUCTURAL CHANGE IN AGRICULTURE

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Introduction

In many parts of Europe, financial and social pressures are leading to rapid changes in the structure of agricultural production. In general, farms are becoming larger and more specialized. This has important consequences for local employment and the rural economy but has also consequences for the environment. Within a region, the changing structure of agricultural production can lead to an overall increase or decrease in the environmental impact of agriculture. This impact depends not only on the overall change in pressure but also on the changes in the spatial distribution of that pressure. For example, fertilizer use might decrease at a regional scale but increase locally. If the location of the local increase coincided with a nutrient-sensitive ecosystem, the environmental impact might still increase. In this paper, we will show how two models can be linked to explore the interaction between the dynamics of structural change and environmental impact. Here we apply the approach to an artificial region where farm and production structure were based on a 112,000 ha area in the river basin Gudenaa in Denmark.

Methodology

AgriPoliS simulates the dynamics of farm structure change at the regional scale. The model is spatially-explicit and describes the dynamic adjustment processes and interactions between many different farms within the regional (Happe et al. 2006, Happe 2004). AgriPoliS maps the key components of regional agricultural structures: heterogeneous farm enterprises and households, space, factor and product markets. These are embedded in the technical and political environment. Individual farms adapt to changing conditions on markets and to policy changes by adjusting their production mix, investment, disinvestment, growing or downsizing, part-time farming, or by leaving the sector. At each time step, each farm agent maximizes farm income. Farm agents are individualized e.g. with respect to production costs, location, age, and the vintage of assets. Technical coefficients and gross margins of production activities are based on standard indicator sets. The model produces results on economic indicators, production, and investment for each individual farm at each time step.

FARM-N is a static model of the flows of nitrogen on farms that has been developed to assist farmers, farm advisors and environmental regulators assess how farm structure and management affect the losses of nitrogen to the environment. The model takes as input the structural and production variables of the farm. The structural variables include the number of different types of livestock, the cropped area and soil type. The management variables include the previous management, the livestock’s feed ration, how the manure is managed (e.g. slurry or farmyard manure), the cropping regime and the plant-available nitrogen applied to each crop. In addition, the model requires parameters relating to the crop and animal production e.g. the yield and protein content of the crops and the growth rate of the animals. Further details of the model can be found elsewhere in the proceedings of this conference.

Both models use a parameterization suitable for Denmark. Importantly, this includes a restriction on the maximum application of animal manure per unit area land, to comply with the EU Nitrates Directive. It was assumed that the manure was exported from the region. The inputs taken from the AgriPoliS model were the previous farm management, the number and type of livestock, the crop plantings and the soil type. The nitrogen losses were simulated with FARM-N separately for each simulation year.
The scenarios examined are shown in Table 1.

Table 1. Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) REF</td>
<td>- successive implementation of 2003 CAP reform</td>
</tr>
<tr>
<td></td>
<td>- additional agri-environmental payment for extensive grazing lands (50 €/ha)</td>
</tr>
<tr>
<td></td>
<td>- stocking density limit: 2 LU/ha (LU = livestock units, 1LU is about 1 cow)</td>
</tr>
<tr>
<td>(2) LU-reduce</td>
<td>- like REF</td>
</tr>
<tr>
<td></td>
<td>- reduction of stocking density to 1 LU/ha</td>
</tr>
<tr>
<td>(3) AEP</td>
<td>- like REF</td>
</tr>
<tr>
<td></td>
<td>- additional agri-environmental payment for extensive grazing lands (250 €/ha)</td>
</tr>
</tbody>
</table>

The measures were introduced four years before the decoupling of agricultural area payments.

Results

The results show that in the REF and AEP scenarios, there is a decline in the livestock within the region (Fig. 1). In the AEP scenario, support payments maintain livestock numbers. The nitrogen (N) surplus (N imported to the region minus N exported) is an indicator of environmental pollution. In the REF and 1LU scenarios, the N surplus shadow the fall in livestock numbers, whereas there is also a fall in the AEP scenario, despite the fairly static livestock numbers (Fig. 2). This was because the FARM-N model obliged farms with more than 2 LU ha\(^{-1}\) to export manure from the farm. Where this manure to be used within the region, the losses of N would have been greater, especially from the AEP scenario.

Conclusions

It is feasible and worthwhile to link a farm structure dynamics model to a nutrient flow model. The dynamics of agricultural structure appear to have an important influence on the magnitude and type of nitrogen loss. The export of manure from the region masked some of the effects of the structural dynamics on N losses and the effect varied between scenarios. If this approach is to be used for scenario investigations, there is a need to account for the transfer of nutrients between farms.

References


STAKEHOLDER PAYOFF MATRIX FOR DISPARATE TRADEOFFS

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Introduction

One of the most difficult tasks decision makers face is to compare across disparate objectives. Evaluating environmental and economic tradeoffs is perhaps the most contentious of all decisions. Decision makers have to make comparisons with incomplete information and with nebulous value systems. The objective of this paper is to introduce a stakeholder payoff matrix (SPM) that can incorporate information about multiple and diverse attributes for given management decisions. We also discuss several methods that utilize the SPM information to help make decisions.

Methodology

We adapt a payoff matrix approach from financial risk to develop a comparable framework for disparate tradeoffs and call it the Stakeholder Payoff Matrix (SPM). The traditional payoff matrix utilizes a probability function for management alternatives to represent multiple pieces of information at one time for each system (e.g., mean, variance, standard deviation). This allows a decision maker to choose one system over another based on multiple attributes. For example, an agricultural producer might choose a system that minimizes the risk of groundwater contamination, while at the same time assuring that any system chosen has a positive probability of making money (this criterion is called safety first). There have been many types of decision rules developed for payoff matrices over the years (e.g., minimax regret and maximin strategies) to address the many different ways there are to value tradeoffs. In this paper we develop the SPM that uses similar features from the payoff matrix. We first demonstrate the ability of the matrix to incorporate multiple attributes, such as economic, social, and environmental. We then discuss the adaptation of several financial decision rules to facilitate comparing these attributes. Finally, we demonstrate the SPM with an example of agricultural production systems through the creation of a vector of economic and environmental outcomes (e.g., surface runoff, nitrate in surface runoff, and soil erosion).

Results

The SPM is highly flexible, and presents opportunities for many types of decision rules. By placing the outcomes of the scenarios (actions) side by side, the matrix approach permits the use of a simple index (or complex indices) as decision criterion and also provides an opportunity to incorporate information across actions in the decision rules. For expository purposes, we compare profit and two environmental outcomes for four tillage systems. For soil erosion, the target can be related to a sustainability criterion of 8 metric t/ha, as suggested by Adriaanse (1993). This target is a proxy for the maximum level of sustainable soil erosion. For nitrogen in groundwater, a maximum concentration level (mcl) of 10 ppm (the U.S. standard for health safety) is used. Normalizing the variables allows cross-column comparisons since the variables are expressed in different units. In order to solve this problem, each variable is expressed in terms of EPeq. A target value (or standard) is used to normalize each variable as follows:

\[ \text{EPeq}_{\text{Variables}} = \frac{\text{Impact (units)}}{\text{Target (units)}} \]  

[1]
The pressure value calculated for sediment yield, for example, using the conventional management practice is:

\[
\text{EPeq}_{\text{SY Conventional}} = \frac{4.72 \text{ (t/ha)}}{8 \text{ (t/ha)}} = 0.59
\]  

Converting all pressure variables into EPeq’s results in SPM presented in Table 1.

Table 1. Stakeholder payoff matrix for selected agricultural management practices.

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment Yield</td>
<td>0.59</td>
<td>0.42</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>Profit</td>
<td>5.64</td>
<td>4.12</td>
<td>2.14</td>
<td>1</td>
</tr>
<tr>
<td>Nitrogen Leaching</td>
<td>0.96</td>
<td>0.71</td>
<td>0.87</td>
<td>2.61</td>
</tr>
<tr>
<td>Simple Average</td>
<td>2.40</td>
<td>1.75</td>
<td>1.03</td>
<td>1.21</td>
</tr>
<tr>
<td>Expected Value (^a)</td>
<td>1.16</td>
<td>0.84</td>
<td>0.44</td>
<td>0.63</td>
</tr>
<tr>
<td>Maximax Value</td>
<td>0.59</td>
<td>0.42</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>Maximum Regret – SY</td>
<td>0.58</td>
<td>0.41</td>
<td>0.08</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Regret – RO</td>
<td>4.64</td>
<td>3.12</td>
<td>1.14</td>
<td>0</td>
</tr>
<tr>
<td>Maximum Regret – NLG</td>
<td>0.25</td>
<td>0</td>
<td>0.16</td>
<td>1.90</td>
</tr>
<tr>
<td>Regret Index</td>
<td>5.74</td>
<td>3.53</td>
<td>1.38</td>
<td>1.90</td>
</tr>
</tbody>
</table>

Source: Adapted from Hoag and Ascough (2002)

\(^a\) Assume that probabilities are the following: SY=0.70, RO=0.10, and NLG=0.20.

Conclusions

The result of this research is a tool that allows economic and environmental tradeoffs to be incorporated into a single place that can be adapted to different situations, and thus be used in a variety of contexts while remaining simple to understand. The matrix is flexible and facilitates a variety of methods to compare complex, multifaceted systems. This flexibility provides freedom to accommodate disparate value systems across different decision makers.

References


USING COLLABORATION TO IMPLEMENT AN ECO-FRIENDLY CHANGE IN AGRICULTURAL POLICY

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Introduction

Collaboration and adaptive management practices have emerged in several policy fields as methods to deal with intractable, complex and wicked problems. In many Federal agencies responsible for natural resource policy in the United States, these practices have turned orthodox policy on its head. No longer is policy focused primarily on extraction and arguably the interests of the businesses that do the extracting. Instead, collaboration has offered stakeholders a voice in determining policy and in determining how various economic, social and environmental interests are balanced and adaptive management has helped increase technical knowledge and improved problem management.

In this paper, I am proposing that U.S. Federal agricultural policy abandon its use of production subsidies and government payments aimed at keeping farmers in business no matter the negative externalities. Instead, I suggest that U.S. policy embrace collaborative management and adaptive management, and focus on achieving a maximum sustainable productive capacity (MSPC) subject to other policy goals determined collaboratively. Existing policy has had deleterious effects on the environment and the soils, while driving down production capacity. A policy aimed at MSPC, could drastically improve environmental quality and ecosystem integrity by altering technology choices and reducing certain chemical and fertilizer use and concomitantly the non-point pollution. Government payments would shift from production subsidies and historical awards to incentives and disincentives, possibly including "green box" payments to achieve a new slate of goals.

This paper offers a prospective case study examining how collaboration and adaptive management could be implemented to manage peanut farms in the Mid-Atlantic region in the United States that have historically sought profit from the production of the Virginia-type peanut and until recently were guided in their decisions by mandated quotas.

Methodology

In order to fully implement the policy proposal, this paper suggests the use of distributional simulated active and interactive models to allow for the kind of continual collaboration and adaptive management that would be required. By active I am implying that the models should be constantly updateable and adaptable. By interactive, I am implying that at least at a readable level, the models should be accessible to all stakeholders, including congressional lawmakers, USDA officials, agronomists, extension agents, agricultural economists and interested citizen councils or groups. In an abstract sense these aspects could be viewed as creating and maintaining a Virtual Room for the collaborating of multiple stakeholders.

A linear-programming sector model template for peanut farmers in four sub-regions (North Carolina high, medium and low yield and Virginia) of the Mid-Atlantic region of the United States is delineated with the current policy of marketing loans, fixed decoupled payments and counter-cyclical payments set as the initial policy condition. The model first determines an initial soil quality and productive capacity from USDA data for the four specific sub-regions in the mid-Atlantic and then simulates crop rotations and technology choices historically chosen by farmers, as well as those suggested from consultations with agronomists, extension agents and economists. Farmers have historically planted peanuts in a 3-year rotation, while a four-year rotation has been suggested as a means to perhaps reduce chemical and fertilizer use while increasing yields.
Prices for alternate crops are taken from FAPRI predictions and strategy success is determined relative to a range of world prices for peanuts. The model is easily extendable to various sub-models as well as a comprehensive complete model.

Results

The expected world prices for Virginia-type peanuts are expected to hover between $ .20 and $ .22 a pound. Given the traditional 3-year rotation, until the price reaches $ .22, there is no supply of peanuts offered in the Mid-Atlantic. At $ .22, only the high-yield region in North Carolina will produce and a price of $ .24 a pound is required for the entire Mid-Atlantic region to meet domestic demand. At that price it is the Virginia region that comes into production, but at the low level of only 4,700 acres.

With a proposed 4-year rotation, higher yields and lower costs enable full domestic demand to be met by supply at just $ .20 a pound. Or in other words, at a price just above the guaranteed price for historic producers ($355 + $36= $391 a ton, .20= $ 400 a ton). All production is met by the same two regions, with most production done in the high-yield region of North Carolina. However, production is significantly higher in Virginia and actually at higher prices, lower in North Carolina. This is because the 4-year rotations lessen the amount of production that the high-yield region can produce per year. The interesting result is that the 4-year rotation is the dominant strategy for both regions (in fact it was for all regions, despite the inability for the other regions to enter into the production). Despite the lower production, the high-yield region of North Carolina generates a higher profit at all prices. And that outcome, allows Virginia to produce a significantly higher amount of peanuts with an equally significantly greater profit generation.

Conclusions

Current U.S. agricultural policy focuses on production associated payments which have led to reduced soil quality and have been brought into legal question by the WTO. The results from the model indicated that extending and altering the crop rotations would lead to much higher yields, lower input requirements and costs, and reduced non-point pollutant discharges while also leading to more economically viable and competitive farmland. Through collaboration and adaptive management, this model shows how productive capacity could be increased and optimized subject to this and other policy goals, including those that have social and environmental value. Additionally, policy payments could easily be flipped into incentive or disincentive payments that would be aimed at achieving sustainable productive capacity and or as “green” box payments aimed at improving environmental quality, both of which would be compatible with WTO rules.

References

ROLE FOR MODELS IN DECISION MAKING FOR COMPLEX NATURAL RESOURCE PROBLEMS - THE CASE OF DRYLAND SALINITY IN AUSTRALIA


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Introduction

Salinisation of agricultural land and waterways is a significant natural resource management issue in Australia. As a result of clearing native vegetation, groundwater tables have risen, mobilising the salt and causing adverse impacts to farmland, infrastructure, water resources, and biodiversity. The national and state governments have committed considerable public funds to assist farmers with efforts to recover, contain and adapt to land salinity, and to minimise salt loads in waterways. As land use change occurs at the farm business level (even though impacts on salinity may occur beyond the farm boundary) dealing with tradeoffs between impact on salinity and farm profit are required.

Scientists have developed and applied models of various forms to predict future impacts of salinity and explore management scenarios to mitigate the impacts. While simulation models have been successfully used to analyse farm management issues at field and farm scale, the biophysical nature of salinity can be difficult to understand and predict and requires a range of approaches. In this paper we present a range of approaches for the use of models in dealing with dryland salinity with farmers and highlight what we believe to be some key principles for their effective use.

The appropriate use of models to analyse and suggest management responses to salinity depends whether it is viewed as a complicated or complex system. It is our view that scientists have traditionally treated salinity as a complicated system, and this has resulted in deterministic modelling spurred on by the demand for predictions of future impacts of salinity. In practice this has involved ‘one-off’ applications of dynamic catchment-scale water balance models linking vegetation to surface and groundwater hydrology. That is, applying models that are demanding to parameterise, opaque to interpretation and subject to considerable uncertainty as a ‘one-off’ - often without learning from local landholder knowledge and not part of an ongoing adaptive cycle of catchment monitoring, verification, review, and revision. The use of a catchment-scale "top-down" approach has also meant that predictions and management scenarios bear little relevance to farm management. With the need for "bottom-up" approaches comes the requirement for models to deal credibly with farm production matters and hence input from agronomists. Our reflections in this paper arise from experiences in two contrasting catchments where we have been developing and applying models to analyse and arrive at suggested management actions for farmers to respond to salinity.

Methodology

In one case study, located in the central wheatbelt of Western Australia (WA), land salinity affects 6% of a 44,000 ha catchment with a forecast that 15-20% may be eventually affected. Most outbreaks and on-going areas of salinity are small enough to manage and potentially control through management actions under direct control of the farm manager. The benefits generally only accrue to the farmer concerned; there are few public benefits. This is due to the highly localised nature of groundwater flow systems (mostly <100 ha). Farmers require knowledge of where to locate intervention for maximum impact: to reduce recharge primarily through planting of deep rooted perennial plants, abstract groundwater before it discharges, or increase the rate of groundwater discharge through deep rooted perennial plants or engineering works to remove groundwater.

In the second case study, located in southern New South Wales (NSW), salinity does not affect agricultural land but stream water quality, and this is a major concern for the local catchment management body. Land use change, to reduce recharge of water to groundwater, through the
planting of high water use vegetation is required. This will come at a cost to farmers, hence the challenge for research is to define where to plant what for maximum impact and what monetary incentives will be required to offset economic losses incurred by farmers implementing land use change.

Results

In the WA case study, as there are no externalities we have used a site-based rather than catchment-scale approach. Agronomic implications of land use change are less important because the main aim is to prevent land being completely lost to production. The main role for models is to assist with knowledge of where to locate an intervention (that reduces recharge), quantitative estimates of “when” and “how much” are secondary to “where”. Detailed knowledge of field-scale groundwater flow systems are required if dynamic hydrological simulation models are to be used in this situation, generating such data is beyond the resources available. A more practical approach is to use a set of heuristics that relies on hydro-geological interpretation the at field scale. The heuristics rely on the use of observable geological features and this means that farmers can be involved in applying the method themselves. Where a valuable asset (e.g. iconic nature reserve) is under threat and justifies expensive intervention (e.g. groundwater pumping) then dynamic hydrological modelling is needed to quantify “where” and “how much” to gain maximum impact. In this case site investigation is required to derive parameters to drive a hydrological model.

To meet the research challenge for the southern NSW case study a requirement is knowledge of how the surface groundwater hydrologic processes connect with salt stores and deliver salt to the streams. Also necessary is agricultural production modelling able to deal with relationship between land management change, impact on groundwater recharge and profitability. Thus the analysis needs to be able connect specific and practical management options available at the farm scale, through to a catchment water quality (and quantity) impact. The methodology uses hydrological and soil information from regional surveys, economic and land use information, and the APSIM farming systems simulator is used to model plant production and the water balance predictions for land use and land management options. APSIM is then used within a catchment hydrological framework (FLUSH; Paydar and Gallant, 2003) to enable calculation of lateral flows of surface water through the catchment, and used an input into a simple groundwater water and salt flux calculator. Finally, a bio-economic model integrates this information to calculate minimum-cost changes in land use to attain a range of specified targets.

In both case studies the methodology is being applied participatively with local landholders who are involved in providing economic and land use information, defining scenarios to be investigated, contributing to the description and prediction of hydrological processes in their catchment (based on their local observation and monitoring), providing feedback on predictions, and contributing to the overall assessment of alternative land use and land management scenarios that have been analysed.

Conclusions

These two situations highlight that, for a natural resource management issue such as salinity, knowing where in a catchment to target management interventions is crucial. Models have a key role where specific estimates of timing and magnitude of the impact of salinity management interventions is needed, and where the economic consequences of alternative salinity management approaches require analysis. Modelling within an adaptive framework and utilizing the knowledge and experience of local landholders can enhance both the accuracy and the relevance of modelling to support management of dryland salinity.

References

ECONOMIC ANALYSIS OF COMPLEX INTERACTION IN CROPPING SYSTEM AND ALLIED ENTERPRISE OF FARMING SYSTEMS TO AUGMENT MORE INCOME

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Introduction

Farming systems represent integration of various farm enterprises in a farm to ensure growth, stability and overall productivity. It ensures recycling of residues, optimization of resources, minimization of risk, and generation of employment. The basic objectives were to find out the complex interactions in farming systems to economically analyze the best combination of crops and allied enterprises for more income. Integration of various farm enterprises in a farm ensures growth and stability in overall productivity and prodigality, and also ensures recycling of resources (and their optimization), minimizes risk and helps generation of employment. Improved livelihood initiatives for the poorest by including both natural resource and non land-based activities encourage the rural poor to diversify their livelihood so as to mitigate risks and cultural indigenous technology knowledge.

Methodology

The technology assessment and refinement through institution – Village programme (TAR-IVLP) under rainfed rice based production systems for Chhattisgarh plains – Indira Gandhi Agricultural University, Raipur (C.G) through on farm trials in three tehsil (Zone) in 14th village in Chhattisgarh state, India covering all categories of farmers.

A complete picture of the agro-ecosystem of the project area was obtained to provide sufficient background information about the ecology and the people. Various agro tools were applied to identify major problems and triangulation amongst the group was done for unified and final identification of major problems. The problems were prioritized and accordingly interventions were collected for category wise, group wise, caste wise, skill wise, inherent skill and knowledge, indigenous technology knowledge, and education.

Table 1. Economic analysis of complex interactions of farmers category wise/inherent skills in cropping system.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Intervention (OFT)</th>
<th>Economic Return (per ha)</th>
<th>Additional Income</th>
<th>Landless (%)</th>
<th>Marginal (%)</th>
<th>Small (%)</th>
<th>Medium (%)</th>
<th>Large (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Only Rice (MTU1010)</td>
<td>11,500</td>
<td>29</td>
<td>16</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Rice- Lathyrus</td>
<td>11,500 +7,780</td>
<td>7,780</td>
<td>24</td>
<td>39</td>
<td>46</td>
<td>48</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Phaseolous Mungo in fallow wet (Additional)</td>
<td>3,876</td>
<td>3,876</td>
<td>6</td>
<td>14</td>
<td>21</td>
<td>28</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>Efficient Utilization of Bunds</td>
<td>1,450</td>
<td>1450</td>
<td>4</td>
<td>11</td>
<td>18</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>Early Rice-Gram</td>
<td>11,500 + 6,172</td>
<td>6,172</td>
<td>2</td>
<td>16</td>
<td>28</td>
<td>38</td>
<td>46</td>
</tr>
</tbody>
</table>
Table 2. Economic analysis of complex interactions of farmers category wise/inherent skills in allied enterprises.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Intervention (OFT)</th>
<th>Economic Return (per ha⁻¹)</th>
<th>Additional Income</th>
<th>Landless (%)</th>
<th>Marginal (%)</th>
<th>Small (%)</th>
<th>Med. (%)</th>
<th>Large (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scientific Cultivation of Fruits and Vegetables in nutritious garden (Back Yard) Avg. 20 decimals</td>
<td>3,560</td>
<td>3,560</td>
<td>11</td>
<td>21</td>
<td>52</td>
<td>78</td>
<td>82</td>
</tr>
<tr>
<td>2</td>
<td>Cultivation of Vegetables for Higher Returns Avg 70 Decimals</td>
<td>12,376</td>
<td>12,376</td>
<td>-</td>
<td>5</td>
<td>11</td>
<td>37</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>Yield performance of Paddy Straw Mushroom Avg. 40 Decimals</td>
<td>2,466/-</td>
<td>2,466</td>
<td>16</td>
<td>22</td>
<td>38</td>
<td>52</td>
<td>54</td>
</tr>
<tr>
<td>4</td>
<td>Stable scientific composite fish culture in village pond 40 decimals</td>
<td>14,970</td>
<td>14,970</td>
<td>-</td>
<td>2</td>
<td>7</td>
<td>26</td>
<td>46</td>
</tr>
<tr>
<td>5</td>
<td>Increasing productivity of backyard poultry Avg. 10+2</td>
<td>3,772</td>
<td>3,772</td>
<td>11</td>
<td>17</td>
<td>20</td>
<td>32</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>Improved breeds of goat 8+2</td>
<td>8,908</td>
<td>8,908</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Results

The results revealed that before the project implementation, it was perceived that in taking a holistic approach all baskets of technologies are not applicable as determined by the PRA exercise finding in the above methodology. The adoption pattern of technology has complex interactions between socio-economic cultural background and categories, and knowledge and skill. The economic analysis depicts that the following returns were gained by adopting various farming system. In interventions Rice-Lathyrus and additional income of Rs. 7,780 is the farmers practice return increasing adoption pattern from landless to small but medium and large farmers they adopt other remunerative crops in winter season. In fallow unbounded land (Vertisol) wet season, early rice-gram, cultivation of fruits and vegetables in nutrition garden backyard, cultivation of vegetables for higher returns, yield performance of paddy straw mushroom, stable scientific composite fish culture in village pond are adopted in increasing percentage from landless to large as in Tables 1 and 2 increasing productivity of backyard poultry Rs. 3,772 and improved breeds of Goat additional income of Rs. 8,908. The adoption rate is increasing order from landless to medium farmers whereas large farmers the adoption rate is less because in the society it is a factor of image that the large farmers adoption rate is less.

Conclusions

The above tables show that landless farmers who had land for cultivation in rent or lease due to their poor socio-economic condition are not able to practice and gain more income because they cannot invest more and take risks in the diverse risk-prone conditions apart from the category wise the interventions like stable scientific composite fish culture in village pond, increasing productivity of backyard poultry and improved breeds of goat are also adopted according to inherent skills, ITKS, knowledge and awareness, and image in the society. The interventions from Serial no. 3-5 in Table 1 and Serial no. 1-4 in Table 2 the adoption rate is in increasing order. And also the income is higher. The investment in this intervention is more so the medium and large farmers who can take risk and invest more opt for more of allied interventions. Intervention of Serial no. 5-6 in Table 2 are adopted in increasing way from landless to medium farmers but the large farmers adopt this two interventions less due to their higher position in society.
A TOOL FOR INTEGRATING BIOPHYSICAL TO POLICY MODELS

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Introduction
Over the last decades, agriculture in Canada has experienced significant structural changes which have dramatically moved the sector from a traditional to an industrial configuration (Parson, 1999). To assess how well the agricultural sector manages and conserves natural resources, Agriculture and Agri-Food Canada (AAFC) has developed economic models (Horner et al., 1992) and a set of agri-environmental indicators (AEI) (Lefebvre et al., 2005). These tools are a practical means of assessing environmental sustainability by combining current scientific knowledge with socio-economic factors supported by public policies. While the demand for this type of analysis is increasing (Payraudeau et al., 2005), many methodological issues still need to be ironed out (Junkins, 2005). In order to help meet this need, AAFC is currently using a multidisciplinary approach to develop a land use allocation model (LUAM) that integrates the Canadian regional agricultural model (CRAM), a policy and economic model, to the AEI models. This paper presents research being done to develop the LUAM model, and an application of the downscaling methodology in Ontario. The data used are derived from agricultural census, remotely-sensed imagery, topographic maps, and output from the CRAM model. The results help to describe land use change (LUC) trends and identify what attributes of landscape or production systems make them more apt to change. The potential for further development of this integrative approach is also discussed.

Methodology
The LUAM model consists of an economic module at a regional scale and an AEI module at the soil landscape of Canada (SLC) scale. The outputs from the regional scale are carried out at the SLC level, so that the cropping and management practices can be assigned to specific locations within the landscape, and fed into the AEI models. Then, results from the AEI models are aggregated and scaled up to the policy level. The overall process is achieved through a combination of mathematical linear programming (LP) (Brooke A. et al., 1998), and down- and up-scaling procedures (SP) within a GIS configuration (Attwood et al., 2000). However, due to the complex nature of the information involved in this analysis one cannot mechanically allocate outputs from one spatial level to another. Also, mathematical processes cannot efficiently store the knowledge and experience accumulated by experts. In the LUAM framework, an analytical decision support system provides a solution to these difficulties by incorporating the knowledge and experience into a rule-based module. The optimal solution found when a scenario is performed is put in a survey database that contains socio-economic and biophysical information from several experts for the generation of new scenarios when needed.

Figure 1. Framework of the integrated LUAM model.
Results
A prerequisite to the development of a realistic integrated economic-environmental modeling is the study of driving forces that might cause LUC (Lambin et al., 2000). In two data-rich pilot sites, statistical analysis of census data spanning 1981 to 2001 have shown that agricultural LUC in Ontario is associated more with cash crops. The more likely LUC drivers seem to be biophysical (soil capability), economic (crop prices and market trends), urbanization and technology. According to Parson (1999) and Huffman (Oral communication), agricultural LUC in Canada is mainly driven by soil capability. Based on these assumptions, the LUAM model was run for Eastern Ontario with soil capabilities, crop productivity, and historical boundaries (maximum and minimum) of census of agricultural data taken as constraints in the LP process. The fundamental parameter was the harvested area of main crops grown in Ontario.

Figure 2a presents the results of agricultural LUC from 1996 to 2001 at the SLC level. Note that the model allows generating a relatively consistent acreage allocation from regional to landscape level compared to figure 2b where census of agricultural data are released by Statistics Canada (Ogston et al., 2006). In fact, the model has detected the regions where the most intensive agricultural activities take place. However, there are some quantitative differences between the two approaches. The problem seems to be that changes in the reporting of land use released by Statistics Canada are greater than the LUC actually going on at the SLC level. The LUAM model also needs improvements with incorporation of economic drivers and enterprise type information.

Conclusions
We have built a flexible and modular methodology that can be used with different agricultural and socio-economic data and easily adapted to various agricultural management scenarios. Work is underway for using satellite imagery, aerial photos and classification products to identify and quantify farmland changes at a series of pilot sites across Canada. We anticipate that this will enhance the approach and allow more accurate and reliable use of CRAM outputs for integrating economic and AEI models.

References
Introduction
To analyze the efforts of companies towards more sustainable practices, the use of a best performance benchmark can play an important role. An interesting way to assess contributions towards sustainability is the sustainable value approach developed by Figge and Hahn (2004, 2005). The sustainable value approach is a value-oriented assessment tool that allows the integration of different resources of companies. This approach assesses contributions to sustainability of a system by comparing the firm’s resource productivity with the resource productivity of a benchmark, and this for each resource. Because benchmarks can give valuable indications to all decision makers, a well defined benchmark is essential. Otherwise, decision support systems can give wrong signals, resulting in wrong decisions. Furthermore, it is important that a benchmark is realistic and feasible for each company. The efficiency of a system is calculated by estimating a production frontier, indicating the maximum feasible production possibilities. In this paper, the sustainable value approach is combined with efficiency analysis to benchmark the sustainability assessment.

Methodology
The sustainable value approach assesses contributions of firms to sustainability. The value contribution of each firm resource is calculated by comparing the firm’s resource productivity with the productivity of a (sustainable) benchmark. Combining the value contributions of all relevant firm resources allows us to calculate the firm’s sustainable value. Information about the sustainable value approach can be found in Figge and Hahn (2004, 2005). An application on the agricultural sector can be found in Van Passel et al. (2007).

Efficiency of a firm is defined as the actual productivity of a company compared to the maximum attainable productivity. The maximum attainable productivity of a firm can be calculated by estimating the production frontier (efficiency analysis). The production frontier describes the relationship between the resources (‘inputs’) and outputs of a production process. Using stochastic frontier analysis, several functional forms (e.g. Cobb-Douglas and translog functional form) can be formulated to estimate the production frontier.

In previous sustainability assessment research, using the sustainable value approach, the benchmark choice was rather straightforward using for example the average resource productivity as benchmark. This paper investigates the possibilities of using efficiency analysis as benchmark to calculate the sustainable value of firms. Benchmarks using best performance or performance targets can be very useful to analyse the efforts of firms in their aim to reach the targets or the best performance (Van Passel et al., 2007). However, the basic best performance benchmark using the best performance of each resource has important shortcomings and is not necessarily the best option to assess the performance of companies. Using a basic benchmark for all companies (independent of the actual resource use and combination) can result in a misleading measurement of the resource performance of a company. The unit isoquant K in Figure 1 shows all the ways of combining two resources X₁ and X₂ to produce a given level of output Y. Points on the unit isoquant are efficient because their actual productivity equals the maximum feasible productivity. Observation ‘a’ can improve the productivity of resource X₁ while observation ‘r’ has the maximum productivity level. In fact, it seems very clear that in this case observation ‘r’ is a perfect benchmark for observation ‘a’ (even for both resources X₁ and X₂), the peer of observation ‘a’ is observation ‘r’. The productivity level of observation ‘a’ for the resource use of X₁ equals 0X₁/0X₁. However, when looking to observation ‘c’, the peer for observation ‘c’, using the basic best performance benchmark, would be observation ‘r’ but with the actual combination of resources X₁ and X₂, this is not always a feasible target. Therefore, a better peer for observation ‘c’ would be observation ‘s’. Using the average productivity or the basic best performance (X₁) would be an inappropriate benchmark choice for the resource use of X₁ of observation c.
Results

We formulated our methodology using two different functional forms (Cobb-Douglas and translog) as benchmark to calculate the sustainable value of dairy farms. The Cobb-Douglas functional form is very attractive because it is easy to estimate and to interpret. However, a major drawback of using the Cobb-Douglas functional form is the lack of flexibility. The value contributions of the different resources are identical because of the fixed elasticity of substitution (equal to 1). A possible solution is using the translog functional form which is more flexible and takes into account substitution between resources. Our example for Flemish dairy farms shows that labour is used less productively than farm capital. Farm capital is used in a more value-creating way, or better in a less value-wasting way, than labour capital. A disadvantage of the use of the stochastic translog functional form is the data requirement, as many data are needed to avoid estimation problems such as multicollinearity problems.

Conclusions

We showed that the production theoretical underpinnings of efficiency analysis enrich the sustainable value approach. Correct benchmarking is important for the following reasons. First, improvement in eco-efficiency (as measured by the sustainable value approach) is often the most cost-effective way of reducing environmental pressures. Efficiency improvements can be seen as the first important step towards sustainability. Therefore, it makes economic sense to exploit these options as much as possible. Second, policies targeting efficiency improvements tend to be more easily adopted than policies that restrict the level of economic activity (Kuosmanen and Kortelainen, 2005). Our approach combines the sustainable value approach with efficiency analysis. Using maximum feasible production possibilities as benchmark offers several advantages. First, substitution possibilities between different resources (economic and environmental) are not ignored as in traditional eco-efficiency analysis. Second, the constructed benchmark takes inefficiency of the considered resources into account. Third, using frontier methods to construct benchmarks provides specific benchmarks for each company adjusted to the particular situation of the company (in other words to the actual resource use). The sustainability of each company is assessed in comparison with its relevant peers which can help to motivate decision makers to take realistic but ambitious measures towards sustainability. Fourth, our approach can be used to simulate and estimate the impact on firm sustainability of possible policy measures. In this way, this method can be used as an integrative sustainability assessment tool for policy measures. The main limitation of the suggested method is its extensive data requirement.

References

Figge and Hahn, The cost of sustainability capital and the creation of sustainable value by companies, 2005. Journal of Industrial Ecology 9, 47-58
WEB BASED AND DATABASE DRIVEN DECISION SUPPORT TOOL FOR INTEGRATED FARMING

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Introduction
There has been a trend in Midwest agriculture to de-integrate crop and livestock production. Livestock is being raised in specialized operations, purchasing much of their feed. Meanwhile farmers growing crops depend on chemical fertilizers rather than manure. Crop farmers have become seasonal workers, causing fluctuating labor demand. With energy prices rising fertilizers will become more expensive, while demand from the growing biofuel industry increases the costs of feed. To make management decisions farmers need information on socio-economical viability and the environmental impacts of management changes. \textit{I-FARM} is a decision-support tool developed by Iowa State Univ. The web-based and database driven tool includes crop and livestock production systems, economic and environmental impact modules, and a user-friendly GIS feature to identify individual fields. Using aerial images, a user can select a specific field. Utilizing soil and topographic databases, \textit{I-FARM} gives estimates for erosion, carbon sequestration, nutrient balancing, required labor, energy consumption, costs, government payments, and expected revenues. Recently a phosphorus run-off model has been added, incorporating the impact of manure application and soil drainage in combination with conservation practices. This paper focuses on economic and environmental impacts of scenarios for integrated crop and livestock farming systems in the US Midwest. Results are presented in multi-dimensional radar diagrams, comparing indicators such as soil loss, labor requirement, fertilizer requirement, farm income, etc.

Methodology
Over the last four years we developed the web application \textit{I-FARM}. The application allows users to evaluate economic and environmental effects of management changes for integrated farms in the Midwest and Northeastern US. Figure 1 shows the main flow diagram. We integrated the soil erosion model RUSLE, the simple carbon sequestration model SCI and the phosphorus-index model for Iowa. The databases driving \textit{I-FARM} include the ISPAID soil database for Iowa, the SSURGO soil database for 24 States, and weather data derived from CLIGEN. Databases have been developed for \textit{I-FARM} for machine properties, labor requirements, custom farming, market prices, nitrogen deposition, and livestock manure production. The main program has been written in VBScript and JavaScript. The GIS interface has been written in ASP.NET, using ArcGIS Server. We use public image servers to support the GIS interface. Communication between the modules occurs through SQL Server database processes. The URL of the free application is \url{http://i-farmtools.org}. The application has been accessed 11000 times in 3 years.
For this paper a number of scenarios has been developed for a five representative 400 ha crop and livestock farms in Western Iowa.

We compare (1) a non-integrated farm growing corn, soybeans, and hay, (2) a semi-integrated grain and swine farm, growing corn, soybeans, and hay; producing hogs, (3) a fully-integrated grain and swine farm, growing corn, soybeans, and hay; closed farrow to finish system, (4) semi-integrated grain and beef farm, growing corn, soybeans and hay; producing beef, and (5) fully-integrated grain and beef farm, growing corn, soybeans, and hay; closed beef production system. Each farm has three fields. Hill slopes are respectively 2.5, 9.5, and 22%. Farm fields are identically sized, except that in farm 5 field 2 has been divided into two fields in order to produce the necessary forages, using a 6-year corn/soybean/corn/alfalfa/alfalfa/alfalfa rotation. Grains are produced in 2-year crop rotations: corn and soybean on fields 1 and 2; perennials on field 3. All land is owned, while machines and buildings are purchased on bank loans. Tillage practice is minimal to avoid above-tolerant soil erosion. Livestock numbers are limited to avoid phosphorus excess levels in manure applied fields. Machine investments, market prices and production costs are estimated for 2007.

Results

The simulated economic results are shown in Table 1. It is obvious that, at current market prices and subsidy policies, the highest farm income can be achieved by growing grains and producing market pigs. However, the highest income per labor hour can be earned from cash grains and hay.

Table 1 Economic bottom line in dollars per year (Rev=revenues; Exp=expenses)

<table>
<thead>
<tr>
<th></th>
<th>1 Non-integrated</th>
<th>2 Semi-integrated</th>
<th>3 Full-integrated</th>
<th>4 semi-integrated</th>
<th>5 Full-integrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Livestock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crops</td>
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<td>481655</td>
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<td>223231</td>
<td>481655</td>
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<td>158987</td>
<td>275368</td>
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<tr>
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<td>4829</td>
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<td>74046</td>
<td>104769</td>
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<td>82099</td>
<td>17534</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net farm income</td>
<td>211873</td>
<td>334251</td>
<td>329451</td>
<td>181307</td>
<td>147247</td>
</tr>
<tr>
<td>per labor hour</td>
<td>222</td>
<td>143</td>
<td>105</td>
<td>70</td>
<td>84</td>
</tr>
</tbody>
</table>

Costs, $/ha (0,1500)  Labor, h/ha (0,8)  Diesel, l/ha (0,60)  N-fertilizer, kg/ha (0,100)  Soil cond. index (0,0.5)  Field 2 soil erosion, kg/ha (0,40)

Figure 2 Radar diagram of multi-dimensional simulation results

Conclusions

The non-integrated farm shows the highest farm income per labor hour, although the chemical nitrogen input is highest. The fully integrated beef farm has the lowest farm income per labor hour, although the energy input is lowest. All farms are “sustainable” in terms of carbon sequestration (SCI index is positive). All soil erosion losses are below tolerable levels using minimum tillage. However, on fields with 9.5% hill slope medium or high phosphorus runoff is being expected, which demands application of additional conservation practices, such as vegetative buffer strips, terracing, or other measures.
NUANCES-FARMSIM: A TOOL TO ANALYSE ENTRY POINTS FOR IMPROVED MANAGEMENT OF SMALLHOLDER FARMING SYSTEMS IN SUB-SAHARAN AFRICA

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Introduction
African smallholder farming systems are complex, dynamic systems with many interacting biophysical subcomponents with different time coefficients, all managed by human agents. Smallholder farming in sub-Saharan Africa takes place along a wide range of soil, climatic and socio-economic conditions. Modeling tools aiming at understanding the constraints of smallholder farming and aiming at identification of potential development pathways under these conditions need to fulfill two key requirements:

1. The tool needs to be limited in its complexity.
2. The tool needs to take into account the socio-economic and biophysical components of the system in a balanced way, describe their interactions and quantify their development over time.

Existing models do not fulfill these requirements. We present a new, dynamic, model, NUANCES-FARMSIM, which describes processes at component level (livestock, soil fertility, crop production, manure management, labour and cash resources) and their interactions at farm level, and is thereby able to describe the functioning of the farming livelihood in time. We used this tool to identify possible entry points for management recommendations. We parameterized the model for farming systems in Western-Kenya, and quantified:

1. The uncertainties in each of the process-descriptions in the individual model components
2. The uncertainties in the coupling of these components (for example nutrient flows)
3. The uncertainties in the interactions of the socio-economic part of the model and the biophysical part of the model (for example effects of labour shortages on crop production)
4. The ranges of possible realistic management options (e.g. manure management, labour allocation and cash investment decisions).

By performing an overall sensitivity analysis in which both process uncertainties and ranges in management options were combined in one analysis, the robustness of management recommendations were quantified for a set of farming system indicators and entry points for recommendations and key areas for future research were identified.

Methodology
The following components of the farm are dynamically simulated in a separate sub-module using summary models: Crop and Soil (‘FIELD’; Tittonell et al. 2007a), Livestock (‘LIVSIM’; Livestock SIMulator), Manure handling and storage (‘HEAPSIM’; Heap SIMulator), Cash availability (‘CASHSIM’; CASH SIMulator) and Labour availability (‘LABOURSIM’; Labour Simulator).

The most important flows between the biophysical modules are shown in Figure 1. Labour balances are calculated on a monthly basis and the crops and livestock components in the farming system determine when in the year certain activities (e.g. planting and ploughing, weeding, feed collection, etceteras) should take place for optimum production. If not enough labour is available for an activity, production levels are reduced similar to the approach taken in Tittonell et al. (2007b). Based on selling products, off farm income and remittances on the positive side and spendings on the negative side a simple monthly cash balance is calculated. Management decisions take place throughout the model: how much of the monthly available labour is allocated to certain activities, whether or not part of this labour is sold to off farm activities, how the available manure is allocated over the different fields, how the available cash is invested, etceteras.

NUANCES-FARMSIM can be used to evaluate quantitatively the consequences in terms of short and long term productivity of the farm. The modules of NUANCES-FARMSIM have been tested individually for the smallholder farming systems under study.
The sensitivity analysis was performed by determining the settings of the most important management options and biophysical parameters in each of the modules, together with the potential ranges in these values of these parameters. By using Latin Hypercube sampling the effects of changes in the settings of the different parameters and their interactions on the productivity of the farm were evaluated. For this a case study farm in Western Kenya was chosen with 2 cross bred cows, 2 fields were Napier grass is grown and three fields (with different soil fertility levels) where maize is grown.

Figure 1: Most important flows between the biophysical modules of NUANCES-FARMSIM

Results
The model results were compared to observed production levels on smallholder farming systems in Western Kenya and values obtained for the flows between the individual farm components using resource flow mapping. Although this is not a very strict model testing the model showed reliable behaviour, and was capable of capturing the most important differences between different farm types. The results of the sensitivity analysis showed that description of crop growth processes and livestock productivity were minor contributors to the uncertainty at farming system level productivity, i.e. improvements in process description of these components would only lead to a limited improvement in the reliability of system level outputs. The main source of uncertainty was in the quantification of the manure handling, and results show that interventions in that component (improved manure management and storage) could increase the nutrient use efficiency of the farming system drastically. Most important area on which research should focus for improved prediction of farming system behaviour is on the interactions between limiting socio-economic resources (e.g. labour, cash) and productivity of crops and livestock.

Conclusions
The approach in NUANCES –FARMSIM of combining summary models to represent the different components of smallholder farming systems in Sub-Saharan Africa seems to be a promising approach to be able to analyse the consequences of strategic decision making on the functioning of the farm livelihood. The key factors determining this functioning could be identified, and the model was manageable in terms of its complexity and the information needed for parameterization. The sensitivity analysis showed that not our knowledge of the biophysical processes is limiting our ability to analyse smallholder farming systems quantitatively, but our knowledge of the interactions between the socio-economic and biophysical elements within the farm.

References
USING THE RESPONSE SURFACE METHOD (RSM) FOR EMPIRICAL TRADEOFFS BETWEEN ECONOMICS AND THE ENVIRONMENT AT THE FARM LEVEL

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Introduction

Farm inputs such as nitrogen are essential for maintaining crop yields, however, farmers commonly apply excessive nitrogen inputs as an insurance policy. U.S. farmers typically spend over $10 billion annually on commercial fertilizer with nitrogen fertilizer consumption increasing from 3 million tons in 1961 to over 12 million tons in 2004 (USDA-ERS, 2004). In addition, per hectare nitrogen fertilizer use more than quadrupled from 20 kg/ha to 87 kg/ha during the same period due to increased cropping intensity (USDA-ERS, 2006). Excessive nitrogen use has been associated with the impairment of streams, lakes, and aquifers. The U.S. Geological Survey concluded that large amounts of nitrogen fertilizer applied to croplands is responsible for more than 48% of all nitrogen loads to surface water in areas where nitrogen runoff per unit of land area is high, i.e., greater than 1,000 kg/km² annually (USGS, 2006). The USGS also determined that large applications of irrigation water, which accelerates nitrogen movement, causes high nitrogen concentrations in water bodies across many areas of the United States (e.g., California, and other northwest, northern plains, and southwest states). The goal of this research is to develop an integrated farm-level economic and environment analysis framework for tradeoff analysis between farm profitability and environment externalities created by high levels of on-farm nitrogen application.

Methodology

Response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. Box and Wilson first introduced the method in the early 1950’s (Box and Wilson, 1951). The main idea of RSM is to use carefully designed empirical data sets to obtain an optimal response. RSM is a useful alternative to classical optimization and mathematical programming techniques in the presence of experimental design data and the need for an econometric model describing economic systems. Box and Wilson (1951) showed a mathematical framework for an economically-constrained RSM model. Furthermore, they concluded that constrained RSM optimization of the implicit response function had been completely ignored by researchers in general and economists in particular. In the last five decades RSM methodology has evolved to cover a large number and a wide range of applications, especially as computational capabilities have advanced. We used field data from treatments carried out at the Northeast Iowa-Nashua Agricultural Research and Demonstration Farm at Nashua, IA, USA. The Nashua site consists of 36 0.4-hectare plots; experimental data were summarized to estimate economic budgets in order to rigorously assess and measure costs and profitability for each plot. The Constrained Response Surface Method (CRSM), including optimization algorithms (i.e., steepest descent and ascent), was then applied to find the surface optimum regions of corn and soybean profitability subject to two constraints representing environment externalities - nitrogen measured in tile drainage for each plot and total nitrogen measured in the soil profile.

Results

Our research results indicate that tradeoffs between farm profit and nitrogen consumption (and consequently nitrogen environmental externalities) varies significantly. The variations depend on the year, choice of crop planted, crop rotation, tillage system, amount of nitrogen applied, planting...
density, soil water content, and soil effective porosity. Our tradeoff analyses compared corn and soybean yields (and gross margins) on one hand, and the relevant nitrogen amounts in tile drainage and the soil profile on the other. Study results showed that the tradeoffs between economics and the environment for corn are significant and complex (Fig. 1). For example, a reduction of nitrogen in tile drainage for corn plots from 55 kg/ha to 20 kg/ha (64%) required a much lower reduction in gross margin from $451 per hectare (the maximum possible corn gross margin) to $308 per hectare ($143 per hectare difference or 32%). This reduction in gross margin was accompanied by approximately a 50% reduction in soil profile total nitrogen (from 114 kg/ha to 55 kg/ha). Additional study results showed that the tradeoff potential between economics and the environment may be even larger for soybeans. For example, a reduction of nitrogen in tile drainage for the soybean plots from 53 kg/ha to 14 kg/ha (74%) required a reduction in gross margin from $546 (the maximum possible soybean gross margin) to $380 per hectare ($166 per hectare difference or 30%). Furthermore, this reduction in gross margin was accompanied by approximately a 81% reduction in soil profile nitrogen (from 218 kg/ha to 41 kg/ha).

![Graph](image)

**Figure 1.** Tradeoffs between corn gross margin and nitrogen in tile drainage and the soil profile.

**Conclusions**

Farmers face challenging decisions when considering tradeoffs between economics and the environment. An important lesson learned from this study is that there is no singular point of optimal tradeoff between economics and the environment (even for a single crop). Assessing economic and environment tradeoffs is a complex issue and involves a large number of factors that influence on-farm decision making. These factors include farmer-controlled management practices such as the amount of inputs applied (e.g., nitrogen, amount of seeds used, irrigation system, crop rotation, and tillage system) and uncontrolled variables such as weather and inherent soil properties. Interactions between these variables were also found to significantly influence the magnitude of the tradeoffs. Well designed and implemented response surface experiments accompanied by detailed economic, biophysical, and environmental data were found to be useful and necessary for analyzing complex decision making problems of this nature.

**References**


Session 1.7:
Adapting farms to an uncertain future climate

Session Convenors:
Marco Bindi, Jorgen Olesen and John Roy Porter
LONG-TERM ANALYSIS OF TEMPORAL VARIABILITY OF DURUM WHEAT YIELD: FIELD STUDY AND SIMULATION APPROACH IN SOUTHERN ITALY

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Introduction

Intergovernmental Panel on Climate Change claim that globally 0.23°C per decade increase will occur in average annual temperatures and indicated that in next century, if the rate of emission of greenhouse gases to atmosphere continues, global mean temperatures will increase by 1.4 to 5.8°C (IPCC, 2001). Several studies on climate change effects on crop yield have been reported in the literature (Andresen et al., 2001; Bindi et al., 1993). C3 plants, like durum wheat, will benefit from elevated CO2, due to increase photosynthetic rates resulting in increased biomass and yield production. Atmospheric CO2 level increase is predicted to occur simultaneously with increase in temperature and decrease in precipitation that could even lead to an overall loss of yield.

CERES models have widely been used to assess the impact of climatic change on agricultural crops development and production (Otter-Nacke et al. 1986; Tubiello et al., Ewert 2002). The objectives of this study were a) to evaluate the effects of climate change on the Creso cultivar of durum wheat for the period 1975-2006; c) to validate the CERES-Wheat model using the long term weather and yield data; d) to perform a sensitivity analysis on the effect of CO2 increase to 550 ppm, increase of 4°C in the mean annual temperature and 20% less precipitation on yield and yield components.

Methodology

The study was carried out in CRA-Cereal Institute experimental station. A statistical analysis was performed on the weather data, assessing standard deviation and coefficient of variation of each month of the year for the 56 years of available weather. Yield data collection started in 1975 and they were provided by the Ministry of Agriculture variety trial project. Tillage operations and fertilizer applications were constant for the whole period 1975-2006. Simulation was performed using CERES-Wheat (Ritchie et al., 1985) and comparing measured and simulated results using RMSE for the study period (1975-2003).

Results

The yield varied from 1.5 t ha⁻¹ to 6.4 t ha⁻¹, with a mean value of 3.9 t ha⁻¹ (Fig. 1). A poor correlation was found between seasonal rainfall and yield, demonstrating that water was not always the limiting factor (Fig 2). A similar relationship was also found by Passioura (2002) for Australian wheat yield. Increases of the simulated ratio ΣET/PET with yield showed that low values of ET/PET are indicators of low yield (Fig. 3). The curve was established with ET and PET simulated from CERES. The minimum temperature in March was able to explain 50% of yield variability (Fig. 4).

The CERES-Wheat model performed well when compared with the 29 years of measured data. The model was able to correctly simulate the trends of low (1982, 1987) and high yield (1975, 1981, 1991) that occurred during those years.
Results of the simulation scenarios showed that when increase in CO2 level are combined with increases in temperature and decreases in precipitation amount the yield of current variety of wheat is decreased. Additional details on such results will be presented in the conference communication and in journal papers.

Bibliografia


CHARACTERIZING CLIMATE CHANGE SCENARIOS WITH AGRO-METEOROLOGICAL INDICATORS FOR FARM ADAPTATION PLANNING: CASE-STUDY IN CENTRAL ITALY

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Introduction
Incorporation of climate information into farm management decisions is a key issue for successful agricultural business. Generation of climate scenarios, in conjunction with global circulation or regional models, provides the basis for understanding whether the demands of crops and livestock will be met by climatic change. Using agro-climatic indicators is helpful to characterize future trends, reducing risks, and to take advantage of better seasons (Matthews et al., 2007). A study was conducted at a Mediterranean site (central Italy), where climate data representative of current conditions were compared against a future scenario. The objective was to characterize current and changed climates via an array of agro-climatic indicators. Remarks were made concerning the possible consequences of climate change on crop productivity to assist farm planning on a typical mixed farm of the area.

Methodology
The study site was Montepulciano (province of Siena, region Tuscany, central Italy, 43.08 °North latitude, 11.78 °East longitude, elevation 250 m above sea level, 1-m average soil depth). Daily data aggregated at the 50×50 km grid scale that are representative of current climate conditions (1975-2005) were supplied by the Mars Unit (http://agrifish.jrc.it/marsstat/databdistribution) of the European Commission Joint Research Centre (Ispra, Italy). A climate scenario (A2 medium-high emissions, IPCC, 2000) was generated for the periods 1960-1990 (‘hindcast’) and 2070-2100 (‘future’) by the Hadley Centre Regional Model HadRM3, also on a 50×50 km grid (http://www.metoffice.gov.uk/research/hadleycentre). The hindcast and Mars-data largely overlap in time, so they were compared for identification of possible biases in the hindcast. Bias correction factors (Rivington et al., 2007) were applied to the hindcast and future data. The current and bias corrected future climate series were characterized by an array of agro-meteorological indicators.

Results
Assessment of the bias corrected hindcast showed that it had a better match with the Mars current climate (data not shown). The indicators computed for current and future climate scenarios are reported in Tab. 1. The projected increase in temperatures is reflected in the reduced risk of late-spring frost (earlier dates of frosts, lesser number of air frost days), in longer seasons available for crop growth, and larger accumulated temperatures (indicating a shorter time required for completion of growth stages). An enhanced hydrological cycle is accompanying warming, but transition towards heterogeneous precipitation patterns are expected (e.g. Fournier index) with larger amounts of water in winter (e.g. excess winter rainfall, negative rainfall seasonality index) and less soil water available in summer (including longer dry spells).

Remarks
The bias correction approach helps address issues of climate model parameter and structural uncertainty, improving confidence in the use of future projection data. Results suggest that increases in temperature will influence the site in summer, and that these changes will cause increasing water shortage. Higher temperatures will make crop cycles shorter, with less time available to accumulate biomass. For winter-sown crops (e.g. wheat), however, shorter cycle would help skipping over summer water shortages. Heat-loving crops (e.g. horticultural) are expected to take benefit from higher temperatures, with the support of infrastructure building to match ever-increasing irrigation requirements. Other options may include insurance systems with regards to droughts. With mild winters, early sowing of spring-sown crops (maize, sunflower) can
be an option to avoid summer drought, although severity of pests and diseases is expected to increase. Longer growing periods may offer an opportunity for new enterprises (e.g. late summer-sowing crops), strengthening the multifunctional role of agriculture and striking a balance between economic and environmental functions. An extension of the season available for plant growth would in particular assure protracted periods with vegetation covered soils, which will be beneficial for the environment and the hydrologic management of the area.

Tab. 1. Median value of the agro-meteorological indicators computed at Montepulciano for current and future scenarios (doy: day of year).

<table>
<thead>
<tr>
<th>type of indicator</th>
<th>indicator</th>
<th>current climate (Mars)</th>
<th>future climate (HadRM3)</th>
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<tr>
<td>Dates</td>
<td>Last spring air frost (doy)</td>
<td>103</td>
<td>54</td>
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<tr>
<td></td>
<td>First winter air frost (doy)</td>
<td>324</td>
<td>344</td>
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<td></td>
<td>Last spring grass frost (doy)</td>
<td>131</td>
<td>103</td>
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<tr>
<td></td>
<td>First winter grass frost (doy)</td>
<td>291</td>
<td>330</td>
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<td></td>
<td>Maximum soil moisture deficit (doy)</td>
<td>263</td>
<td>210</td>
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<td></td>
<td>Minimum soil moisture deficit (doy)</td>
<td>11</td>
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<td></td>
<td>Wettest week (doy of midpoint)</td>
<td>275</td>
<td>288</td>
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<td></td>
<td>Start of growing season (doy)</td>
<td>22</td>
<td>1</td>
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<td>End of growing season (doy)</td>
<td>352</td>
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<td>149</td>
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<td></td>
<td>Modified Fournier index</td>
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<td>4585</td>
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</tbody>
</table>

negative values indicate larger precipitation amounts in winter, and vice versa; the higher the value, the more heterogeneous is the precipitation distribution within year.

References
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AGRO-CLIMATIC INDICATORS OF VEGETATION GREENNESS AND CROP DROUGHT: A CASE-STUDY IN SOUTHERN ITALY

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Introduction

Plant communities are regulators of energy, carbon and water exchange between atmosphere, vegetation and soil. For plant ecology monitoring, development of indicators forms an important area of research. The Mediterranean region is a pool of semi-humid environments, characterized by summer aridity and including human disturbances due to conversion of natural areas to anthropogenic use. Case studies reported for the Mediterranean area have demonstrated that extended periods of drought stress still continue to result in significant impacts on agricultural production (Perini and Beltrano, 2004). Evolution of plant communities can be assessed by the Normalized Difference Vegetation Index (NDVI, in the range -1 for snow fields to 1 for dense vegetation canopies), an indicator of vegetation greenness. As a complement to NDVI, a novel indicator (MCDI: Mediterranean Crop Drought Index, Diodato and Bellocchi, 2007a) was used for the purpose of monitoring of drought stress. Drought characterization was done using a crop well fitted to the Mediterranean region and central to the Italian economy as it is the case for maize (Zea mais L.). The objective was to examine the multiyear variation of greenness in a site in South Italy, combined with agricultural drought pattern.

Methodology

The study site was Monte Pino station (province of Benevento, region Campania, south Italy, latitude 41.1 °north, longitude 14.1 °east, elevation 184 m above sea level) of the UN-FAO Terrestrial Ecosystem Monitoring Sites network, for which extended records (1972-2006) of monthly air temperature and precipitation were available. These data were used to compute monthly values of both NDVI and MCDI. Computation of NDVI was based on the approach proposed by Diodato and Bellocchi (2007b), which the reader may refer to for all details. The monthly-based MCDI is as follows:

\[
\text{MCDI} = \frac{\text{MDD}_m}{(0.3 \cdot p_{m-1} + p_m + 50)}
\]

where MDD_m (°C-days) is the degree-day accumulation in the month m, p_m and p_{m-1} (mm) are the precipitation amounts for month m and m-1. MCDI assumes positive values, with large values indicating high drought-stress conditions.

For the province of Benevento, a database of annual maize grain yields was supplied by ISTAT (http://www.istat.it) for the period 1990-2006.

Results

Monthly values of both MCDI and NDVI were reconstructed from 1972 to 2006. For this period, Fig. 1 compares agro-meteorological indicators (summer MCDI, graph [a], and the average NDVI from March to October graph [b]), and climatic variables (graph [c]). The superimposed 3rd-order fitting lines show a similar trend of both indices to increase since the 80s-90s after an inflexion in the preceding years. Based on the general trends from 1972 to 2006, represented by the superimposed 3rd-order fitting lines, several years are shown where MCDI and NDVI patterns (graphs [a] and [b]) are somewhat complementary. It appears from these graphs that high summer drought-stress periods concurred with high vegetation greenness (and vice versa), with both indicators increasing since the 80s-90s after an inflexion in the preceding years.
Fig. 1. Temporal patterns of: (a) summer MCDI (from May to August), (b) average NDVI (from March to October), (c) annual precipitation amount and mean air temperature, and (d) annual maize yield. Three-order polynomials are used to interpret trends.

Yearly precipitation amounts have kept roughly constant over time (or even slightly increasing, graph [c]), thus changes recorded in the temperature pattern (graph [c]) may explain the variation of both MCDI and NDVI. Rising average temperatures observed over the last two decades of the 20th century (of about 1.5 °C, graph [c]) are indeed consistent with both stimulation in vegetation growth (graph [b]), and progressively worse drought-stress conditions (graph [a]). One of the most distinct signs of increase in drought-stress conditions in the last years has been the dramatic fall of yields observed for maize in the same period of time (graph [d]).

Remarks
Decreasing trends in maize yields observed since the 90s in the study area correspond to increasing summer droughts. In the same period, decreases in vegetation greenness were not observed. A complex pattern does therefore emerge, where negative impacts on agricultural crops are not necessarily reflected to the extent of natural plant communities.

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L. Perini et al., Italian agricultural production and the heat wave during summer 2003, 2007. Italian Ministry of Agriculture, Rome, Italy
Trend Characterization of the Maize Irrigation Season in Veneto, Italy
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Introduction
Water is an essential agricultural resource that often limits crop yield. The optimization of plant water use, aiming to maximize and stabilize productivity is fundamental for decreasing risks, increasing economic returns, and minimizing environmental impact. This condition contributes to the sustainability of the farming system. IRRIMANGER ver.1.1 is an easy water balance model developed by Altavia srl in 2001 and is available on ARPAV websites such as IRRIWEB (http://www.arpa.veneto.it/upload_teolo/agrometeo/index.htm). Irrigation scheduling involves determining when and how much to irrigate. Poor scheduling may lead to a waste of water, energy and labor, low yields and environmental problems. Good scheduling should optimize yield and quality of produce whilst making efficient use of resources.

Methodology
Simulation models: the water balance model is a one-dimensional, daily soil water balance. It aims to simulate the soil water storage and rates of inputs (hourly rainfall, daily evapotranspiration and temperature max, min and mean) and outputs (net irrigation requirement, actual amount of water soil evaporation, crop transpiration, and surface runoff) of water in response to climate. By specifying and selecting a few appropriate crop parameters in a Menu driven environment, the program creates a complete set of parameters that can be displayed and updated if additional information is available. The soil profile may be composed of several soil layers, each with their specific characteristics. At the start of each day of a simulation run, the output of the previous day is displayed at runtime.

Simulation procedures: water balances for maize crop are calculated from 1992. The meteorological inputs required in IRRIMANGER were obtained from the ARPAV weather station in Legnaro -Padova (Latitude N 45°20'26" and Longitude E 11°58'0"). These parameters included 14 year records of daily maximum and minimum temperatures, wind velocity, sunshine hours, relative humidity, and hourly precipitation. ET0 was calculated using Penman Monteith equation (FAO, 1998): Penman Monteith Method is adopted as it has been accepted as a new standard for reference evapotranspiration (FAO, 1998). The soil inputs used in IRRIMANGER were available from field analysis made at the Department of Environmental Agronomy and Crop Science. The hypothetical data of maize's sowing is fixed on 1st on April for each year.

Results
In the test station annual rainfall averages during 1992-2006 are about 850 mm. Annual rainfall distribution is changing, in particular during June and July, where the trend is decreasing and August where it is increasing. Monthly averages reference evapotranspiration, during the same period, show an increasing in June and July and a decreasing in July and August (Fig.1); in fact the evaporation is the reverse of the rainfall: in the majority of months, when precipitation occurs, the reference evapotranspiration decreases. This is expected due to the increase in relative humidity, which would cause the evaporation to be less. Consequently, the same situation happens for the simulated values of monthly irrigation needed, starting from 1992: a positive trend during June and July and a negative trend in August, at the end of the growing season, (Fig 2).
Conclusions
The scientific management of agriculture is theoretically tested and it is possible to estimate the daily crop water requirement and to adopt the proper scheduling of irrigation. The simulation techniques can be used in different scenarios to identify the strategy that maximizes the effectiveness of irrigation and crop yield. These results help to understand better how global climate change is founded also in a local area and how rainfall’s distribution is changing during the growing season that is the most critical period for plant stress. For these reasons defining strategies in planning and management of available water resources in the agricultural sector is to become a national and global priority and IRRIMANGER can support the farmer in them.

References
SOIL WATER BALANCE OF A WINTER CROP CULTIVATED IN SOUTHERN ITALY AS INFLUENCED BY FUTURE CLIMATE

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Introduction
The climatic change induced by global warming is expected to modify the agricultural activity. An efficient management of the water resources is considered very important for Italy and in particular for Southern areas characterized by a typical Mediterranean climate in order to improve the economical and environmental sustainability of the agricultural activity. In particular, climate warming could have a substantial impact on some agronomical practices as the choice of the crops and/or varieties to be included in the cropping systems, the sowing time, conservative tillage for reducing soil evaporation and runoff and increasing water infiltration. Concerning the irrigation management, the scheduling, the method choice and the soil water status monitoring are the most important factor to be optimized in order to obtain high value of water use efficiency (WUE).

In this paper we applied SWAP model to optimize the management for scarola, cultivated in winter period in a farm located in the Metapontino Area in the Jonical coastal zone of Southern Italy.

Methodology
SWAP (Soil-Water-Atmosphere-Plant) is a physically based model (van Dam et al, 1997) that resolves the Richard’s equation in order to describe soil water fluxes and solute transport in saturated/unsaturated soil media. The model includes modules concerning solute and heat transport, soil heterogeneity, shrinking and swelling of clay soils, water repellency, simplified or detailed crop growth model and irrigation water management. SWAP was parameterized by using crop and soil data set collected in a private farm situated in the coastal area of the Puglia region in Southern Italy (lat. 40° 28' 48.40" N and long. 16° 47' 37.97" E). The soil is sandy-loam with average clay and silt contents of 18 and 14%, respectively. This typical farm for Southern Italy is characterized by intensive winter cultivation of scarola (Cichorium endivia var. latifolium Hegi cv Growers Giant) on an area of 20 ha. In particular SWAP was applied with the simple growth module with the measured soil cover fraction utilised as input variable for separating the potential soil evaporation and plant transpiration from the reference evapotranspiration. Moreover the crop cycle length was modelled in function of the temperature sum.

The Regional Circulation Models adopted in this work was HadRM3P, developed by the Hadley Centre, UK. HadRM3P has a spatial resolution of 0.44° latitude by 0.44° longitude and is the result of a dynamical downscaling. It takes boundary conditions from a coarser resolution global model and provides a higher spatial resolution of local topography and more realistic simulations of fine-scale weather features. In particular, the outputs from HadCM3 experiments provide the boundary conditions to drive a high resolution (~120 Km) model of the global atmosphere (HadAM3P). In turn, the outputs from this model in turn provide the boundary conditions to drive the HadRM3P. This double nesting approach is performed to improve the quality of the simulated climate.

In order to simulate climate change, two emission scenarios (A2 and B2) were a selected among those proposed by the Special Report on Emissions Scenarios (IPCC 2000), to have a wide and representative range of changes in temperature patterns.
The climatic daily data of the scenarios A2 and B2 (from 2071 to 2100) and reference period (REF, from 1961 to 1990) were utilized for SWAP applications with unique initializations. For each scenario we compared three transplanting dates (October 1st; October 15th and October 30th with the second one representing the typical date) submitted to no irrigation (NI) and full-irrigation (FI) as typical for fertigation scheduling. For each run we considered these output at a temporal scale of cultivation period: cycle length (CL), rain (R), potential evapotranspiration (ETp) and drainage (D). We have also considered the ratio between actual and potential transpiration (RT) and irrigation depth (ID) for NI and FI treatments, respectively.

**Results**

The comparison among the three climatic scenarios shows higher monthly averages of maximum temperatures for A2 and B2 than the REF scenario with differences up to 7 °C in the summer period. Significant reductions of annual rainfall are detected under A2 and B2 (-17 and -24%, respectively) particularly during the spring and summer months. Under A2 the winter precipitations compensate partially the summer drought.

In Figure 1 the percentage departures of soil water balance components with normal transplanting date and relative to RP are presented. The first important results is the reduction of the crop cycle (-17 and -35% under B2 and A2, respectively). According with this reduction R and ETp (-30% for A2) are predicted to decrease. Without irrigation the analysis indicates a lower RT fraction (-12 and -7%) corresponding to higher water stresses for lettuce cultivation. The irrigation water requirement (ID) is forecast to increase under B2 (+6%) and to decrease under A2 (-15%). The higher rainfall concentration in the winter period under A2 explains the larger water losses under A2.

In the Figure 2 we present the impact of transplanting times on soil water balance and irrigation requirement. With advanced transplanting date and regardless of IPCC scenarios, a significant cycle reduction is expected by 20% in average that determines a decrease of irrigation requirement of the same order of magnitude. At the contrary with a delayed transplanting date, the crop cycle and consequently the irrigation depth is expected to increase above all under A2 scenario.

**Conclusions**

This paper shows a significant evidence that the changes of climate would can have on the winter lettuce cultivation in Southern Italy. The expected warming can be expected to shorten the cultivation period with consequent reduction of rainfall, potential evapotranspiration and irrigation. The transplanting time is found to be an useful agronomic practice in order to decrease the irrigation requirement of lettuce. Compared to normal time of transplanting, an advanced date of 15 days is expected to save water by 20% in average.

**References**

ADAPTATION OF EUROPEAN AGRICULTURE TO CLIMATE CHANGE

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Introduction
Climate change is expected to affect agriculture differently in different parts of the world (Gitay et al., 2001; Olesen and Bindi, 2002). Potential impacts of climate change on food production are generally assessed with site-specific crop models. Crop models strongly emphasize biophysical factors, such as climate and soil. The dynamic nature of climatic effects is well understood for potential, water and nitrogen limited growth and yield at field level. However, validation for regional applications of these models remains unsatisfactory. Actual farm yields are also affected by other factors such as pests and diseases, which depend on farm management and regional conditions. Projections of actual impacts at higher aggregation levels, such as farm and region, should take farm management and adaptation into account.

Farm management and adaptation are influenced by farmers’ objectives, such as increasing or stabilizing income and environmental services (e.g. agricultural biodiversity). Decreasing crop yields do therefore not necessarily imply that farmers’ income decline or that farmers’ vulnerability increase. Therefore, in order to assess agricultural vulnerability, multiple ecosystem services need to be considered.

The main objective of this study is to assess how adaptation influences the impact of climate change and climate variability on European agriculture. The aim is to improve insights into adaptation processes in order to use this information in integrated assessment modeling. By including adaptation in impact assessments, actual impacts of climate change and the vulnerability of agricultural systems can be better quantified.

Methodology
In this study we used farm level data from 1990-2003 to assess the impact of climatic and socio-economic conditions and farm characteristics on crop yields and farmers’ income throughout the European Union. Multi-level models, linear regression models and frontier analysis are used to assess effects on yield and income (Reidsma et al., 2007a; Reidsma et al., 2007b; Reidsma et al., 2007c; Reidsma et al., 2007d). The ecosystem services crop yields and farmers’ income comprise the main part of the analyses in this study. Farm performance at farm and regional level is influenced by two groups of factors related to (i) farm characteristics and (ii) regional conditions such as biophysical, socio-economic and policy factors (Fig. 1).

Results
Adaptation has a large influence on the impact of climate change and climate variability on European agriculture. This study suggests that actual impacts of climate change and associated climate variability will be less severe for the Mediterranean regions than projected by earlier studies. Impacts of climatic variability are more pronounced for temperate regions. Farmers adapt their management to prevailing climatic, socio-economic and policy conditions. This current management influences adaptation strategies that can be adopted in the future and hence the climate impacts.

Within regions, crop yields and farmers’ income are increasing with increasing farm size and farm intensity. Also land use (e.g. arable land area, crop area) significantly influences farm performance.
Climate impacts are different for different farm types. Interestingly, farms that seem better adapted to prevailing conditions do not necessarily adapt better to climate change and variability. Regions and farm types that obtain higher crop yields and farmers’ income have lower variability herein, but relationships between crop yield or income variability and climate variability are generally stronger than for regions or farm types with low crop yields and farmers’ income.

**Figure 1.** The investigated relationships (represented by the block arrows). Impacts of climate change on farm and regional agricultural performance are not only influenced by biophysical conditions, but also by other regional conditions and farm characteristics, which influence adaptation.

**Discussion and Conclusions**

In order to assess the impact of climate change and variability on agricultural ecosystem services, an integrated assessment model is needed that assesses both bio-physical processes and socio-economic processes accurately and explicitly includes feedbacks among different model component. Although mechanistic modelling of all the processes involved in agricultural performance is currently not feasible, for reliable projections on the impacts of climate change on agriculture we need models that represent the actual situation more accurately. Farmers continuously adapt to changes. This affects the current situation as well as future impacts. Therefore, adaptation should not be seen anymore as a last step that might be assessed, but it should be explicitly included in the crop model and the linkages with other components.

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Modeling Farmers’ Adaptation to Climate Change – Integrating a Biophysical and an Economic Model

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Introduction

Existing studies that analyze the impact of climate change (CC) on crop production are either based on crop simulation or regression models based on historical data. Both approaches are not fully suitable to analyze the impact of CC on crop production (Antle and Capalbo, 2001). Crop simulation models are not suitable to integrate adaptation actions taken by farmers because the analysis focuses on crop physiology. Data used for regression models, in contrast, comprise previous adaptation of farmers. However, such models can not sufficiently integrate future plant-climate interactions. In particular such models cannot integrate expected CO2 fertilization effects on plants due to low variation in historical CO2 concentrations. Furthermore, extrapolation of historical data does not allow for analyses of innovative adaptation measures. To overcome these drawbacks, we use a combination of both approaches to provide both adequate description of future crop productivity and modeling of farmers’ adaptation behavior in future.

Methodology

Our approach integrates results of a biophysical simulation model into an economic assessment model. Crop yield data for current and future climatic conditions at the eastern Swiss Plateau are generated with CropSyst (Stöckle et al., 2003), a process-based, multi-crop, multi-year cropping system simulation model. CropSyst is parameterized for the Swiss Plateau by Torriani et al. (2007). CropSyst outputs are used to estimate the economic model which consist of production and yield variation functions. Even though crop yields are influenced by various factors, our analysis is restricted on the crucial agricultural inputs nitrogen fertilizer and irrigation water.

Coefficients of the production functions are estimated employing the robust regression method of reweighted least squares. Ordinary least squares (OLS) regression is vulnerable to outlying observations due to e.g. climatic extreme events such as droughts. Inclusion of climatic extreme events in the analysis can result in misleading inference if OLS regression is used. In contrast, the application of robust regression leads to a more efficient estimation of production functions (Finger and Hediger, 2007). The (robust) regression residuals of the production function estimation are used to estimate yield variation functions. In these functions, the influence of input use and climatic conditions on yield variation is modeled. Application of robust regression improves yield variation estimation due to more efficient estimation of production function residuals. Taking into account that such events are more likely to occur along with changing climate (e.g. Fuhrer et al., 2006), this property is of particular interest.

In contrast to other integrated models (e.g. Antle and Capalbo, 2001) we use a nonlinear programming approach to simulate farmers’ future adaptation behavior and consequential effects of CC on yields, utility and input use. Structural adaptation strategies such as changes in sowing dates, changes in production intensity and the adoption of irrigation farming are considered in the model. Numerical examples are given for winter wheat and corn production at the eastern Swiss Plateau where irrigation in cereal production is today virtually not existent.

Besides changes in climatic conditions, Swiss agriculture will face market liberalization in the next decades, e.g. due to a free trade agreement with the European Union (EU). The development of input and output prices has to be taken into account if projections for the next decades are made. Existing differences between current Swiss and EU prices are much smaller for inputs such as nitrogen fertilizer than for outputs such as corn and wheat. Thus, the ratio of output/input prices will decrease. Several scenarios of risk aversion, input and output prices are assumed to identify critical parameters of adaptation. Moreover, two climate change scenarios covering the period of 2030 to 2050 are taken into account.
Results

Our results show that shifts in seeding dates and the possibility to change production intensity to changed economic and climatic conditions reduce the vulnerability of cereal farming to climate change. Earlier seeding of corn, for instance, reduces water need in midsummer where projections for both increases in temperature and reductions of rainfall have the largest magnitude. The possibility to change production intensity enables to adjust nitrogen application to the given water supply from both rainfall and irrigation. In the model, optimal nitrogen application is reduced if rainfall decreases for non-irrigation farming. In contrast, nitrogen application which is not adjusted to the available quantity of water leads to economic losses.

The economic (and agronomic) benefit of irrigation is found to be much higher in corn than in winter wheat farming. This is due to relatively low water need of wheat. Moreover, the decrease of rainfall in spring, where wheat is most susceptible to droughts, is expected to be low. In contrast, maximum water requirements of corn occur during summer where the largest future rainfall decrease is projected. But, alternative adaptation measures such as earlier seeding and the possibility to adjust production intensity reduce the need for irrigation in corn farming. The profitability of irrigation in corn production is mainly triggered by output prices. High profitability of irrigation in corn farming in future is possible for high output prices only. Irrigation is no key adaptation measure to CC in corn farming if output prices decline due to market liberalization.

Model results show furthermore that expected price changes in a liberalized market in Switzerland have larger influence on crop yields, input use and farmers’ utility than expected CC. We find increasing corn and winter wheat yields for all CC scenarios. This is in particular due to the assumed increase of CO2 concentration. The development of yield variation is ambiguous because yield variation is in particular sensitive to output prices. However, due to the consideration of adaptation measures CC leads to decreasing yield variability if prices remain constant.

Conclusions

Using an integrated model to analyze impacts of CC on crop production and production risk is a valuable approach. It enables the simultaneous analysis of climate change, price and risk aversion scenarios. Furthermore, our modeling approach improves the estimation of economic model coefficients by employing robust regression. Efficient and reliable estimation is ensured even if climatic extreme events such as droughts occur in the data. Applying our modeling approach on corn and winter wheat production on the eastern Swiss Plateau, we find simple on-farm adaptation options to be sufficient to generate positive effects of CC in Swiss crop production.

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The EU Communication Towards a Thematic Strategy for Soil Protection (COM 179, 2002) has underlined the need to protect the soil for the unique variety of its functions, all necessary for life: food and other biomass production, storing, filtering and transformation, habitat and gene pool, physical and cultural environment for mankind, and source of raw materials. Soil organic matter decline has been identified among the eight threats affecting soil, the others being erosion, contamination, sealing, compaction, decrease of biodiversity, salinisation, floods and landslides. The proposal for a Framework Directive for soil protection (COM 232, 2006) has set out common principles for protecting soils across the EU. Within this framework, the EU Member States will have to implement policies for soil protection and sustainable use at national scale. At present, the dynamic processes governing the C and N cycles in relation to the specific land use in the Mediterranean environment are not well documented, particularly for agro-forestry in rainfed areas and grazing systems, and hence require further scientific efforts.

This paper illustrates the main objectives and expected results of the Italian research project “SOILSINK”, aimed at the identification of efficient agro-forestry production systems in terms of soil carbon sink under Mediterranean climate. This three-years project is part of the Strategic Programme for Sustainable Development and Climate Change and it has been co-funded in 2006 by different Italian Ministries (Environment and Territory, Agricultural and Forestry Policies, University and Research, Economy) within the Integrated Special Fund for Research (FISR). The project involves about 70 Italian scientists from a number of different disciplines, and is organised into four main research headlines (RH).

RH1 (UNIVPM and UNISS) is focused on the integrated analysis (agronomy, vegetation, soil sciences and socio-economic) of Mediterranean cropping and agro-forestry systems.

RH2 (CRA-ISNP-Cropping Systems Ecophysiology, project coordinator, CRA-ISAGRO) deals with simulation models on C and N cycles and GIS applications, for the assessment of the long-term effects of different agro-forestry systems on soil C-sink under current and future climatic scenarios.

RH3 (DBAG, UTS-ENEA, DSSNP, CRA-ISSDS, DBBA, BIOVEG, CRA-ISNP-Plant Growth & Physiology) studies genetic diversity and the influence of climate change on the soil microbial community, including soil functional microbial diversity involved in the GHGs cycles and humic acids metabolism, and genetic, functional and morphological diversity of symbiotic fungal communities in plant roots and soil.

RH4 (CRA-ISNP-Nitrogen Nutrition & Agricultural Microbiology, DCBA, CNR-IBAF, DABAC) is related to C and N mineralization parameters under potential and field conditions; microbial biomass activity and organic C characterization; the role of arbuscular mycorrhizal fungi in the transfer and stock of atmospheric C in the soil; C and N fluxes and deficits in microbial communities; C, N and P soil enzymatic activities.
Methodology
The project is designed to investigate field data collected from two case-study sites with contrasting pedoclimatic, agricultural and socio-economic contexts: Agugliano (AN), in Marche, central Italy, and Berchidda (OT), in Sardinia. The soil samples collected from the same experimental sites and plots are being shared by all research units for a wide range of analyses. In Agugliano, under clay-silt soils with 10% slope, long term effects of contrasting cropping systems on soil C dynamics are being studied from samples collected from a 13 years field experiment comparing three tillage systems (no-tillage, minimum and conventional) and 3 levels of nitrogen fertilization (0-90-180 kg N ha\(^{-1}\)) in a 2-years crop rotation (durum wheat-corn).

In Berchidda, long-term effects of different land uses with increasing level of intensification are being studied in an area characterized by the same soil and vegetation potential and include rainfed annual fodder crops; vineyards (with/without grass cover); grazed grasslands mixed with cork oaks; semi-natural forest systems (e.g. Mediterranean maquis, and cork oak forest).

In both sites, RH1 is aimed at the identification and characterization of the study areas from an integrated agro-ecological perspective, in order to identify the possible implications of different land uses in relation to the soil C sink dynamics under different land uses. Climatic, pedologic and crop data are also used (RH 2) as data-input for the parametrization and calibration of different simulation models (e.g. EPIC, DAISY), and the set-up of a georeferenced data-base for upscaling of results at landscape scale. Simulation models are used to quantify the long-term evolution of soil C sink in the agro-forestry systems. Future climate change scenarios are generated from the actual long-term climatic series with specific General Circulation Models, to provide an input to the models and compare their actual and future predictions, and to evaluate the effects on soil microbial diversity and C dynamics. GIS tools, supported with aerial photogrammetry and land use maps (Corine Land Cover) will be used to map model outputs, to represent specific thematic findings of the research (e.g. soil C stocks), and to address the land use policies towards the most conservative mitigation measures to balance GHGs emissions. Soil samples are collected at different stages of the crop cycle to evaluate the dynamic processes governing the C and N cycles (stocks, mineralization, humification, etc), with laboratory tests on the biologic and enzymatic activity, and the growth of soil microbial communities (RH 4), as well as the genetic and functional microbial diversity of bacteria and fungi controlling the soil C cycle (RH 3).

Results and conclusions
Expected results cover a wide range of thematic findings, such as: a) characterization of the productivity of the different agricultural and agro-forestry systems and long term effects on the soil physical, biological and chemical characteristics of the two sites; b) assessment of the genetic and functional diversity of soil microorganisms, of their biological and biochemical activity, and of the vegetation of specific importance in the C and N cycle in the soil; c) evaluation of soil C and N balance change under different climatic scenarios and their relationships with soil functioning and sustainable use; d) availability of data-sets to run the simulation models on soil organic C to improve the knowledge of the C sink processes; e) interpolation and mapping of model outputs and any available data with GIS tools; f) development of new tools to support learning of researchers, stakeholders and policy makers to share issues and strategies to increase soil C-sink; g) evaluation of the expected impacts of different climatic scenarios as an input for C cycle models, and analysis of the effects on the microbial diversity and C dynamic; h) involvement of local communities and stakeholders to increase the awareness about climate change and the potential role of agro-forestry in implementing mitigation strategies; i) assessment of socio-economic implications of the expected consequences of adopting most conservative agro-forestry production systems.

References
THE ROLE OF MULTI-SCALE MODELLING IN ASSESSING LIVELIHOOD ADAPTATION STRATEGIES TO CLIMATE CHANGE

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Introduction

The Earth’s climate is changing at unprecedented rates, largely due to anthropogenic factors (IPCC 2007). This, together with other drivers such as population increases and increased demand for crop and livestock products, is causing agro-ecosystems to evolve faster than previously expected. These changes will have profound impacts on land use, global food security, energy use, the economics of agricultural systems and their sustainability, and the livelihoods of rural populations. Inevitably, the associated uncertainty of the magnitude and timing of these effects will make farming decisions more riskier and difficult. Climate change adaptation strategies will need to be developed, particularly in situations where vulnerability is high. The role of integrated models at different scales (regions and households) is likely to become more prominent as scenarios and solutions need to be devised and downscaled to be useful to relevant stakeholders. This paper outlines the climate change impacts and the effects of other drivers of change on agricultural systems and the livelihoods of farmers dependent on them. We continue with a description of existing models operating at different scales (from downscaled global circulation models to household models) and suggest ways in which they can be used to assess different adaptation strategies to cope with climate change impacts. We illustrate these concepts with case studies from highly vulnerable regions, mainly in smallholder systems in Africa.

Methodology

The analysis of adaptation options to climate change is complex and requires an integrated approach at different scales. This is mainly because climate change effects operate largely on the global atmosphere, while their impacts are felt to different degrees at regional and household levels and on their key components (crops, livestock, soil, etc). The integrated models used and their key aspects are shown in Table 1.

We use the downscaled outputs of global circulation models (GCMs) to estimate the length of growing period (LGP) and its changes in the future for different parts of Africa. LGP has been found to be a good proxy variable for assessing the effects of climate change on agriculture (Thornton et al. 2006). We then assess biophysical and social vulnerability (adaptive capacity) of regions and people with the use of regional spatial models that characterize the main types of production systems, land cover, market access, poverty rates, and access to services, and their possible changes into the future. Overlays of the outputs of the GCMs with the vulnerability analyses provide information on the most vulnerable regions to climate change in Africa (Thornton et al 2006). Household surveys are then carried out in hotspot regions and different systems and livelihood options are characterized with the use of database and household modeling tools such as IMPACT (Herrero et al. 2007). IMPACT provides analyses of income, labour use, nutrient balances and food security. A range of alternative management options are simulated using crop and livestock models under different climatic regimes (Thornton and Herrero 2001). The outputs of these (crop yields, animal production, soil nutrient status, etc) are then used in household models to assess options (management practices or land use options) that may allow farmers to adapt to climate change. This assessment is done in relation to the trade-offs that may be needed between differing household objectives, such as food security, income, and soil fertility maintenance.

Results

The use of integrated multi-scale models has allowed an appropriate disaggregation of well targetted adaptation options by production system. The spatial analyses permit the identification of priority regions where vulnerability is high and were systems may be affected by significant contractions in the length of growing period (i.e. parts of Sahelian West Africa, the Great Lakes...
region in East Africa and parts of Southern Africa). Depending on their livelihoods strategies and their integration in markets, smallholder households have different choices to adapt to climate change and its variability. Intensification, diversification, and in some cases both, may be appropriate, depending on system type, economic status, and location. Intensification (use of fertilizers, cash crops, water harvesting, better fed animals) is possible for semi-commercial farmers in regions with relatively good markets, while for the bulk of smallholder producers in marginal areas where climate change effects may be significant, a more feasible option might involve income diversification to spread risk. This includes in some cases additional sources of income such as trading and off-farm employment. Crop substitution (i.e. sorghum instead of maize), the increased use of small ruminants instead of cattle, and livestock selling strategies, are amongst the options used by agro-pastoralists in marginal areas, together with collective-action coping mechanisms and social safety nets.

Table 1. Models at different scales and their role in identifying climate change adaptation strategies

<table>
<thead>
<tr>
<th>Scale</th>
<th>Type of model / method</th>
<th>Purpose</th>
<th>Some variables obtained for studying adaptation options to climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global / continental</td>
<td>Downscaled global circulation models</td>
<td>Study global climate changes at regional and global levels</td>
<td>Length of growing period, rainfall, rainfall variability, temperature</td>
</tr>
<tr>
<td>Continental / regional</td>
<td>Regional land use models and spatial data analysis methods</td>
<td>Study the susceptibility of landscapes to climate change, systems evolution (biophysical vulnerability)</td>
<td>Changes in land cover, land productivity, hotspots of potential problems, areas where climate change effects could be severe, resource degradation, market access</td>
</tr>
<tr>
<td>regional / household</td>
<td>Vulnerability assessments</td>
<td>Study the susceptibility and adaptive capacity of households to climate change (social vulnerability)</td>
<td>Access to services, poverty rates, expenditure in health, child mortality and under-nutrition, governance and others</td>
</tr>
<tr>
<td>Household</td>
<td>Household / Livelihoods models</td>
<td>Understand the impacts of climate change on livelihood options</td>
<td>Income and its variability, maintenance of assets, food security, main constraints to production, diversification options, others</td>
</tr>
<tr>
<td>Household / plot</td>
<td>Crop, soil, livestock models</td>
<td>Understand the responses of different components in the farm to climate change</td>
<td>Crop responses to different climatic regimes, livestock feeding strategies and productive responses, others</td>
</tr>
</tbody>
</table>

Conclusions

Multi-scale modeling is an effective way to identify the impacts of climate change on rural communities and to identify options to adapt to these effects. It allows the spatial identification of areas were climate change effects will be significant and where vulnerable groups of smallholders are located. Results can help in understanding livelihood strategies and the role of different components (crops, livestock, off-farm income, etc) on households' wellbeing. Modelling can also help to identify which system components are most prone to climate change and its variability, and allows the targeting of adaptation strategies to particular groups of producers. While the differential effects of climate change are likely to differ considerably depending on region (IPCC 2007), these integrated methods are generic and can be used in different locations. Adaptation to climate change is not only a bio-economic problem. A new level of multidisciplinarity is required, and more interaction with stakeholders in the political arena is needed in order to provide viable options for the poor and vulnerable of the world.

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A KEY ISSUE LIES IN THE LOCAL CATTLE INDUSTRY

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Introduction

Agricultural systems have served multiple purposes for centuries. Only recently, one part has not done it. Among specialized farms, certain flexible systems are more suited than others to withstanding climate change. We suggest that the key issue to enduring climate change lies in the flexibility of the local cattle industry, strongly linked with the practices on farms. Their particular feature is that farmers can choose to produce two or more different marketable products from the same animal. We suggest illustrating this issue, and drawing general lessons from two cases.

In most Western European regions, agri-food systems have moved towards a standardization of products intended for end consumers. Industries have responded to market pressures, aided by the CAP (Common Agricultural Policy), by developing production processes that are compatible with what are called economies of scale. For the dairy industry for example, the effect of the phenomenon has been an increase in the number of production stages (from full cream milk collected at the farm through to the knob of butter) and a sharing out of the specialist paid work (non-versatile) throughout these production lines. The major primary processing companies (for milk, meat, flour and oil mills) had no choice of strategy. They had to have the upper hand via costs (Porter, 1982). That strategy means working the most standardized "materials" possible (pig carcasses 55% quality class E, milk with 38 g fat content and 32 g protein, wheat with a known gliadin rate, etc.). Standards are becoming increasingly comprehensive, demanding and sophisticated. But farmers, despite the price incentives, cannot always produce exclusively standardized materials. Apart from a few rare exceptions, the basic consumer products reach our plates very much standardized thanks to a succession of non-standard co-products that have been eliminated from the race1. The role of some of the processors is to juggle with this obvious fact. They send the pigs that are too fat for "pâté", the cull dairy cows for "manufacture" (of sausages), the milk that cannot be made into cheese for gelled desserts and the fruit that is a little too ripe for puréed fruit. We call them "adjusters" because they enable the dynamic adjustment of supply and demand for all food products. They work in the huge network that food companies weave among themselves. Adjustment does not just take place within a single industry, defined by its end product, but in interaction with the other industries per product. For instance, such and such an adjuster buys cows and calves but also pigs and sells cattle feed. Another collects top fruit, soft fruit and market garden vegetables. Thanks to the adjusters, the network can operate: the major companies that exclusively work standard products do not bear the cost of the co-products with which they could do nothing. How much would bread wheat cost if the non-bread wheat remained in the silos? Adjusters not only see to getting the most possible out of non-standard products but also take on the two ghastly spatiotemporal shortcomings of agricultural produce: being connected to the soil and being offered for sale at an untimely moment2. In other words, they collect in the field and then gather together, store, sort and allocate what the farms produce to the best outlet, as it comes. The adjusters are farm cooperatives (especially multi-product ones), merchants, wholesalers, distributors, small mills, etc. They give Western European agricultural markets the flexibility that makes for the profusion, variety and availability of our food. This remarkable flexibility can become inadequate if a dramatic rise in energy costs and climate change become involved. The latest data from the European Commission (Outlook, 2007) concerning international trade show that world grain stocks have reached their lowest level in history. An increase in all agricultural prices is forecast and a further decrease in global trade. In the light of this, practitioners and researchers would be well advised to find the most flexible food systems possible to prepare for the future. And there are some particularly flexible food systems which encompass and reassure the major standardized product industries. These "super-

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1 A visible manifestation of this race for standardization is shown in Brittany where "iffy" pigs are euthanized at the farm, rather than running the risk of seizure on the slaughter line.
2 For example, small dairies stock the surplus spring milk as cheeses that require lengthy ripening.
flexible" systems have developed in agricultural regions where the typical features of the soil, the climate and its vagaries, and the poor collection or market structures were making it almost impossible for the farming of standardized materials to develop. New systems have been created. This is not just a question of the survival of ancestral food systems, at all events in the cases we are aware of, but a fairly recent phenomenon. These are systems in which the farmer can choose two or three end purposes for each of the animals that are born at the farm. Without escaping from the overall need to supply the most standardized agricultural "materials" possible, the main feature of these super-flexible systems is that the farmer can allot, with varying degrees of lateness, a given animal to two or three different ends. Here are two illustrations.

Illustrations
In the Corrèze département (Limousin region), rearing suckling calves is traditional. A typical calf is of Limousin breed, reared at the udder, without ever eating roughage or leaving the stable. It is sold at the age of 4 months and weighs 200 kg, which will yield about 120 kg of carcass. The production of grass-fed calves was developed in the 1960s. A typical grass-fed calf is an 8-month-old Limousin male weighing 280 to 350 kg and reared in the herd. It is sold to be fattened and ends up in feedlot regions. In addition to these two outlets, stockbreeders can even set aside their females for reproduction. And since the 1990s at least, the herd of nursing cows in Corrèze is stable (about 140,000 head), as is the total of both categories of suckling and grass-fed calves\(^3\) (about 80,000). But distribution varies depending on the years (50 % around 1992, 62 % for grass-fed calves in 2005). This does not mean there is a slow disappearance of the suckling calf in favour of more modern production since, in certain years, grass-fed calves show a fall-off in numbers that is offset by a rise in the number of suckling calves. The area of Saugues (Auvergne region) shows the same phenomenon for lambs. In the mid 1980s, sheep merchants created a market for light suckling lambs for Spain. Coming from the same maternal flock as the traditional heavy lambs, they are slaughtered at an earlier age and eat less forage. Since then, the local market has processed (Chambre, 2004) around 60,000 lambs a year, with varying proportions of light and heavy lambs. Even though the contribution provided by light lambs has declined greatly today, it introduced great flexibility among sheep breeders so they could cope with climate uncertainties.

Conclusion
In both the French cases reported, the ability of the area to produce kilos of meat, whatever the climate or economic uncertainties, is based on the same conditions. There is a market (built by the adjusters) and local technical and economic conditions that make it possible to rear an animal for several purposes\(^4\). With the help of the adjusters, and often at their instigation, some of the breeders move from one purpose to another, which makes the market more fluid for everyone. The examples of super flexibility are even greater for plant productions through allocating plots to different plant species and even to "dual purpose" crops on an annual basis. The adjusters and farmers with super-flexible systems make all the markets fluid to everyone's advantage. For various reasons, these players have not always been recognized. The common view is that they should have "disappeared" a long time ago because they represented archaic systems. In some really standardized regional industries (pigs and poultry), most of the adjusters have already disappeared because the co-products they used to deal with have become inferior products or indeed have been eliminated (that is the case of dubious pigs euthanized at the farm). We think on the contrary that it is not a good idea for these adjusters to disappear because they give flexibility to the food network. In a world faced with changes of every kind, this role will be increasingly important.

References

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\(^3\) It is not possible to deduct heifers kept for renewal using the data available.

\(^4\) Obviously, the prices of the various "end purposes influence the breeders in their choice.
THE EFFECT OF CLIMATE CHANGE ON CROP SPRAYING OPPORTUNITIES: A RISK ASSESSMENT AND OPTIONS FOR ADAPTATION

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Introduction
There is now strong evidence that human activities are changing global concentrations of atmospheric greenhouse gases (GHG) (IPCC 2007a). As a result of GHG increases, warming of the climate system has been observed evidenced from increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (IPCC 2007a). Continued greenhouse gas emissions will result in further warming and induce many changes in the global climate system (IPCC 2007a). There is a growing concern that changes in the climate system will have detrimental yield/quality impacts on many cropping systems through changes in water and heat stress and pest, disease or weed pressures (e.g. IPCC 2007b). The management of pests, diseases and weeds involves the spraying of agri-chemicals. These spraying operations can be restricted by atmospheric conditions, in particular where 1) high temperature and low relative humidity conditions negatively affect droplet dynamics and/or 2) wind conditions are unsuitable by being either too high or too low. Both temperature and wind speed are expected to change in the future, impacting on the number of days unsuitable for spraying operations. In this study we undertake a preliminary risk analysis of the implications of climate change on the frequency of conditions unsuitable for crop spraying operations for sites across the Australian cropping zone.

Methods
Three sites across Australia’s cropping zone – Emerald, Queensland, on the northern edge, Birchip, Victoria, in the south-east and Kellerberrin, Western Australia, on the south-west edge – were examined in terms of changes in suitable spraying conditions. Daily climate data (maximum and minimum temperature and vapour pressure were extracted from the SILO data base (Jeffrey et al., 2001) and the difference between the drybulb and wetbulb temperatures (Delta T - °C) was calculated using established methods. Delta T is an important indicator for acceptable spraying conditions as it affects spray evaporation rate and droplet lifetime. In particular, high values of Delta T will result in short droplet lifetime and low efficacy when using low volume spraying equipment. When spraying, Delta T should not be above 8°C and this threshold was used to classify days in the historical record that were unsuitable for spraying. Wind speed is also logistically important to spraying operations with both high winds and low wind (via atmospheric inversions) being associated with spray drift problems. In terms of wind speed generally accepted guidelines in Australia are to avoid spraying with wind speeds greater than 15 km/hr and less than 3 km/hr, so these thresholds were used as an additional indicator of changes in spray suitability conditions. This classification was combined with that for Delta T to give an aggregate assessment of days unsuitable for spraying (i.e. days could be unsuitable due to wind, Delta T or a combination).

The likely impacts of climate change on spraying conditions on the three sites was determined by modifying the observed daily climate record with monthly climate change scenarios generated from the CSIRO Mark 3.5 Coupled GCM (Global Climate Model) using the A2 (high) and B1 (low) emission scenarios for 2030 and 2070. Historical baseline data were also extracted from these model runs in order to express changes proportional to the baseline (i.e. 1961-1990). Delta T and windspeed were used to classify days unsuitable for spraying in these scenarios as for the observed record.

Results
Climate change scenarios increased the frequency of days unsuitable for spraying at all three sites, particularly in winter. By 2030, the days unsuitable for spraying during the winter crop period...
may increase by about 30% for all sites (Birchip results not shown) for the A2 emissions scenario (Fig 1a,b). There was only a small additional increase in number of days unsuitable for crop spraying by 2070 based on opposing changes in RH and wind speed determined by this GCM. The results are similar for the B1 emissions scenario. In Emerald, where both summer and winter crops are grown, the frequency of days unsuitable for spraying is already high and will increase further with climate change to encompass most days of the month (Fig 1a). A significant component of the large changes in winter is associated with a reduction in windspeed which increases the frequency of occurrences where wind speed is below the 3 km/h threshold. The increase in frequency of conditions unsuitable for spraying contrasts with the declining trends in this factor over the past few decades due to changes in wind fields in southern Australia (Rayner, 2007).

Figure 1. Frequency of days per month unsuitable for sprayi ng due to either unfavourable Delta T or wind conditions for a) Emerald, Queensland and b) Kellerberrin, Western Australia for the historical baseline (solid bold line), 2030 (solid thin line) and for 2070 (dotted line) for the A2 emissions scenario.

Discussion
The frequency of climatic conditions unsuitable for spraying agri-chemicals appears to be likely to increase due to climate change. This increase could be around 30% by 2030 with additional small increases in frequency over the following decades. This reduction in opportunities to spray effectively could be a particular concern where climate change is increasing agronomic risks via 1) the potential reduction in effectiveness of glyphosate under elevated CO2 concentrations for some weed species (Ziska and Teasdale 2000); 2) where the relative competitiveness of weeds is increased as a result of climate changes; 3) where the range and occurrence frequency of pests, diseases or weeds is increased or 4) where there is increased damage from pests due to increased dry matter intake as a result of elevated CO2 increasing the carbon to nitrogen ratio of leaves (IPCC 2007b). There are likely to be a range of adaptations to these changed conditions. These include: coarser nozzles, reduced application speed, use of adjuvants to alter droplet characteristics, lowered boom height, changed nozzle angle and spray pressure and increased water volume. All of these have implications for scheduling, costs of operations and water use and not all options are sufficiently understood to ensure consistent and effective results.

There are some caveats for this assessment including 1) we have not explicitly included the change in variance in wind and temperature conditions that may arise, and 2) we have used only one GCM whereas other GCMs will show different changes in the driving climate variables. A more comprehensive assessment of this climate change risk factor is needed. The occurrence of rainfall also limits acceptable spraying conditions but was not considered for this analysis.

References
WATER USE EFFICIENCY DETERMINED AT THE FARM SCALE IN THE MEDITERRANEAN REGION

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Introduction

Mediterranean region is characterized by water scarcity, mainly in southern countries. A population increase, mainly in the south, and chronic deficit in food balance resulted in an increase of irrigated areas. Nevertheless water is wasted. Farmers allocated a large amount of water, exceeding crop requirements for all winter and summer crops. They over irrigated their crops by 30 to 49 %. The improvement of water use efficiency (WUE) on farms in the Mediterranean region represents the crucial phase in setting up any strategy of water management in this region.

After reviewing the WUE values determined at farm scale, the main causes affecting WUE variability are analyzed and possible research themes are suggested.

Methodology

Water use efficiency can be written as follows: WUE (kg\ m\(^{-3}\)) = yield / water consumption. Yield can be indicated by global dry matter yield or marketable crop yield expressed in kg\ m\(^{-2}\). Water consumption is considered approximately equal to evapotranspiration in mm or in m\(^{3}\). This approximation, discussed by Feddes in 1985.

WUE values analyzed in this paper are limited to those obtained with two inputs: marketable yield and ET determined by lysimeters, microclimatic, or soil water balance methods. This restrictive approach leads to ignore numerous research works. However, it helps reduce the dispersion of observations, and thus makes it possible to analyze WUE with higher data liability.

Results

Table 1 reports the minimum and maximum WUE values of 16 species cultivated in the Region.

Tab. 1 Observed WUE values (kg\ m\(^{-3}\)) for species cultivated in the Mediterranean region

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Minimum WUE</th>
<th>Maximum WUE</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>0.50</td>
<td>2.50</td>
<td>T. Oweis, 1997. ICARDA eds., 16 pp</td>
</tr>
<tr>
<td>Barley</td>
<td>1.46</td>
<td>2.78</td>
<td>N. Katerji et al., 2006. Agric. Water Manag., 85, 184-192</td>
</tr>
<tr>
<td>Corn</td>
<td>0.22</td>
<td>2.16</td>
<td>C. Gencoglan &amp; A Yazar, 1999. Tr. J. Agric. For., 23, 233-241</td>
</tr>
<tr>
<td>Grain sorghum</td>
<td>0.67</td>
<td>1.59</td>
<td>M. Mastrorilli et al., 1995, Agric. Water Manag., 28, 23-34</td>
</tr>
<tr>
<td>Soybean</td>
<td>0.39</td>
<td>0.77</td>
<td>N. Katerji et al., 2003. Agric. Water Manag., 62, 37-66</td>
</tr>
<tr>
<td>Sunflower</td>
<td>0.39</td>
<td>0.72</td>
<td>F. Karam et al., 2005. Agric Water Manag., 75, 226-244</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.22</td>
<td>1.3</td>
<td>F. Karam et al., 2006. Agric Water Manag, 85, 287-295</td>
</tr>
<tr>
<td>Sweet sorghum</td>
<td>3.7</td>
<td>4.2</td>
<td>M. Mastrorilli et al., 1999. Eur. J. of Agron., 11, 3-4, 206-216</td>
</tr>
<tr>
<td>Broad bean</td>
<td>0.45</td>
<td>1.39</td>
<td>T. Oweis et al., 2005. Agric. Water Manag., 73, 1, 57-72</td>
</tr>
<tr>
<td>Chickpea</td>
<td>0.40</td>
<td>0.98</td>
<td>N. Katerji et al., 2003. Agric. Water Manag., 62, 37-66</td>
</tr>
<tr>
<td>Lentil</td>
<td>0.36</td>
<td>2.09</td>
<td>N. Katerji, 2003. Agric. Water Manage., 62, 37-66</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>6.60</td>
<td>7.00</td>
<td>N. Katerji, 1997. Agric. Water Manage., 34, 57-69</td>
</tr>
<tr>
<td>Tomato</td>
<td>20.0</td>
<td>22.2</td>
<td>G. Rana et al., in press</td>
</tr>
<tr>
<td>Grapes</td>
<td>16.0</td>
<td>18.1</td>
<td>G. Rana et al., 2004. Scientia Horticulturae, 102, 105-120</td>
</tr>
</tbody>
</table>
The experimental data include cereals, leguminous, horticultural and industrial crops. This review, however, underlines that WUE data of fruit trees are lacking, despite they represent one of the main productions of the Mediterranean agriculture.

Large differences can be observed among the WUE values of the same species. These differences can exist not only in studies made at the same site, but also in studies conducted in different countries. This can be seen for winter and summer crops.

For explaining such variability 10 sources have been claimed (tab.2). They can be grouped in (Katerji et al., 2006):

1. Plant: differences between species (Katerji and Bethenod, 1997), variety effects (Condon et al., 2004), phenological stage sensitivity to water constraints (Katerji et al., 1993; Mastrorilli et al., 1995; Mastrorilli et al., 1999).
2. Agro-techniques: water regime analyzed in terms of quantity and quality (Katerji et al., 2003), and mineral regimes applied to crops (Oweis, 1997; Ben Nouna et al., 2000)
3. Environment: soil texture (Katerji et al., 2007) and climate parameter (Campi, 2007; Angus and Herwaarden, 2001; Zwart and Bastiaanssen, 2004). These factors include atmospheric pollution (Bou Jaoudé, 2006) and climatic changes (Ayoub, 2006).

Tab. 2 Parameters involved in the determination of WUE

<table>
<thead>
<tr>
<th>1) PLANT</th>
<th>2) AGRO-TECHNIQUES</th>
<th>3) ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHOTOSYNTHESIS / TRANSPIRATION</td>
<td>SOIL WATER AVAILABILITY</td>
<td>VPD</td>
</tr>
<tr>
<td>VARIETAL EFFECT</td>
<td>WATER QUALITY</td>
<td>WIND SPEED</td>
</tr>
<tr>
<td>PHENOLOGICAL STAGE SENSITIVITY</td>
<td>MINERAL NUTRITION</td>
<td>AIR POLLUTION</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CLIMATE CHANGES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SOIL TEXTURE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Katerji et al., 2007, in press</td>
</tr>
</tbody>
</table>

Conclusions

The paper reviewed WUE values in order to:

✓ Up-to-date the agronomic knowledge on WUE of the Mediterranean crops;
✓ Analyze the parameters influencing WUE measurements at the plot scale;

Research themes, those more promising for improving WUE at farm level in the Mediterranean region, should be addressed to:

- methods of ET determination at natural sites,
- complementarities between the eco-physiological and agronomical approaches,
- association of plant water status indicator to soil water status criterion,
- identification of the phenological stages sensitive to water constraint,
- research on WUE of multi-annual crops (mainly fruit trees),
- WUE in relation to water quality,
- relationships between WUE and mineral supply.

References

M Mastrorilli et al., 1999. Europ. J. of Agron., 11, 3-4, 206-216
EFFECT OF WINDBREAKS ON YIELD AND CONSUMPTIVE WATER USE

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Introduction
The limited water resource implies the necessity to search agronomic solutions to improve the water use efficiency in Mediterranean environment. Since any climatic scenario indicates reduction in precipitation and increase in evapotranspiration, how farms can adapt to the future climate? Among the agro-techniques specific for the dry-farming systems, windbreaks mitigate the aerodynamic and thermal components of the evapotranspiration. In the Mediterranean area, the agronomic studies on windbreaks are limited. Fragmentary informations are derived by trial experimental in Italy (Casa et al., 1993) and in Tunisia (Ben Salab et al., 1989), while exhaustive experiments have been set-up in North America and Australia (Cleugh et al., 2002), under conditions which differ from the Mediterranean farming systems. Since actual benefits on Mediterranean crop water requirements are not quantified, a 3-year field study has been carried on. Results on wheat and bean grown in presence of windbreaks are here reported.

Methodology
The work was conducted in 2003 – 2005 at the experimental farm of the Agronomical Experimental Institute of Rutigliano (41°01’N, 17°01’E, 122 m asl). Soil has a clay texture, with a mean depth of 0.60 m, due to the presence of underlying calcareous rock. Soil Available Water Capacity is low (102 mm). The climate of Rutigliano is characterized by a mean annual rainfall value of 610 mm, concentrated mainly in late fall and early spring seasons. Summer is generally dry and evapotranspiration demand is much higher than precipitations.

The study concerned the rotation durum wheat (cv. Simeto) – bean (cv linguarossa). A Cupressus arizonica windbreak (3 m in height) bordered at North the experimental field (200 x 80 m). It was divided in 7 sub-plots at different distances from the windbreak. Each sub-plot was harvested for determining yield and its components and it was equipped with micro-meteorological sensors (wind-speed, air temperature and humidity) and TDR probes.

Results
The microclimatic survey allowed to define the extent of canopy zone influenced by the windbreaks. Any influence of windbreak was monitored on air humidity. When wind blew from the North direction, temperature increased in a distance of 5H (H is the windbreak height) from the barrier, at further distance, windbreak didn’t affect the air temperature. For the summer crop (bean) the air temperature increase (3 °C) was higher than for wheat (fig. 1a). The windbreak presence influenced the wind speed until the distance 15H, for both crops (fig. 1b).

On the basis of the soil water content, continuously measured by TDR technique, evapotranspiration (ET) was daily determined as the unknown term of the soil water balance equation. Windbreaks mitigated seasonal ET for a distance of 15 times the windbreak height. Out of this area, the seasonal evapotranspiration was 16% and 18% higher for wheat and bean, respectively (fig. 1c).

Yield performances changed accordingly the distance from the windbreaks. Within the distance of 12 times the windbreak height, wheat productions were higher than those obtained in the zone not influenced by windbreak (fig. 1d). These differences of yield with the distance from the windbreak were not statistical significant in the case of bean.

Data of yield and seasonal ET let to calculate the water use efficiency (WUE). WUE was improved if crops are protected by windbreaks. Within the protected area, WUE attained the maximum value of 1.2 for the wheat and 1.4 kg m⁻³ for the bean crop; out of the windbreak protection WUE was 0.7 and 1.1 kg m⁻³ for wheat and bean, respectively.
Conclusions
Since windbreaks reduce ET without affecting yield, farms of the Mediterranean environments should be re-designed in order to consider the windbreaks as possible issue of sustainability for vegetal productions.

References
ADAPTING DRYLAND WHEAT PRODUCTION SYSTEMS OF IRAN TO CLIMATE CHANGE

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Introduction
Rainfed wheat accounts for about 60-65% of the cultivated wheat area and contributes 30-35% of wheat production in Iran. While the demand for wheat is predicted to be over 20 Mt in 2025, results of impact studies have shown average country level yield reduction of 18 and 24% for target years of 2025 and 2050, respectively (Nassiri et al., 2006). Adapting to climatic variability will have a substantially greater effect in reducing impact than will mitigation. However, adaptive measures for dry land systems of Iran are poorly investigated. The purpose of this study was predicting the effects of adaptation and evaluating these strategies based on adaptation costs and benefits.

Methodology
This study concentrated on the 12 major rainfed areas of rainfed wheat production in west, northwest, northeast, and north central parts of Iran. Climatic data were collected from the nearest weather stations to the rainfed growing areas from 1968 to 2000. Weather data generated from mean monthly values were used with UKMO General Circulation Model. The adopted UKMO climate change scenarios in this study for years 2025 and 2050 are based on recently published data for the country (Koocheki et al., 2006). [CO2] for these targeted years have been reported to be 425 and 500 ppm (IPCC, 2001). To satisfy the spatial resolution of the crop model, statistical downscaling method was used. The World Food Study (WOFOST) v 7.1 crop growth model was used (Boogard et al., 1998) for simulation of rainfed wheat yield under current and predicted climatic conditions for the target years, after validation (Nassiri et al., 2006). Wheat yield was also simulated under future climatic conditions with adaptation strategies such as changing cultivars and planting dates. Changes in site yield (t ha\(^{-1}\)) were scaled to regional productivity (tons) using the existing average regional production statistics and the change in yield under a given global change scenario. For example, the production is summed and the total is multiplied by the change in yield predicted by the simulation model with and without adaptation. Regional crop value is calculated from the regional productivity and the revised crop value. This was compared with baseline values with no global change. These regional values were then aggregated to give national production.

Results
National mean yield predicted for the base-line climate (1968-2000) was 900 kg ha\(^{-1}\) ranging from 500 kg to 3.5 t ha\(^{-1}\). In 2025 and 2050, the geographical distribution of yield potential was not predicted to change, but the yield in all areas was predicted to decrease, with possibly greater decreases to the North West (Fig. 1). For all studied sites, yield was reduced by about 19 to 28% for 2025 and 2050, respectively. This yield reduction is mainly due to decreased length of growth period and increased water deficit days (Koocheki et al., 2006) leading to earliest harvest time of currently sown cultivars. Therefore, potential improvements in wheat adaptation for climate change in Iran may include introduction of new cultivars and changing management practices like sowing dates. Including such an adaptation strategies in the simulation model was led to considerable yield improvement under climate change scenarios (Fig. 1).

On a national basis, mean wheat production may decrease in the years 2025 and 2050 by 24 and 31% from current levels, respectively (Table 1). When adaptations of changing varieties and changing planting windows (to take advantage of drought risk) were simulated across the wheat growing regions for the target years, there was a marked offsetting of the negative impacts of global change (Table 1). Similarly for value of production, when management was adapted to cope with climate change, mean value of production was higher than when no adaptations were used. The grain prices assumed in this study will change by the target years due to changes in both global supply and demand and we have used these prices for comparative purposes only.
Figure 1: Simulated reduction of rainfed wheat yield in the major wheat growing regions of Iran under climate change conditions compared to national yield average. a) Year 2025; b) year 2050. (Vertical bars show SE of sites within each region).

However, studies of possible climate change impacts on global supply and demand (e.g. Rosenzweig and Parry 1994) suggest only relatively minor changes in prices due to similar changes in both factors.

Table 1: Effect of climate change for the years 2025 and 2050 on percent change in average production and value of production assuming either current management practices or adapted management practices. The values in parentheses are the maximum and minimum values.

<table>
<thead>
<tr>
<th></th>
<th>Year 2025</th>
<th>Year 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production - current</td>
<td>-24.3 (± 6.8)</td>
<td>-31.8 (±9.5)</td>
</tr>
<tr>
<td>- adapted</td>
<td>-8.0 (± 5.3)</td>
<td>-9.9 (± 6.1)</td>
</tr>
<tr>
<td>Value of production - current</td>
<td>-22.1 (± 7.2)</td>
<td>-37.2 (± 11.2)</td>
</tr>
<tr>
<td>- adapted</td>
<td>-9.4 (± 4.2)</td>
<td>-11.2 (± 8.7)</td>
</tr>
</tbody>
</table>

Conclusions
Simulation results obtained by WOFOST model showed that among different studied strategies, using new rainfed wheat cultivars with higher tolerance to drought/higher water use efficiency and changing planting dates are the most efficient management practices and prevent yield reduction under defined future climate scenarios up to 85%. The results indicated that investment in developing adaptation strategies could be highly effective. Use of these readily implemented adaptation strategies are profitable based on the available resources by improving both national rainfed wheat production and value of production compared to the same climatic scenarios without adaptation.

References
Introduction
Agriculture is particularly sensitive to climate changes and crop models have been extensively used in impact assessment studies to simulate the effects of elevated CO2 and Global Circulation Models (GCM)-generated climate scenarios on crop growth and yield (e.g. Tubiello et al., 2006). The magnitude and direction of climate change impacts on crop yields will vary locally, because of regional differences in both natural and anthropogenic factors that control plant response. Several studies have assessed the effects of climate change on agricultural productivity at various scales, but more case-studies remain to be assessed (especially in the Southern hemisphere, Tingem et al., 2007) to give more focus to generalizations that often characterize regional and global assessments. Argentina is a major farming country, where climate variability is one of the most important sources of risk for agricultural production. The main objective of this study was to explore the impact of climate change on the agriculture of an Argentinean region (La Pampa Huméda).

Methodology
The study-region is located north of 40 °S and east of 67 °W. Three sites were selected for this study: Pergamino (33.90 °S, 60.57 °W), Anguil (36.50 °S, 64.02 °W) and Marcos Juárez (32.68 °S, 62.10 °W). Daily weather data of maximum and minimum air temperature (°C) and precipitation (mm) were collected at each site in the period 1980-2000. At each site, 19 climate scenarios - a baseline scenario, representing current climate conditions, and 18 scenarios of climate change – were generated. Climate change scenarios consisted of 20-year continuous time series of daily air temperature and precipitation, produced from the original observed weather files for two future decades (2045-2064, 2081-2100) by means of three GCMs, mpi_echam5, ipsl_cm4, and cnrm_cm3, according to the IPCC scenarios A2 ([CO2] 414, 677 ppm), A1B ([CO2] 414, 600 ppm) and B1 ([CO2] 414, 540 ppm). Simulations were run using both the model CropSyst and DSSAT for cropping systems (CS) representative of the three sites. Daily weather data of both 20-year base and projected scenarios were used as input to cropping systems models to simulate crop production under conditions of current and changed climate.

Results
Simulated scenarios of future climate show common trends with larger differences between alternative GCM towards the end of the 21st century. The A2 scenario was identified as expected the most critical for CS productivity. Yearly precipitation (Fig. 1) is estimated to increase, particularly over summer months. Air temperature (Fig. 2) is also expected to increase, markedly for ipsl_cm4.
Some simulation results are presented. For maize yield, Fig. 3 shows variations with respect to baseline conditions under rainfed and irrigated conditions. Water use was also estimated. The responses ranged from a general yield reductions estimated for Anguil (with no adaptation) to mixed situations occurring at Marco Juarez and Pergamino. Similar responses were observed with other crops (data not shown).

**Fig. 3.** Rainfed and irrigated maize yield (and water use) changes (scenario A2) at three sites.

Conclusions
GCM estimates vary across the three sites, although ipsl-cm4 is consistently the most critical one. Diverse crop responses to CC scenarios were observed showing a different variability of yields mostly due to air temperature impacting on crop cycle length. Adaptation to CC may alleviate their impact (at times outperforming current CS). Water use due to adaptation is not always larger than the baseline, due to improved rainfall patterns. Estimated yield variability, although varying with crop, environment and GCM model, is in general expected to be larger than observed under current conditions, and it represents at this stage the major concern in future scenarios.

This research is funded by the EU project CLARIS (A Europe-South America Network for Climate Change Assessment and Impact Studies, [http://www.claris-eu.org](http://www.claris-eu.org)).

**References**
SUSTAINABILITY OF AGRICULTURAL PRODUCTION SYSTEM IN A CHANGING CLIMATE

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Introduction
It is widely accepted that our climate is changing due to increasing atmospheric concentrations of the ‘greenhouse gases’ and these changes may determine strong impacts on different economic sectors. In particular for agricultural systems, such a change may have significant impacts for crop yield, cattle breeding and their management practices. Accordingly, the sustainability of agricultural production system in the future scenarios is a main concern especially for policy-making purposes. Unfortunately, many global change impact assessments in agriculture concerned mainly the performance evaluation of a single part of the system whereas a ‘holistic’ approach was neglected. On these premises, the objective of this paper was to use the downscaled outputs of a general circulation model (GCM) (Tmin, Tmax, Rainfall and Radiation) as climate input drivers in a comprehensive farming system toolkit of methods for a more comprehensive global change impact assessment on agricultural systems at local scale. In particular, an ecological–economic optimisation model was run for the present and future scenario for an integrated assessment of sustainability of conventional and organic dairy farming systems (CFS, OFS respectively) in Tuscany region (Italy).

Methodology
In this work, the two synthetic climate series representing present and future climate conditions (daily Tmax, Tmin, rainfall and solar radiation) were used as input variables of Cropsyst model to derive the impacts of climate change on crop and soil parameters (e.g. actual and potential evapotranspiration, AET and PET; soil erosion and nitrogen leaching). Such parameters, in turn, were used to feed a farm and field-scale optimisation model already validated for conventional and organic dairy farming in northern Tuscany (Pacini et al., 2004) (Fig. 1).

![Diagram of modelling framework for the evaluation of climate change impact on farming systems](image)

In particular, the synthetic climate data were obtained using: a) the observed meteorological data recorded at the weather station of Borgo San Lorenzo, Italy (Lon 11.4 Lat 44.0, 290 asl); b) the result of a GCM (CCCma model, A2 emission scenario, 2007-2037 time window); c) the LARS weather generator. The Cropsyst model was used to simulate the soil water budget, soil-
plant nitrogen budget, dry matter production, yield, and erosion. Management parameters such as sowing date, cultivar genetic coefficients, soil profile properties (soil texture, thickness), fertilizer and irrigation management, tillage, atmospheric CO$_2$ concentration were properly selected depending on farming system. The Outputs of Cropsyst were fed into the integrated farm management optimisation model. Such a model was constructed starting from a Linear Programming economic model and the input-output matrix was extended to include emission and evaluation figures retrieved from ecological models (Cropsyst). Finally, the global change impact on 6 site-specific farm rotations was assessed including conventional and biological management (Tab. 1).

Table 1. Site-specific rotation implemented in the modelling framework

<table>
<thead>
<tr>
<th>Site</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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</thead>
<tbody>
<tr>
<td>FS</td>
<td>CFS</td>
<td>OFS</td>
<td>CFS</td>
<td>OFS</td>
<td>CFS</td>
<td>OFS</td>
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</table>

Rotation

<table>
<thead>
<tr>
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<th>B-BB</th>
<th>MS-B-R-3A</th>
<th>MS-B-BB-B-3A</th>
<th>MG</th>
<th>MG-I</th>
<th>MG-B-Mg-B-3A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2-3-4-5-6</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Optional rotations included in the conventional and organic version of the model

1 Crop legend: A, Alfalfa; B, Barley; BB, Broad bean; MS, Maize for silage; R, Italian ryegrass; MG, Maize for grain; MGi, Maize for grain - irrigated
2 sites 1 and 2 are hilly, sites 3 to 6 are flat, and sites 4 and 5 have irrigation facilities
3 conventional farming system
4 organic farming system

Results

The results of this preliminary modelling work indicated some common trends for OFS and CFS in the near future. In particular AET and nitrogen leaching decreased for both farming systems, soil erosion increased whereas gross margin and herd size were found to be substantially stable for CFS and increased for OFS (Fig. 2)

Conclusion

Climate change caused considerable impacts both on OFS and CFS. These impacts, however, differentiated in terms of trend directions and intensities. Future research will include a further exploration of climate change impacts using other GCM and for other future time windows.

References

1. Introduction

Agricultural water rights in the Murray Darling Basin, Australia are volumetrically defined and have been unbundled from land rights, such that the water can be traded in the market. Seasonal or temporary water trading assists irrigators to adjust their water supply by purchasing additional supplies or temporarily selling water to enhance returns to their farming enterprise and boost productivity (Etchells et al., 2006). But neither the information on water allocations nor future water trading prices are available beforehand. Asymmetric information remains the main obstacle to water trading decisions for efficient land and water allocation (Brill et al., 1997).

The price variations create uncertainty and discourage irrigators to participate in water marketing (Australia, 2006). When information on water prices is imperfect, transaction costs could be higher and opportunities for trade may be foregone. However, if farmers have prior information on water trading prices, they can more efficiently plan their crops with better understanding of either buying additional water or selling surplus water. This paper contributes to the literature on water markets and price forecasting. Specifically, it aims to forecast quarterly water trading prices for trade in temporary water rights using the artificial neural network.

2. The Methodology

The study was conducted in Murray River Basin, where Murray Irrigation Limited supplies an annual bulk water entitlement of 1,479 Gigalitre to irrigators, serving some 2,416 landholdings with a total area of 748,000ha. Land use pattern shows the diverse nature of agriculture in the region. Major crops include cereal and oilseeds, rice, and annual pastures for grazing and dairy stock.

To forecast temporary water trading prices, the artificial neural network (ANN) approach was used because of its availability to capture nonlinearities in the system without human intervention (Lawrence, 1997). There models were developed—basic, intermediate and full—to cater for different level of input availability. The main inputs for ANN models include quarterly prices of cereal, meat, grapes, water trading, general security water allocation and standard precipitation index.

To obtain good relationship with better correlation coefficients, networks with different topologies of ANN models were trained and optimised by changing the internal parameters. The Radial Basis Function was used as it performed best among different models tested.

3. Results and Discussion

The performance of the model would be judged by its ability to accurately predict water prices. Despite drought driven volatility of the actual price curves in 2002/03 and in 2006/07, the model generated forecasts fit the actual data curves closely (Figure 1) for the respective months.
Using entire data set, all models indicate better prediction between actual prices and the forecasted prices. Overall the full model show better forecast; it was due to the inclusion of all pertinent variables in the model which contributed to capturing the volatility of price moments in low water allocation periods such as dry year 2002/03, where allocations were very low and 2006/07 where initial allocations are close to zero (up to March 07). The results show that next quarter trading prices are mainly driven by current prices (Table 1).

Table 1  Summary of parameter contribution for all models

<table>
<thead>
<tr>
<th>Performance Type</th>
<th>Basic Model</th>
<th>Intermediate Model</th>
<th>Full Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary water trading price ((Pw(m)))</td>
<td>62 %</td>
<td>52 %</td>
<td>20 %</td>
</tr>
<tr>
<td>Temporary water trading price ((Pw(m-1)))</td>
<td>38 %</td>
<td>21 %</td>
<td>18 %</td>
</tr>
<tr>
<td>General security water allocation ((m))</td>
<td>--</td>
<td>8 %</td>
<td>7 %</td>
</tr>
<tr>
<td>General security water allocation ((m-1))</td>
<td>--</td>
<td>9 %</td>
<td>6 %</td>
</tr>
<tr>
<td>General security water allocation ((m-2))</td>
<td>--</td>
<td>7 %</td>
<td>2 %</td>
</tr>
<tr>
<td>Standard Participation Index ((SPI)(m))</td>
<td>--</td>
<td>3 %</td>
<td>1 %</td>
</tr>
<tr>
<td>Cereal price ((m))</td>
<td>--</td>
<td>--</td>
<td>20 %</td>
</tr>
<tr>
<td>Grape prices ((m))</td>
<td>--</td>
<td>--</td>
<td>12 %</td>
</tr>
<tr>
<td>Meat price ((m))</td>
<td>--</td>
<td>--</td>
<td>14 %</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Cereal includes wheat, maize, oat, barley and rice. Meat includes beef, lamb, chick and pork. -- Not applicable.

All three models were tested for predicting temporary water trading prices for November 2006 to April 2007 (Tables 2). The models show good predictive capabilities, as the model predicted temporary water trading prices were close to actual water trading prices. Among the three models, full model indicate minimum error, primarily due to inclusion of relevant variables. The full model was also better to forecast future water prices. For instance, forecast error margins are lower for the full than the intermediate or basic model and this holds for all quarters.

Table 2  Forecasting temporary water trading prices using Artificial Neural Network

<table>
<thead>
<tr>
<th>Quarter ending</th>
<th>Actual price ($/ML)</th>
<th>Basic Model</th>
<th>Intermediate Mode</th>
<th>Full Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 06</td>
<td>307</td>
<td>277</td>
<td>9.8</td>
<td>296</td>
</tr>
<tr>
<td>December 06</td>
<td>461</td>
<td>448</td>
<td>2.8</td>
<td>445</td>
</tr>
<tr>
<td>January 07</td>
<td>602</td>
<td>624</td>
<td>3.7</td>
<td>632</td>
</tr>
<tr>
<td>February 07</td>
<td>696</td>
<td>693</td>
<td>0.4</td>
<td>687</td>
</tr>
<tr>
<td>March 07</td>
<td>705</td>
<td>673</td>
<td>4.5</td>
<td>687</td>
</tr>
<tr>
<td>April 07</td>
<td>718</td>
<td>625</td>
<td>13.0</td>
<td>638</td>
</tr>
</tbody>
</table>

4 Conclusion

This paper shows that artificial neural network successfully forecast temporary water trading prices, given their ability to simulate complex and non-linear processes often not addressed adequately by conventional regression or time series models. Case study results in the Murray Irrigation Area in Australia show that water trading prices can be successfully predicted with an error margin less than 5%. The models can be integrated into commercial softwares for online water trading price forecasting. The results can be used for managing price risk volatility, contingency planning, irrigation infrastructure investments and asset management decisions.

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RECONCILING ADAPTATION AND MITIGATION TO CLIMATE CHANGE IN AGRICULTURE

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Introduction

Climate change is expected to affect agriculture very differently in different parts of the world (Parry et al., 2004). The resulting effects depend on current climatic and soil conditions, the direction of change and the availability of resources and infrastructure to cope with change. The economic consequences may be considerable on a global scale, and it has recently been estimated that the costs of climate change greatly exceed the costs associated with reducing greenhouse gas emissions (Stern, 2006). However, the emissions and the related consequences occur on very different timescales, making economic evaluations difficult not only due to uncertainties in predictions of climate changes and impacts, but also due to uncertainties in the costs of technologies to mitigate change. Taking proper action on mitigating and adapting to climate change also requires long lead times, which have impacts on how related policies should be devised and implemented.

Adaptation to climate change

To avoid or at least reduce negative effects and exploit possible positive effects, several agronomic adaptation strategies for agriculture have been suggested. Studies on the adaptation of farming systems to climate change need to consider all the agronomic decisions made at the farm level. Economic considerations are very important in this context. The agronomic strategies available include both short-term adjustments and long-term adaptations. (Easterling, 1996). Most of the short-term adjustments involve relatively little cost to the farmers, since they are often just extensions of the existing schemes to deal with climatic variability. However, long-term adaptations and changes in farming systems, institutions, land use etc. may carry considerably higher costs. Some of these costs can be reduced, if timely action is taken (Stern, 2006). However, there is a need at regional, national and international levels to analyse the needs for such planned adaptation options, their costs and their time horizon.

Mitigation in agriculture

A major part of the agricultural greenhouse gas (GHG) emissions originate from methane (CH$_4$) and nitrous oxide (N$_2$O) from livestock, manures and soils. The intensive carbon and nitrogen cycling on livestock farms may cause these farms to be particularly large sources of both methane and nitrous oxide emissions (Oenema et al., 2005). However, the emissions are greatly affected by both environmental conditions and management, and there most likely is a considerable scope for reducing emissions by improving management and through introduction of new technologies, in particular in feeding and handling of manures. For arable land the most important greenhouse gases are N$_2$O and CO$_2$ (Six et al., 2004) and management practices highly affects the emissions. The CO$_2$ fluxes are affected through the carbon inputs and through tillage, which affect the soil carbon turnover rate by affecting soil organic matter protection. The N$_2$O fluxes are primarily affected through nitrogen inputs.

Links between adaptation and mitigation

Many of the options available for adapting agricultural activities will influence the emissions of greenhouse gases either by enhancing or reducing the fluxes. However, it should be kept in mind that agricultural activities affect several greenhouse gases simultaneously, and it is the net effect on the global warming potential of all gases that should be considered. There may also be differences between short- and long-term responses to introduction of system and management changes, in particular for measures that involve changes in soil management and input of carbon and nitrogen to the soil. There are very few studies available linking adaptation and mitigation in agriculture, so only a few speculations can be made.
It may be particularly difficult to obtain increases in soil carbon storage or even maintain current stocks, since the global warming will inevitably lead to higher turnover rates of soil organic matter, which will only partly be compensated by increased inputs.

Several water-conserving practices are commonly used to combat drought. These may also be used for reducing climate change impacts. Such practices include conservation tillage, which is the practice of leaving some or all the previous season’s crop residues on the soil surface in combination with non-inversion tillage. This may protect the soil from wind and water erosion and retain moisture by reducing evaporation and increasing the infiltration of rainfall into the soil. These practices also have major impacts on GHG emissions.

Irrigation is a commonly proposed adaptation option for coping with increased summer droughts. Irrigation management can be used to improve considerably the utilisation of applied water through proper timing of the amount of water distributed. When irrigation is applied this will increase crop productivity and usually also the amount of crop residues returned to the soil, which will increase carbon sequestration. However, the energy use associated with irrigation can often be a major component of the GHG balance of irrigated systems.

**Conclusions**

An effective adaptation to the changing climate at farm, sector and policy level is a prerequisite for reducing negative impacts and for obtaining possible benefits. These adaptations include land use and land management, as well as changes in inputs of water, nutrients and pesticides. Some of the most wide ranging adaptations involve changes in water management and water conservation, which involves issues such as changing irrigation, adoption of drought tolerant crops and water saving cropping methods (e.g. mulching and minimum tillage). Many of these adaptation options have substantial effects on greenhouse gas emissions from agriculture. However, so far few studies have attempted to link the issue of adaptation and mitigation in agriculture. This is primarily because the issues have so far been dealt with by different research communities and within different policy contexts. As both issues are becoming increasingly relevant from a policy perspective, these issues will have to be reconciled. Dealing with these issues requires a highly interdisciplinary approach.

**References**


AGRO-METEOROLOGICAL METRICS TO COMMUNICATE CLIMATE CHANGE IMPACTS TO LAND MANAGERS

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Introduction

Agro-meteorological metrics and soil water balances are important indicators of conditions that influence farm scale decision making. Metrics derived from projected future climates provide an opportunity to characterise the impacts of climate change (CC) on agricultural practices. Such indications are vital for determining how changes in the biophysical environment can lead to adaptations to farming systems. Regional Climate Models (RCM) produce estimates at the 50×50 km grid cell scale, hence there is a need to downscale to the farm level to enable site-specific CC impacts studies (Rivington et al 2007a), e.g. using agro-meteorological metrics. It is also important to include stakeholders in the evaluation of the metrics (Matthews et al 2007), in terms of comprehension of the forms of presentation and utility in aiding adaptation strategy development.

Methodology

Weather data from the Hadley Centre HadRM3 RCM for the period 1960-1990 (hindcast) (http://www.metoffice.gov.uk/research/hadleycentre) were compared with observed data from 15 stations in the United Kingdom. This provided evidence of where and when the RCM was either able or unable to make good estimates of the past climate (Rivington et al 2007b). Based on the differences between modelled and observed data, monthly downscaling factors (DF) were developed for precipitation, max and min temperature and solar radiation. DF were applied to the hindcast data which were then re-compared with observations to determine the improvement in match. The DF were then applied to future projection data (A2 medium-high emissions scenario for 2070-2100, IPCC, 2000). The 1960-1990 observed and 2070-2100 downscaled future projection data at six sites in Scotland were then used to produce a range (34) of agro-meteorological metrics. These were presented to different groups of land manager based stakeholders for evaluation.

Results

The HadRM3 produces data that approximate the mean conditions at a specific site reasonably well, but contain too many errors for the data to be used to derive metrics directly. The number of dry days was greatly under-estimated, while minimum temperature and solar radiation were over-estimated. Variables were however sufficiently similar overall to permit meaningful adjustment by downscaling. The DF greatly improved the match between observed and hindcast estimates (data not shown).

Table 1. Summaries of metrics for six locations. ► = increase or later in year, ◄ = earlier in year from observed

<table>
<thead>
<tr>
<th></th>
<th>Aberdeen</th>
<th>Mylnefield</th>
<th>Camwath</th>
<th>Dumfries</th>
<th>Eskdalemuir</th>
<th>Auchincruive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Daily Temp (°C)</td>
<td>2.8</td>
<td>3.1</td>
<td>2.8</td>
<td>3.3</td>
<td>3.0</td>
<td>2.8</td>
</tr>
<tr>
<td>Average Annual Rainfall (mm)</td>
<td>36</td>
<td>26</td>
<td>35</td>
<td>100</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>Start of Growing Season (day)</td>
<td>48</td>
<td>35</td>
<td>37</td>
<td>27</td>
<td>50</td>
<td>14</td>
</tr>
<tr>
<td>Tsum200 (day)</td>
<td>22</td>
<td>22</td>
<td>21</td>
<td>22</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>End of Field Capacity (day)</td>
<td>3</td>
<td>2</td>
<td>na</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Last Air Frost in Spring (day)</td>
<td>42</td>
<td>41</td>
<td>52</td>
<td>36</td>
<td>49</td>
<td>37</td>
</tr>
<tr>
<td>Return to Field Capacity (day)</td>
<td>14</td>
<td>18</td>
<td>na</td>
<td>23</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>End of Growing Season (day)</td>
<td>17</td>
<td>17</td>
<td>16</td>
<td>19</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>Access Period Length (days)</td>
<td>11</td>
<td>19</td>
<td>na</td>
<td>47</td>
<td>22</td>
<td>30</td>
</tr>
<tr>
<td>Access in Growing Season (days)</td>
<td>20</td>
<td>26</td>
<td>na</td>
<td>51</td>
<td>30</td>
<td>33</td>
</tr>
</tbody>
</table>

Stakeholders were able to discern possible effects of CC directly from meteorological summaries, but the use of metrics (Table 1 for selected sites) enhanced their ability to generate specific adaptations strategies (Matthews et al 2007). Stakeholders identified additional metrics with greater utility, which were derived by combining different existing metrics (Fig. 1C). Average daily
temperature may increase by ~3°C (Table 1, Fig. 1A for Mylnefield), while annual rainfall total is expected to remain similar, but with greatly different seasonal distribution (Fig. 1B). Whilst growing season is estimated to expand (starting earlier and finishing later) (Fig 1C), and temperature based start of field operations (i.e. Tsum200, Fig.1D) are projected to occur earlier, return to field capacity will remain the same, posing possible access restrictions at a time when growth conditions will be favourable. Crop access to water will be restricted more severely and more often. Warmer temperatures in winter and lack of frosts may result in increased pests and pathogens.

Figure 1. Meteorological summaries (A and B) and agro-meteorological metrics (C and D) for multi-year observed (blue) and downscaled future climate data (red) at Mylnefield, Scotland. C is a combination of growth days (mean temp >5.6 °C for five consecutive days) and field access days (where the soil moisture is more than 5 mm below field capacity). Tsum200 is the thermal time accumulation to 200 °C-days.

Conclusions
Consideration of CC impacts on farm system design requires careful appraisal of the quality of climate model projections, evaluated by assessing their ability to represent the past climate. Simple methods of downscaling greatly improve the utility of future projection estimated agro-meteorological metrics. Projected changes indicate there will be both positive and negative impacts on farming from CC in Scotland, but substantial changes to management may be required to maximise the potential and minimise the risks. Information from site-specific agro-metrics is vital in order to adjust existing forms of farm management and develop appropriate mitigation and adaptation strategies to cope with future climate change.

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CLIMATE CHANGE AND SOIL ORGANIC CARBON DYNAMICS: APPLICATION OF DSSAT CROP MODELS

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Introduction

Agriculture is highly dependent on weather, and therefore changes in global climate could have major effects on crop yields and world food supply. Potential effects are difficult to assess not only because of the uncertainty in the magnitude of changes in climate variables, but also because of uncertainties in crop responses to combinations of CO₂, weather, soils, and management factors, the spatial variation of these factors, and the uncertainties in the evolution of global social, political, and land-use systems. (Jones et al. 1995). While some key interactions between elevated CO₂ effects and crop management, especially irrigation and fertilization regimes, are fairly well understood (Tubiello et al., 2007), the real strength of the effects of elevated CO₂ and temperature on crop yields and related implications on cropping systems in farmer’s fields is still largely unpredictable, because of several key uncertainties.

Climate change could alter terrestrial carbon (C) storage as changes in temperature, precipitation and atmospheric CO₂ concentration could affect net primary production (NPP), C inputs to soil and soil C decomposition rates. Higher atmospheric temperatures anticipated in future climate scenarios will lead to warmer soil conditions that are likely to increase the rates of organic matter decomposition and rates of other soil processes that affect fertility. In this context, there is an increasing need to develop a range of local options for the adaptation of cropping systems to future climate scenarios and for mitigation strategies.

The objective of this study is to analyze the impacts of climatic change scenarios on characteristics of soil organic carbon in the most common hill-land cropping systems of central Italy, and thus to provide information to support the development of mitigation strategies by the calibration of the DSSAT model (Decision Support System for Agrotechnology Transfer) incorporating the CENTURY SOM module (Gijsman et al., 2002). This study used a version of the DSSAT 4.02 crop models that incorporates tillage effects on soil processes.

Methodology

The experiment was established at the farm of the Faculty of Agriculture 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 a silt-clay soil type. A split-plot with two randomised blocks was designed to compare three tillage techniques (T) as main plot (P: conventional 40 cm deep ploughing; M: scarification at 25 cm; S: sod seeding) and three nitrogen fertilisation rates (N) as subplot (0–90–180 Kg N ha⁻¹ for each crop) in a 2-year crop rotation (durum wheat - corn). The main and sub-plot sizes were 1500 m² and 500 m², respectively. Wheat and corn were alternatively sown on two adjacent groups of 18 sub-plots (3T x 3N x 2rep), so that both crops were sown every year. Observed daily meteorological data (Tmax, Tmin, precipitation) from 1998 to 2005 and daily radiation estimated from air temperature data using the Radest 3.00 (Donatelli et al. 2003) were used as meteorological inputs.

Texture, bulk density, organic carbon, cation exchange capacity, pH, total nitrogen were measured from sixteen different soil profiles within the experimental field, while lower limit, drained upper limit, saturation and saturation hydraulic conduct were estimated with pedo-transfer functions (Saxton, 2006). Yield and main yield components were monitored for both crops.

Two types of future climatic scenarios, obtained from the “transient GC” model of the Hadley Center, are used for climate input to the DSSAT model to simulate changes in soils over a 100-year time period. “Equilibrium” scenarios contain 50-years climatic series developed by assuming steady CO₂ concentrations in each of the following series: “baseline”, “2040” and “2090”, using the emission scenario of “business as usual” (Is-92a) (Donatelli et al. 2002). “Transient” scenarios are composed of two 100-year climate data series characterised by two different progressive CO₂ concentrations.
increases according to emission scenarios (A2 and B2) as a result of different socio-economic
developments (IPCC, 2007).

Results and conclusions
Simulations will produce 50-year “Equilibrium” results for each of the three selected analysis series
(baseline, 2040, and 2090). In addition, simulations will be made for the 100-year transient
scenario of weather data. Analyses of changes in soil carbon and crop yield will be made to
compare each scenario result vs. result of current climate conditions. Model outputs will be
discussed for a durum wheat – corn rotation in relation to crop productivity and long term estimates
of soil organic matter content variation. The results will be discussed also in relation to different
tillage techniques and nitrogen fertilization rates to show possible changes of current agronomic
practices to prevent negative impacts of climate change on cropping systems and to enhance soil
C. DSSAT simulations will also be compared to results obtained in the same area with other
models in order to understand better different processes by comparing several simulation tools and
to plan sustainable and feasible cropping systems (De Sanctis et al., 2006; Ferrara et al., 2007).

Acknowledgements
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THE INFLUENCE OF CLIMATE WARMING ON POTATO PLANT DEVELOPMENT IN POLAND

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Introduction

Potato as a plant of moderate climate is very popular and commonly cultivated in Poland. Optimal temperature for its development is about 20°C but is differ for above part of plants (20-25°C) and for tubers (15-20°C). Under conditions of temperature higher than optimal the tuberization and tuber growth is limited or stopped. The prognosis of global climate warming enjoin to special study making. The aim of our experiment was the determination of high temperature stress effect during potato growth period on plant development and yield by using both classical and chlorophyll a fluorescence methods.

Methodology

The experiment was conducted in the year 2006 in Jadwisin, 34 km from Warsaw. Meteorological data were noted by automatic meteorological Campbell’s station. Potato minitubers of different size and traditional seeds of two potato cultivars: Tara (middle early) and Jasia (middle late) were planted on 23 April in randomized plots with four replicates in the experimental field. The size (transverse diameter) of mintubers was 1, 2, 3, 4 cm and traditional seeds – 5 cm. During growth period particular stages of plant development were determined as well as Leaf Area Index (LAI) and Photosynthetic Active Radiation (PAR) using LI-COR 3100 Area Meter (LI-COR, Lincoln Nebraska - USA) at the time of flowering. From the beginning to the end of potato growth, in the interval of two weeks, Plant Efficiency Analyzer HandyPEA (Hansatech Instruments Ltd., UK) was used to measure basic chlorophyll a fluorescence parameters: minimal fluorescence (Fo), maximal fluorescence (Fm), maximum quantum efficiency of photosystem II (Fv/Fm), variable fluorescence (Fv), time at which Fm occurs (Tfm), area over the curve between Fo and Fm (Area) and finally vitality index of PS II (PI). During drought period the experimental field was irrigated (total water dose30 mm). The yield was determined in the middle of September after haulm destruction. Analysis of variance (two and three ANOVA) was carried out, using the Student test at P<0,05 to compare means.

Results

The period of potato growth characterized by small amounts of rainfall and very high temperature. The sum of rainfall in Jadwisin during the months May-September amounted to 278,1 mm and was lower than multi-year average by 63,6 mm. The most unfavorable conditions for potato development took place in July when the sum of rainfall was only 9,2 mm and average maximum temperature 28,1°C. Unfortunately during 12 days exceed 30°C and reached 33,3°C. Water deficiency in the soil was alleviated by irrigation. Thermal conditions and soil moisture improved in August. The sum of rainfall in this month amounted to 156, 1 mm and the average air temperature brought down to 17,0°C and in the first decade of September until 14, 9°C on the average.

The plant development of tested cultivars in the first stages was correct. After growth termination, the indices LAI and PAR were dependent on potato seed tuber size. LAI was on the average 1,67 - the highest in case of plants grown from traditional seed tubers (2,00), and PAR was on the average 408 μmol m⁻² s⁻¹ and was the highest on the experimental plots where were used the smallest minitubers (597 μmol m⁻² s⁻¹).
However in July, in spite of the field irrigation, a physiological state of plants fell into a decline, not depending on the cultivar and a size of seed tuber. Plants were withered and their development was stopped what was connected with very high air and soil temperature exceeding 30°C. The results of basic chlorophyll a fluorescence parameters which were measured during whole growing period showed that on 8th July took place an intense decrease of photosynthetic activity lasting during the time of high temperature stress. The vitality index of PSII (Pi) turned out to be the best parameter of physiological state of potato plants. The resumption of photosynthetic activity was followed after an improvement in the thermal conditions. At the time, changes in habit of plants were observed. They were caused by second growth, which took to prolongation of growing period. In consequence, mechanical haulm destruction was indispensable before harvest.

The tuber yield was quite high and for tested cultivars and seed size amounted to 42, 13 t·ha⁻¹. However it was characterized by many physiological defects, which covered more than 50 % of the crop. The main defect was particularly appearance of tubers physiologically younger, with not mature skin, as the effect of second tuberization. Finally, in the total yield existed tubers in differ physiological age. They needed to different treatment during storage period. However in the practical way it is difficult to realization.

Discussion
The weather conditions prevailing during growing period of the year 2006 in Jadwisin were typical for the climate conditions in whole country. According to the National Hydrological and Meteorological Service (Anonymous, 2006) the air temperature in Poland was considerably higher than many-year average. Positive deviations were going from 2,6 to 6,1 °C. In many regions maximum air temperature exceeded 30°C and reached the level of 36,5°C. Maximum air temperature higher than 30°C were noted during as many as 23 days. It influenced potato plant development in nearly whole Poland (Anonymous, 2007).

In this situation, the information about problems with potato quality during storage period of 2006 / 2007 is not surprised.

Conclusions
The assessment of photosynthetic activity of potato plant during growing period with using the chlorophyll a fluorescence method may be helpful in estimation of plant physiological state under unfavourable climatic conditions and in introducing of signalling system about necessity of harvest acceleration for avoid the second growth and second tuberization. It may cover whole country.

References
MANAGING FARM-LEVEL PRODUCTION AND ENVIRONMENTAL OUTCOMES IN A VARIABLE AND CHANGING CLIMATE

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Introduction
Australia’s agricultural industries are heavily impacted by both climate variability and change (Hammer et al., 1996; Meinke et al., 2003). Australia’s variable rainfall has influenced the location and success of all agricultural industries. Seasonal climate forecasting has been extensively promoted throughout the Australian grains industry as a way of improving long-term, sustainable profits in such a variable environment. Broader community recognition of climate change means that information on expected future climate scenarios is now being added to the climate information disseminated throughout the grains industry. While the statistical skill of seasonal climate forecasts have been extensively tested, the extent to which farmers are able to realise the economic and environmental benefits of their use is less well understood. Even less is known about the extent to which farmers are effectively adapting to observed climate changes, with any adaptation to date largely autonomous. In this paper, we summarise the results of participatory research with farmers in three areas within Australia’s winter cropping zone. We explore some of the potential economic and environmental benefits achievable through use of existing sources of information regarding both climate variability and change.

Methodology
Thirteen farmers in three grains regions - Jandowae (southeast Queensland), Birchip (northern Victoria) and Kellerberrin (southwest Western Australia) - provided detailed information on their current understanding of seasonal climate forecasts and climate trends, and how they would apply this information to adapt crop management decisions if the information was reliable. Through this process we were able to establish a set of robust on-farm management rules for each region. The potential economic and environmental value derived from using climate information to adapt on-farm management was estimated using the Agricultural Production Systems sIMulator (APSIM) (Keating et al., 2003).

A series of six operational and/or experimental climate indices were used to modify on-farm management decisions. Incorporating the climate indices into the APSIM framework required that the indices be separated into discrete categories. In this analysis we have used tercile categories based on the empirical relationship between each index and rainfall in the following month, for the period 1938 to 2004. Management inputs were increased if the index predicted rainfall in the upper tercile, decreased if the index predicted rainfall in lower tercile and unchanged if the index predicted rainfall in the middle tercile. Annual gross margins were calculated from yields simulated over a 49 year period (1957 to 2005) using the six climate indices or antecedent climate conditions to modify management decisions. Gross margin comparisons were made to determine what additional value resulted from use of seasonal climate indices.

The value of climate change information to farmers was also evaluated using APSIM to estimate the potential production and environmental benefits of varying planting windows in response to changing trends in frost risk. Annual gross margins were calculated from yields simulated over a 96 year period (1910 to 2005) for three different planting strategies:

1. a benchmark strategy where frost risk was ignored and wheat planted whenever a planting opportunity occurred between 1 April and 15 July (largely current practice);
2. a conservative strategy where the planting window was offset to avoid all but 10% or less frost risk at or after anthesis based on the minimum temperature trend from the entire climate record; and
3. an adaptive strategy where the 10% frost risk was assessed at each planting time based on the trend in minimum temperatures for the preceding decade (Howden et al., 2003).
Results
The results from the comparative analyses showed marked differences in the value of utilising seasonal climate information between regions, between farms and for different management decisions. Using a single seasonal climate index to modify a series of on-farm management decisions throughout the growing season reduced gross margins in farming systems where most of the inputs (e.g. fertiliser etc.) are decided at the beginning of the cropping season (April to June). This was characteristic of farms in the Jandowae region, for which seasonal climate information provided no benefit in less profitable years (i.e. a 90th percentile gross margin of AU$32 ha⁻¹ y⁻¹ less) compared with using antecedent climate information to alter management decisions. In more profitable years (i.e. AU$415 ha⁻¹ y⁻¹ or more) seasonal climate information provided additional benefits of between AU$24 ha⁻¹ y⁻¹ to AU$48 ha⁻¹ y⁻¹. In the Birchip region where fertiliser is applied more evenly throughout the growing season rather than at sowing, seasonal climate information increased both the 90th (AU$ 40 ha⁻¹ y⁻¹) and 10th (AU$289 ha⁻¹ y⁻¹) percentiles of gross margins compared to using only antecedent climate information.

In an attempt to explore whether additional value could be extracted from more targeted use of seasonal climate information we applied a single climate index (SOI Phase) to determine optimal in-crop fertiliser application rates for a range of different sowing dates and initial soil water starting conditions. The tactical application of nitrogen returned 50th percentile gross margin benefits of between AU$6.00 ha⁻¹ y⁻¹ and AU$12 ha⁻¹ y⁻¹ depending on the sowing date and starting moisture conditions, over optimal fixed fertiliser rates.

NRM benefits were achieved through the appropriate use of seasonal climate information to encourage tactical variation in the degree of stubble retention. In all three regions the use of the SOI Phase index to modify stubble resulted in reductions in runoff and/or deep drainage and in some cases enhanced median gross margins. The use of forecast information involved a trade-off between the production related benefits to individual farmers and the achievement of sustainability goals at both the farm and catchment scales.

The gross margin benefits of adapting to changing trends in frost occurrence varied across the three study regions with greatest gross margin benefits simulated in the northern cropping region (i.e. between AU$24 ha⁻¹ y⁻¹ and AU$42 ha⁻¹ y⁻¹ gross margin benefit in Jandowae) in response to a strong warming trend in minimum temperatures reducing frost risk and thus allowing earlier plantings. However, in those areas where minimum temperatures were declining, the benefits were less clear because of a trade-off between reduced frost risk, and increasing risk of moisture and heat stress during grain fill.

Conclusions
The results have shown that a limited number of opportunities exist where both production and environmental benefits can be achieved through appropriate use of climate information. However more generally, the research suggests there are trade-offs as in some cases the individual farmer’s economic benefit arising from use of the climate information may be at the risk of broader achievement of sustainability goals at both the farm and catchment scale. The benefits shown from the use of climate indices to determine optimal management inputs e.g. nitrogen application holds clear potential to increase farm profits and realise environmental benefits.

References
INTRODUCING MODELLING TOOLS TO SUPPORT AGRICULTURAL DECISION-MAKING: THE AGRIDEMA EXPERIENCE

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Introduction
Climate change could significantly affect European agriculture. Negative climate impacts could be reduced by following adaptation options, which can be obtained from crop-model simulations combined with climate scenarios. The usefulness of such simulation tools has been proved in manifold papers, usually produced in Universities or similar centers. However, despite of the considerable public concern about climate change, European stakeholders and farmers are not yet using these scientific results for agricultural decision-making. Actually, the most reliable climate-change mitigation options depend on each specific situation.

While experts and researchers at high-level centers in Europe and other places (“developers”) have established significant Know-How and produced relevant of the above-cited tools for such climate-impacts studies; practical experts at local agricultural-research or extension centers as well as agricultural advisers (“users”), those who should apply these tools for agricultural decision-making, are often not aware about the available tools or their access to such tools is quite limited due to several reasons, as financial issues or lack of user-friendly design of tools.

In that context AGRIDEMA, a FP6 Specific Support Action, aims to promote a research network, linking European modeling tool-providers and developers with the potential users of their research results. This paper outlines the experience of AGRIDEMA, focusing on what is currently limiting the introduction of such simulation tools in agricultural decision-making under variable climatic conditions.

Methodology
AGRIDEMA comprised courses of relevant climate and crop-growth simulation tools, as well as pilot assessments.

Results
Several lectures on climate and crop-growth simulation tools were held in Vienna late 2005. The courses program and the lectures of the can be seen in www.agridema.org.

More than 40 “users” from the Mediterranean region, as well as Eastern and Central Europe attended the AGRIDEMA courses. Those “users” knew in the AGRIDEMA courses how to access to GCM data and seasonal forecasts, they receive also basic knowledge on weather generators, statistical and dynamical downscaling; as well as on available crop models as DSSAT, WOFOST, CROPSYST, SWAP and others. About 20 pilot assessments were conducted in several Mediterranean and European countries during AGRIDEMA. All of them were aimed to apply the modeling tools in particular cases. The Pilot assessments reports can be downloaded from the AGRIDEMA web.

As a summary of the use of climate simulation tools in AGRIDEMA pilot assessments, the most used GCM outputs were the HADCM3 (3 times) and the Canadian CCCMa (3 times). The ECHAM and CSIRO GCM outputs were used in one assessment, where a GCM output comparison was performed. The LARS-WG appeared in 7 of the AGRIDEMA pilot assessment, which makes this weather generator as the most frequently used climate-tool in the framework of AGRIDEMA. According to Wilby and Wigley (2001), LARS-WG is one of the most used weather generators. The AGRIDEMA results confirm this conclusion. The Met&Roll weather generator was found in 3 assessments, including one comparison with LARS-WG. The Regional ReGCM3 model was used in 2 assessments and the MAGICC model in one.

Regarding the crop models considered in the AGRIDEMA Pilot assessments, the Wageningen model WOFOST was the most used, but in its SWAP (2 times) and PERUN (3 times) versions. DSSAT models were employed in 4 Pilot Assessments, while CROPSYST was used 3 times, ROIMPEL was considered 2 times and SIRIUS was used in one assessment, which performed a model comparison with PERUN. The frequency of using crop models in the AGRIDEMA Pilot
assessments is similar to that found in climate-change impact assessments by Tubiello and Ewert (2002).

“Users” and “Developers” were invited to the final AGRIDEMA workshop, which was held in Valladolid, Spain, middle 2007. The results of the assessments report were presented, focusing on the “users” points of view regarding the limitations of the available climate and crop-growth modeling tools. Hence, the “developers” received a feedback on how to improve the corresponding tools. Furthermore, the “developers” also pointed out the current development of the tools. Some representatives of farmer organizations, insurance companies and policy makers were also present.

AGRIDEMA interactions between “Users” and “developers” yielded some interesting results. Regarding the GCM outputs, “users” complained on the data format and the time scale. Only the Canadian CCCMa model provides daily data in an easily-converted format, through a Web service. This became such model as the most used in the AGRIDEMA framework. Besides, “Users” request to the national meteorological services to provide statistical (and/or) dynamical downscaled data of the most relevant GCM and emission scenarios. Such data can be used at each country in climate-change agricultural applications. Some of the “Users” and particularly the farmer representatives argue about the utility of RCM data, since the 2070-2100 seems to be extremely far for practical medium-term assessments. Farmers are mainly interested on seasonal or short-term applications. Furthermore, market prices, CAP, WFD and European or national policies can significantly influence farmer decision, besides of climate conditions. Particularly, CAP cross-compliance and the rural development funds can be an important instrument to introduce and evaluate climate-change adaptation measures in the European agriculture.

Concerning the weather generators, “Users” from the Mediterranean region pointed out that the main current approach, based on generating the variables needed for Priestly and Taylor evapotranspiration approach might not be useful. The Penman-Monteith approach has been largely recognized as the most adequate in dry conditions. “Users” took note about the facilities provided through the EU proposal ENSEMBLES. The availability of downscaled data from seasonal forecast and decadal scenarios could be an important encouragement for climate-risk agricultural assessments.

According to the AGRIDEMA results, DSSAT, WOFOST and CROPSYST are the most relevant crop-growth simulation models that are being used in Europe for climate-change risk assessments. The utility of crop models to support agricultural decision-making has been recognized. However, the “cascade approach” considered in many models to simulate soil water balance might be not adequate. This approach ignores capillary rising, which might be important in rainfed or deficit irrigation crop systems.

Conclusions
The AGRIDEMA participants strongly encouraged Universities and Educational politicians to held courses of current climate and crop-growth simulation tools. These tools are still unknown by most of their potential “Users”, which has been considered as the main current limitation to introduce them in practice. Besides, they encourage also conducting demonstration proposals, addressed to calibrate and validate the simulation tools in several farm conditions. FP7 cooperation program aims to increase private investment rates in R+D in Europe. The demonstration proposals, funded by FP7, could count on farmers and agribusiness since they are interested in adopting reliable measures in order to reduce climate risks. The participation of agricultural applied-research or extension services in those proposals is crucial.

References