Sustainable Land Use in Intensively Used Agricultural Regions

Edited by
Burghard Christian Meyer

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University of Tours, France

Available from Landscape Europe Secretariat:
Marion Bogers,
Alterra Wageningen UR,
PO Box 47,
NL-6700 AA Wageningen (The Netherlands)
Phone: +31317474610
Fax: +31317419000
E-mail: marion.bogers@wur.nl

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1. Introduction

Burghard C. Meyer (email: Burghard.Meyer@ufz.de)

There is an ongoing debate on the opposing approaches of “Multifunctionality of Agriculture” and “Multifunctional Landscapes” in science and practice. The book on “*Sustainable Land Use in Intensively Used Agricultural Regions*” will bridge the gap between both concepts by focusing on the integration of conflicting goals for landscapes. Scientific discussion is needed to identify and solve the landscape problems related to intensive land use, biodiversity, and abiotic, economic and social functions of sustainability. Spatially explicit GIS-techniques with a focus on agricultural landscapes rapidly developed in applied sciences, such as spatial planning and information science. Independently and without a strong link to these disciplines, approaches were developed for integrative landscape planning and the optimisation of agricultural enterprises. Spatially explicit compromises for decision making concerning land use are needed. The book will discuss these issues based on evaluation and assessment models. Application projects and the connection to policy are discussed.

Five main parts related to the sustainable land use in intensively used agricultural regions are in focus of the publication:

- landscape multifunctionality/multifunctionality of agriculture;
- indicators and assessment of multifunctionality;
- landscape integration, modelling future landscapes;
- structuring new landscapes; and
- economy and society.

Different approaches to multifunctionality have recently been developed. Terms such as ‘non- commodity’ and ‘commodity outputs’, ‘goods’ and ‘services’, ‘externalities’ and ‘internalities’ or the concept of the ‘functions of nature’ and others are mostly related to the three dimensions of sustainability. The societal, economic and ecological dimensions of intensively used agricultural regions, as normal landscape type for Central and Western Europe, support the main aspects of regional or rural development strategies and planning. This part of the publication discusses the similarities and differences, and the needs and problems of the integration of different scientific approaches relating to multifunctionality.

Indicators and assessments are needed for policy and planning purposes. Assessment includes the normative aspects on the measured parameters related to planning or monitoring. Following the OECD-approach, indicators for driving forces, pressure, state, impact and responses are needed. Indicators for biodiversity and the societal dimension are especially scarce. They should be integrated into an indicator set for the multifunctionality without neglecting the ecological and economic dimension. This part of the book will discuss models and indicator approaches for the assessment of the regional, landscape and local scale in the context of the land usage as indicators to monitor sustainability.

The methodological integration of contradicting goals and targets into rural and landscape development is not well developed. Approaches for integrative goal development (Leitbildentwicklung) have their origin in specific sciences: e.g. agricultural economy, landscape planning, or geography. The aim of this part of the publication is to discuss different approaches to the integration of multiple goals or targets into consistent models (e.g. spatial decision support systems, linear-programming based models, multicriteria analysis, scenario techniques, landscape prognosis) and related problems and needs.

The restructuring and planning of multifunctional agricultural landscapes into new cultural landscapes is connected with a multitude of application or practice problems. This part of the book will discuss the advantages, problems and needs on the basis of core projects of local and regional landscape development. The participation of stakeholders in the planning or application processes should solve the problem of landscape multifunctionality. The integration of the main functions of sustainability relating to the land use will be discussed and will focus on the problems of intensively used agricultural regions.

Ownership of land and production functions are related to economy and society. Subsidies from the European Union are increasingly orientated to ‘non-production’ related requirements. The needs of society in Europe are not predominantly related any more to agricultural production. The topic refers to the governance of landscapes related to directives of the European Union: e.g. ‘Water Framework Directive’ or ‘Flora-Fauna Habitat Directive’.

The aim of this part of the book is to discuss the scientific issues of functional assessments from both, an economic and a societal viewpoint relating to the multifunctionality of landscapes and regions and policy related application of the concepts.

The following part gives an overview about the wide range of scientific topics related to intensive agriculture.

Landscape multifunctionality/ multifunctionality of agriculture

Ryszkowski and Kędziora (page 6) give an overview on the multifunctionality of agriculture, ecosystem services, and landscape diversification. They explain in general terms that "the non-commodity side effects of agricultural production, which benefit environment protection, called positive joint production effects, were recently recommended as one of the important tools for the implementation of sustainable agriculture. Simultaneously, recent studies in landscape ecology have shown that structuring agricultural landscape with various non-productive structures like shelterbelts, hedges, strips of grassland, small mid-field water reservoirs called biogeochemical barriers provide ecosystem services that limit environment degradations imposed by agriculture intensification. Those ecosystem services, which are the result of ecosystem processes complement joint production effects." The problems on intensification and diversification are discussed as the drivers of sustainable agriculture development.

Starting with the same clarifications on the problem multifunctionality, Bastian, Lütz, Röder and Syrbe (page 15) discuss that the "growing interest of human society in productive, multifunctional, and ecologically 'healthy' countryside, also as part of regional cultural heritage, is a powerful driving force for the development of rural landscapes." They state that "it is necessary to find and to implement such forms of land use that guarantee the maintenance of ecological functions to the largest extent, and which integrate a sustainable, resource-protecting development as much as possible. The scenario analysis is a suitable way to estimate in which frames the landscape will develop in future, and what could be the ecological and economic consequences."

In the following chapter Rapey, Josien, Lardon, Servière and Fiorelli (page 23) discuss a partial approach to landscape multifunctionality, based on a geo-agronomic viewpoint, "as a basis for a structured and operational approach to the characterisation and comparison of the agricultural contribution to landscape multifunctionality. Two main spatial configurations appeared: 1) large farms with a spatially limited and disseminated contribution to the two landscape functions, and 2) medium and small farms with a relatively large localised contribution to the two functions", and were investigated for the preservation of surface water resources and the preservation of a mosaic pattern of vegetation.

Silber and Wytrzens (page 29) discuss a case study for intensively used urban regions. They state that the "diversity of functions that society demands from open land suggests careful dealing with urban agriculture and farmland. (Peri-) urban communities try to safeguard the survival of farms or at least they want to maintain agricultural land use. Analyses in the study area of Linz/ Urfahr (Upper Austria) showed that measures of the local policy like a restrictive green belt policy or a special subsidy for urban farmers have positive effects on farmland preservation."

Indicators and assessment of multifunctionality

Jessel (page 36) worked out that "in ecologically oriented planning the term 'multifunctionality' has gained high importance as it helps to represent the complexity of landscapes, of their constituents and services. When being used for planning applications and assessments, the term usually refers to the different services a certain landscape unit should provide from a human perspective and thus reaches beyond the field of pure analysis, but is still essentially connected with normative aspects". Jessel illustrates this by using two examples of "the application of the concept in spatial planning and the related problems of finding appropriate indicators:

- Multifunctionality as a sectoral concept being used in nature conservation to determine and to assess impacts on ecosystem functions and to develop functionally related compensation measures.
- Multifunctionality as an integrated, goal-oriented concept that, within spatial planning, is used to determine distributions of land use following the superior overall concept of sustainability".

Jessel concludes "that it is difficult, if not impossible, to find appropriate indicators to picture 'multifunctionality' itself adequately, but it may be a powerful concept for defining complex targets and integrated guidelines for landscape protection and development, and also to reconcile ecological with economic and social aspects. Thus attention should be paid on how to interrelate different functions and to link different indicators to come to interpretations on multifunctionality within defined target systems".

Such a kind of target system has been developed by Piorr, Uthes, Waarts, Sattler, and Müller (page 47) in the European Project 'MEA-Scope' with the aim to make the multifunctionality concepts operational for impact assessment. A "consistent and operable framework has to be developed that refers to all these different aspects" of multifunctionality and sustainability. The project "develops a tool for the ex-ante assessment of policy impact on the multifunctionality of agriculture." They "describe a multilevel approach that integrates the different conceptions and policy levels of multifunctionality into an indicator framework applicable for impact assessment. Both, the demand side of multifunctionality, from the rural development perspective, as well as the supply side of multifunctionality, from the agricultural production perspective, are considered."

Bieñkowski and Jankowiak (page 55) give attention to the necessity of limiting the nutrient balance surpluses in farms as one major and complex aspect of the intensive use of landscapes by agriculture. The aim of the presented study is "to determine the flow and balances of nitrogen (N) and phosphorus (P) in different farming types" on a basis of 30 farms representing three agricultural types: milk production, pig production and crop production (10 farms each). "The results of the research indicate that, while maintaining the existing farming intensity, a decrease in nutrient surpluses would be possible through the efficiency increase in N and P utilisation in animal feeding and higher crop productivity."

The modelling of pricing opportunity costs to meet soil quality concepts in matters of heavy metal inputs into agricultural soils, worked out by Reiher, Weinmann, Düring and Gäth (page 62), uses a "site-specific calculation of land rent" as "an encouraging approach for estimating land use options" on the basis of model tools. Under assumed basic conditions, a calculated "CAP-scenario proved to be sustainable on all sites in the Dill river catchment in matters of heavy metal contents of topsoils during the next 100 years. This is mainly the reason, because German soil protection legislation has introduced the instrument of permissible additional heavy metal loads on sites where precautionary values are exceeded by geogenic reason." It is demonstrated that "the value of these loads is a sensitive parameter in terms of economic and therefore potentially social sustainability."

Landscape integration, modelling future landscapes

Sheridan and Waldhardt (page 68) present "the modelling approach of the interdisciplinary and spatially explicit landscape evaluation tool ITE²M (Integrated Tool for Economic and Ecologic Modelling) using the land use model ProLand and the biodiversity model ProF as application examples. "Linking land use and ecological models allows to assess socio-economic and ecological effects of changes in natural, technological, socio-economic and political variables by identifying interactions and estimating potential trade-offs. ITE²M is a decision support system operating at the level of landscapes or regions. Its rich detail and spatial resolution can support decision makers at sub-national level as they often require reliable estimates of economic and ecologic costs and benefits when implementing supra-national policy measures."

König and Meyer (page 73) describe the methodological steps for an assessment and decision-making framework for the integration of goals related to multifunctional land use for large areas. From the results, landscape-ecological integrative goals (Leitbilder) for natural areas and land use units for mesoscalic (sub-regional in a scale of 5–20 km² per unit) purposes can be formulated. This framework provides an overview concerning different land use functions and natural potential as permitted by the ecological condition of the landscape. Within conflicting areas potential solutions through the development of alternative land use scenarios are offered. Decision trees and a GIS-based spatial decision-making process (SDSS) Land Use Options (LNOPT) or a combination of both are available.

Klug and Zeil (see page 82) again argue that "transdisciplinary planning of different aspects of landscape functionality might add to the understanding of ongoing landscape changes (positive and negative trends) and widen the range of options for the formulation of policy measures as well as the activity radius of farmers which would lead to a more sustainable use of our landscapes." Basing on a 'Leitbild'-approach and on GIS modelling, they "formulate guidelines for improving our present landscape towards an aspired situation in future."

Another main aspect of the landscape usage has been worked out by Palma, Graves, Burgess, Reisner and Herzog (page 91) by integrating silvoarable agroforestry (SAF), the use of trees and arable crops in the same field, on a European perspective. Results show that "SAF had a positive impact on four environmental indicators calculated in comparison with the status quo, but economic benefits varied according to tree species and region. Silvoarable systems are complex, as there are many possible tree and crop arrangements, and implementation takes effect over a long period of time." They state that "with the recent CAP reform strengthening the emphasis on environmental performance and sustainable use of natural resources, SAF could play an important role since growing trees and crops in combination in SAF at the selected test sites 'was found to be more productive than growing them separately in arable and forestry systems'."

A detailed modelling research on the catchment scale describes Hildmann (page 99) by an example from Eastern Germany. He gives suggestions to "improve the ecological functions and produce notable yields" by "newly introduced woody plants and wetlands." It is taken into account that "determining processes of both, the water budget and the transformation of energy are area-dependent processes. Both, woody vegetation and wetlands are types of productive land uses and further the landscape budget is positively influenced: the retention of water, nutrients and material, the improvement of the local climate, and so on is to be mentioned. A spatially high resolution water budget model can help for the placement and local adaptation" of activities to enhance landscape sustainability. Demonstrated planning tools "should be used to improve the quality of landscape planning and plans introduced by the EU Water framework directive".

Matarán Ruiz, Aguilera Benavente, and Valenzuela Montes (page 105) explore current landscape changes by the main factors affecting greenhouse expansion processes in the Mediterranean coast by presenting a "predictive model of greenhouse's growth based on logistic regression on the coast of Granada (Spain). This model of growth has been put into practice in three landscape units from 1990 to 2003. It investigates the identification of the main elements that affect this territorial process." They reveal "that the prediction of the proposed model is more precise in advanced phases of greenhouse expansion when constraints (the physical ones and others) are important. It is also demonstrated a diffusion pattern leading to saturated and monofunctional landscapes that are far away from a sustainable goal."

Structuring new landscapes

Mante and Gerowitt (page 113) discuss the problem to enhance biodiversity in the context of the restructuring and planning of multifunctional agricultural landscapes. "Induced by changes in production methods, the situation at the markets and the conditions in agricultural policy, an accelerated development to short crop rotations and large management units in intensively used agricultural regions is proceeding. In Germany, five pilot projects which contribute to the project network Lebensraum Börde develop and implement nature conservation measures in particular adapted to the conditions of intensively used arable areas focusing on sown flowering strips." Mante and Gerowitt describe basing on a comparative study how projects can be set up successfully. They state that "besides financial instruments, concepts for nature conservation projects require also political and administrative instruments to enable the development and implementation of nature conservation measures. One needs farmers as partners (who provide know-how and in many cases have the property rights), land owners and other stakeholder (e.g. nature conservancy, hunting associations). Public interests should be served to enhance the acceptance of the projects, for instance by presenting flagship species and enhancing the aesthetic value of the landscape by structures and colours."

"Agri-environmental schemes (AES) are the main instrument to improve environmental and nature conservation issues in the agricultural landscape. On the basis of an analysis of ecological effectiveness, economic efficiency and acceptance among farmers", Freese and Steinmann (page 119) propose to "support the environmental improvement by installing or supporting regional organisations for the management of the agri-environment" as a regional activity of the Lebensraum Börde Project." With a regional and co-operative approach, this project developed AES for intensively used agricultural regions namely a flowering field margin strips programme." They conclude that for the "more specific implementation of nature conservation aspects, the farmers lack a service of individual advice and a financial stimulus to inform themselves about voluntary nature conservation measures on their farm. In Germany an initiative has recently begun to build up a network for nature conservation advisory services for farms."

The MULBO method (Multicriteria Landscape assessment and optimisation method) worked out by Grabaum, Meyer, Gerung, Wolf, Friedrich, Kildal and Meyer (page 127), can be considered as a Spatial Decision Support System and was developed for the usage to improve planning processes significantly, by describing spatial explicit assessment models for several landscape functions for science and practice. As the example for a test region in Central Germany shows, the application of MULBO contributes to a greater optimisation of environmental and socio-economic functions helping to make intensively used landscapes more sustainable.

Schneider, Peterson and Fry (page 133) "examine the potential for a design approach to achieve integrative farm plans" with examples from Sweden. The plans enable to identify common conflicts and synergies. They conclude "that farm plans can be a valuable tool for integrating landscape values such as biodiversity, cultural heritage, recreation and aesthetics". The results indicate that "multifunctionality on farms in Sweden could be improved through two measures. The first would be to include a wider range of landscape values (e.g. recreational and aesthetic aspects) in the existing advisory system for farmers. Secondly, the existing subsidy system seems to work better for farms with existing values that should be preserved, rather than for improving farms with few existing values. On farms with low landscape values, farmers could be encouraged to use set-aside areas for serving several functions (greenways, grasslands). Incentives for new hedge and tree planting would also be valuable.

Di Pietro (page 140) describes in detail that in "intensively used agricultural regions, because of the scarcity of grasslands, field margins play a crucial role in allowing species dispersion and thus in enhancing biodiversity". She explores "the relationships between plant diversity of field margins and some agricultural and structural parameters in the 'Gâtine lochoise' (France, Centre region)." and emphasises "the major effect of farm size over the plant composition of field margins. The increase of field size is a major trend of modern agriculture; its effects over biodiversity, by related loss in habitats and corridors, are known and suggest that also the increase of farms size has a dramatically harmful impact on biodiversity, because of the more drastic management of field margins that it entails."

Economy and society

Also related to species richness on grasslands is the contribution on "Auctioning ecological goods within agri-environmental schemes – a new approach and its implementation in species-rich grasslands" presented by Richter gen. Kemmermann, S. Klimek, E. Bertke and J. Isselstein (page 152). "The species richness of grasslands is dependent on an adapted low input management and cannot be conserved by a mere minimum maintenance of a "good agricultural and environmental condition" – e.g. in form of an annual mulching – as required by the cross-compliance agreements of the CAP. Existing agri-environmental programmes lack efficiency in nature conservation purposes, as well as acceptance among farmers and population". They present a pilot programme in Northeim as a first attempt in Germany to implement the combination of the two components result-oriented remuneration and auctions.

Knickel and Kröger (page 162) address the "question of the integration of multifunctionality goals and concerns into evaluation concepts and practice." They "ask how far methods of evaluation and assessment are up to the new requirements that reflect current political and societal trends and changes" on the EU level. Recommendations are given for a more integrative policy evaluation and assessment, for reconsidering the role of research, for organising platforms for collective learning, and for the discussion towards more integrative analytical frameworks. “Overall there is a need for more integrative analytical frameworks that combine quantitative and qualitative elements.”

From the point of view of an Australian governmental authority on modelling, Phillips (page 169) concludes that “the Victorian landscape has undergone significant modification since European colonisation through the eighteenth and nineteenth centuries. Fifty-six percent of the state’s naturally occurring vegetation systems have undergone significant modification (sometimes erasure) to make way for agricultural enterprises and many of Victoria’s agricultural landscapes are now not considered sustainable within the ‘ecosystem service budgets’ that they exist in. The central conclusion of the presented Rural Land Stewardship project is “that achieving the integration of single issue-based approaches to land management is most likely through the use of an ecosystem services framework. This framework opens the potential to consider the rural landscape at a significant scale. That is, to produce ecosystem services through appropriate land use change on private rural land for broader public benefit will require planning and implementation of orchestrated land holder actions at a landscape or sub-region scale, rather than at the individual property level. In moving to planning land use change for ecosystem services as large or landscape-scale project sites it is imperative that systems are created to necessitate collaborative input from both the biophysical and social sciences”.

Acknowledgments

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2. Multifunctionality of agriculture, ecosystem services and landscape diversification

Lech Ryszkowski and Andrzej Kędziora
(Corresponding author: L. Ryszkowski, email: ryszagro@man.poznan.pl)

Abstract

Striving for food supply to satisfy growing human population, farmers intensify production which brings environmental deteriorations like soil erosion, depletion of water resources, diffuse water pollution, or biodiversity impoverishment. The increase of food production required to feed eight billion people in 2050 will be obtained from less land and water because of degradation of arable land. The non-commodity side effects of agricultural production, which benefit environment protection, called positive joint production effects, were recently recommended as one of the important tools for the implementation of sustainable agriculture. Simultaneously, recent studies in landscape ecology have shown that structuring agricultural landscape with various non-productive structures like shelterbelts, hedges, strips of grasslands, small mid-field water reservoirs called biogeochemical barriers provide ecosystem services that limit degradations imposed by agriculture intensification. Those ecosystem services, which are the result of ecosystem processes complement joint production effects. Thus, sustainable development of agriculture should make use of positive joint production effects that are related to farmer's activities and benefit from the structuring of agricultural landscape with biogeochemical barriers providing ecosystem services which are brought by operation of natural processes. Before detailed and specific guidelines for the practical implementation of joint effects and ecoystem services will be disclosed, the very general principle depending upon the diversification of agricultural landscape structures and agrotechnologies should be observed. It will lead to the resistance to threats and the promotion of sustainability.

Key words
Agriculture intensification, ecosystem, non-commodities, environmental threats, sustainable development

2.1 Introduction

The last 50 years brought not only the great civilisation progress and enormous increase of environmental threats but also important changes in human relations to nature. In the time period 1950–2000 the human population increased from 2.5 to 6.1 billion and it is expected that by 2050 it will reach a level of 8–9 billion. Simultaneously, the world economy multiplied almost sevenfold in the last 50 years enabling to increase food production by three times which, nevertheless, did not provided food for all people. There are still about 900 million people chronically hungry. The worst situation is in Sub-Saharan Africa, while in India and China some progress in feeding people has been achieved (Brown, 2003). Visiting China, one of the authors of this paper (L. Ryszkowski) observed a significant increase of yields after the introduction of a new policy enabling farmers to sell products on the market on which they obtain with yields above the established rather low quota of yields required to be sold to the government.

To feed a human population of 8–9 billion the food production has to increase by 50% (Millennium Ecosystem Assessment, MEA, 2005). This demand will have to be achieved from smaller area of land and with less water than today. The cultivated ecosystems (crop fields, livestock range, etc.) cover now 25% of Earth's terrestrial area according to MEA (2005). If one disregards the areas covered by rocks, ice, and deserts then almost 75% of the natural habitats have been affected by human activity (Hannah *et al*., 1994). According to Squires (2001), only 10% of the terrestrial ecosystems area is still suitable for a conversion into agro-ecosystems. Thus, there are little indigenous ecosystems left which could be converted into croplands. Therefore, it is no surprise that many scientists consider that Earth's ecosystems are already dominated by human activity (Vitousek *et al*., 1997) and an option to increase food production by the enlargement of croplands' area is continuously diminishing.

Increasing water demands, at a quantity of more than twice the rate of human population increase, has led to regional water crises (about 80 countries constituting 40% of the world's population show serious water shortages). Presently, people are using about half of the available water (WMO, 1997) of which about 70% is used for agriculture (Brown, 2003; MEA, 2005). Since the attempts to solve water problems brought insufficient success up to now, administration is compelled to look for new water policies. Besides dam constructions to store water, the increased efficiency of water use is recommended in so-called 'soft-path solutions' (Gleick, 2003). Stress is put on the efficiency of water use for sanitation, food production and irrigation and on other water consuming activities in small enterprises that do not require large funding and where part of the cost for water saving devices can be covered by the enterprise. Despite those efforts, in many regions overpumping of aquifers in order to compensate diminishing water supplies from surface reservoirs has led to a fall in the level of ground water, which threatens the agricultural production in areas inhabited by three billion people (Brown, 2003). Rivers are running dry, large cities use more and more water and water crisis is increasing. But to provide food for eight billion people will require an increase in production despite decreasingly available water resources.

The intensification of agricultural production could have a growing impact on the environment, leading to threats like diffuse water pollution by various chemicals used as fertilisers or pesticides, intensification of erosion processes, loss of biodiversity, and many other threats which can undermine the prospect for an increase in food production.

Soil erosion through wind and water is a widespread phenomenon leading to topsoil losses and undermining soil fertility. Land degradations by water and wind erosion were estimated in the 1990s on an area of about 900 million ha (Brown, 2004). Their actions in decreasing the area of croplands and rangelands are slow but unavoidable. Thus, because of erosion processes future food production will have to be achieved in a much smaller area of land.

This situation stimulated the profound change in human relations to nature outlined in this review of recent advances in landscape ecology. For this reason many new insights concerning water management at a landscape level as well as control of diffuse groundwater pollution are disclosed by referred studies carried out by the Research Centre for Agricultural and Forest Environment (RCAFE). Further, the general description of the studied landscape is provided. The methods used in these long-term studies can be found in the cited papers and therefore will not be described again in this article. In this publication the origin of the multifunctionality concept and the disclosure of ecosystem services are discussed and illustrated by results of the studies carried out by the RCAFE. Finally, in the conclusion chapter the concept of intensification and diversification for agriculture development is outlined.

2.2 Characteristics of the Turew landscape

The studied agricultural landscape is situated about 50 km from the large town of Poznan, has an area of 182 km^2 and was shaped by the Pleistocene glaciations. The geographical location of this area stretches from 16°45' to 17°05' E and 51°55' to 50°05' N. Although the differences in altitude are small (from 75 m a.s.l. to 90 m a.s.l.) and the area consists of a rolling plain made up of slightly undulating ground moraine, there are many drainage valleys. In general, light textured soils (Hapludalfs, Glossudalfs, and less frequently met Udipsamments) with favourable water infiltration conditions are found in uplands. Deeper strata are poorly permeable and percolating water seeps to valleys and ditches and then feed the main drainage canal. Endoaquolls, poorly drained and storing water are found in depressions.

The climate of the region is characterised by the conflicting air masses from the Atlantic, Eastern Europe and Asia which are modified by strong Arctic and Mediterranean influences. It results in a great changeability of weather conditions and the predominance of western winds brings strong oceanic influence that manifest in milder winters and cooler summers than in the centre and east of Poland. Annual air temperature is 8.0°C (range from 6.9 to 8.5°C). The mean plant growth season with temperatures above 5°C lasts from 21 March until 30 October.

Mean annual precipitation amounts to 594 mm with a preponderance in the plant growth season. On average, the annual evapotranspiration amounts to 522 mm and water runoff is equal to 72 mm. Although the amount of precipitation in the spring-summer period is higher than in autumn and winter, a shortage of water occurs frequently in the plant growth season. This situation is aggravated by the dominance of light soils with poor water storing capacities. In the land-use structure of the whole catchment arable land makes up 62.2%, afforestations and shelterbelts (mid-field rows of trees) cover 17.9%, meadows and pastures 12.5%, water bodies 3.5%, and villages and roads cover the rest of the area. There are no industrial facilities. The mean density of inhabitants adds to 55 individuals per 1 km^2.

The structure of crops at the beginning of the 21st century was as follows: cereals (mainly, wheat and Triticale) including maize made up 76.7%, legumes 16%, potato, seed-rape, and sugar beet 6%. Plant production was 3.4 t per ha in cereals, 19.6 t per ha for potatoes and 49.6 t per ha for sugar beet. The average density of animals in small farms amounts to 18 large heads per 100 ha of agricultural land, and in large farms (above 500 ha of area) it is equal to 84 large heads per 100 ha of agricultural land. Small farms are located on 56% of the area and six large farms (above 500 ha) cover 44% of arable land. The average fertiliser dose in recent years reached 90 kg N per ha, 50 kg P_2O_5 per ha and 88 kg K_2O per ha in large farms, and 36 kg N per ha, 60 kg P_2O_5 and K_2O per ha in small ones. The characteristic of the Turew landscape is based on the studies carried out by Kędziora (1996), Kędziora and Olejnik (1996), Marcinek (1996), Ryszkowski (1996), and Woś and Tamulewicz (1996).

2.3 Origin of the multifunctionality concept

In many cases attempts to limit environment degradations brought by agriculture are driven by economic concerns because created environmental threats start to limit incomes. The revenues obtained in production are regulated by a market and by the costs of used resources. The environment degradations brought by enormous progress of civilisation stimulated by market economy recently led to a change in understanding hierarchy of drivers responsible for the human society development. The concept that economy is the central driver of human society development together with the neglect of side effects of production processes led to conflicts with the environment, that are fast depleting natural resources (air, water, soil, and many other raw materials needed for production). That situation limits economical revenues because higher and higher funds are spent for solving environmental problems. Such trend, if not limited, will lead to economic decline (Brown, 2001). In order to change that trend economic activities are slowly perceived as part of the Earth system that is composed of physical, chemical, biological, societal, and economic processes. This completely new approach to development of human society accepts that economy is part of the Earth system and can sustain progress only by observing processes, which are compatible with functions of nature. The interrelations of various processes, recycling of materials, carrying capacity of environment, diversity, feedback mechanisms both positive and negative, processes of regulation, resilience, and so on are little by little recognised and considered as important principles of this new approach to development.

This new political concept of development originated during the 1980s (see for example IUCN, 1980; Clark and Munn, 1986; Brundtland, 1987; Holling, 2001) and led to a concept of sustainable development that postulates the need to compromise economic, environmental, and societal processes which were recognised as the three basic and balanced pillars of development. In other words, a sustainable development concept implies fundamental changes in the approach to production processes by recognising the challenges embedded in the awareness that resources are finite, and all Earth's systems are interconnected and interdependent. Thus, the concept of sustainable development of human society is convergent with the ecological approach to grasp ecosystem properties proposed a long time ago. For example, Tansley (1935) characterised ecosystem as a system of abiotic and biotic components where various interactions build an integrated system.

The recognition of side effects of production processes, which are often non-marketable or non-commodity products, induced the comprehension of multifunctional effects of human activities. A notion of multifunctionality plays an important role in the theory of sustainable development by stressing the need to recognise different effects of given production process. Up to now, economists focused mainly on marketable products and such attitude led to environmental degradations because of the neglect of non-commodity effects.

Non-commodity effects (NCOs) can be positive or negative for sustainable development. Environment pollution or soil degradations are well known negative NCOs. They are also called negative externalities (OECD, 2001). The introduction of crop rotation pattern that reduces leaching of nitrogen components into groundwater has a positive effect on environment quality and it is an example for positive NCOs. Negative NCOs still dominate in agriculture, as it was shown, although great progress was achieved in their reduction.

The important point is that positive NCOs can increase the profit of economic activities and thereby offset negative NCOs. Such production technologies that increase positive NCOs lead to so called joint production effects (OECD, 2001). In order to optimise joint production effects with revenues, it is possible to find the most suitable combination of environmental friendly technologies providing the most desirable economic effects by using computer models, e.g. MODAM (Zander and Kächele, 1999; Werner and Zander, 2002). This is an important step in economy to strengthen the sustainable development, but it cannot be considered a solution for equal treatment of economic and ecological processes required by the sustainable development theory. For example, efficiency of recycling of nitrogen, oxygen, or water cycles can not be estimated by joint production effects.

The life supporting processes operating in environment ensures the existence of all beings on Earth and from this perspective the economy forms a sub-sphere of this domain. Principles of ecology providing knowledge on solar energy fluxes that drive abiotic and biotic processes on Earth, e.g. nutrient cycles, hydrological cycle, formation of climate system, and various biological processes ought to be introduced into guidelines for sustainable development. Economists as well as ecologists and representatives of social sciences should work together to foster the framework for the sustainable development theory.

2.4 Origin of the ecosystem services concept

The ecosystem services were recognised by capitalising ecological knowledge that ecosystem processing solar energy and elements builds structures that can increase or retard water fluxes, clean or pollute water, modify microclimatic conditions, product biomass and so on. The ecosystem services are those ecosystem's goods or processes, which benefit people (Millennium Ecosystem Assessment, 2003).

The ecosystem services can be divided into the following categories:

- supporting: underpinning other categories of services. This category includes: solar energy fluxes, matter cycling including water, photosynthesis, soil formation;
- provisioning: providing goods like food, fibre, timber, etc.;
- regulating: cleansing water, modifying climatic conditions, controlling rates of matter recycling, regulating appearance of diseases, etc.;
- cultural: providing non-material benefits from ecosystem.

The knowledge of processes that underpin ecosystem services opened up new prospects for the management of landscapes' structures that aim at the enhancement of their capacities to deliver requested services. Ecosystem services depend on the kind of interactions between abiotic and biotic components of its structure that have influence on the partition of solar energy for driving different processes like matter cycling performance in ecosystems. Use of that knowledge opens up prospects for an ecological management of ecosystems by changes in their structure in order to enhance desirable service.

2.5 Services of ecosystems

Recently there is an increase of ecological knowledge that the management of agricultural landscape for its structural diversity is becoming an important environment protection issue. Co-adaptation of human activities with landscape services relies on the recognition that ecosystem services can be used to build up landscape resistance against various threats brought by production intensification. Then again, the promotion of joint production effects founded on multifunctionality of human activities will increase not only revenues but also protect, to some extent, the environment against threats induced by production. These synergetic effects ought to stimulate the implementation of the sustainable development theory.

The importance of ecosystem services will be illustrated by results of studies carried out by the Research Centre for Agricultural and Forest Environment in Poznan, Poland.

The environmental problems appearing in rural areas all over the world have become one of the serious threats undermining prospects for the implementation of sustainable development, not only in agriculture but also to distort global economy. Agronomic research has traditionally focused on the farm level, leading to more productive and economically efficient methods of plant cultivation and animal husbandry. Simultaneously it often resulted in environmental threats. More recently, however, the recognition of landscape services as an important device to control threats opened up new prospects for a sustainable management of rural areas.

Because of the structural simplification of agro-ecosystems, brought by the obvious need to increase yields, the cultivated fields are characterised by a low tie-up of internal cycles of chemicals. This can result in increased leaching or blowing out of substances from agro-ecosystems. Farmers can moderate the intensity of various material dispersing processes through properly applied tillage technologies, but they are unable to eliminate them entirely regardless whether they use integrated or organic farming systems. Combining environmentally friendly technologies applied within farm area with the structuring of landscapes with various stretches of permanent vegetation can provide a more successful elimination of environmental threats. Thus, protection activities carried out at the landscape level can enhance environmentally friendly technologies applied within the farm (Ryszkowski, 1990, 1998, 2002; Ryszkowski and Jankowiak, 2002).

These conclusions were obtained in the long-term studies carried out in a mosaic agricultural landscape located in the ‘Polish corn-belt’ area of Wielkopolska harbouring cultivated fields, and semi-natural, non-productive components such as shelterbelts, hedges, stretches of meadows, riparian vegetation strips, small mid-field ponds or wetlands.

The results of the studies on processes that have the utmost significance for landscape management, such as partition of solar energy for evapotranspiration or air and soil heating, which were studied under field conditions, provided new options for the management of water cycling and for the improvement of microclimatic characteristics of cultivated fields (Kędziora *et al*., 1989; Kędziora and Olejnik, 1996, 2002; Olejnik and Kędziora, 1991; Olejnik *et al*., 2002).

A newly developed method was used to study heat and water balances of various ecosystems in agricultural landscape of Wielkopolska, Poland and was also used in other countries (Kędziora and Olejnik, 2002; Olejnik *et al*., 2002). One of the important findings was that plants increase evapotranspiration rates. The comparisons of bare soil and wheat fields during plant growth seasons under condition of semi-desert (Kazakhstan), arid zone (Spain), steep zone (Russia), transit climate conditions in Poland and Germany, and humid zone (France) showed that plants were increasing evapotranspiration rates during plant growth seasons by 189% in semi-desert and by 42% in the humid zone with values of 54%–61% in transit zones (Kędziora and Olejnik, 2002). Much higher increase of evapotranspiration rates were observed in shelterbelts (mid-field rows of trees) or forest patches in comparison to bare soil (Kędziora and Olejnik, 2002; Ryszkowski and Kędziora, 1987, 1995). It was also shown that the structure of plant cover has an important bearing on the partition of solar radiation into various energy fluxes (Table 2.1). Thus, for example the range of energy values used for evapotranspiration (LE) during plant growth

TABLE 2.1. Mean values (MJ m^{-2}) of net radiation (Rn), latent heat) LE), sensible heat (S) and real evapotranspiration ETR (mm) for different ecosystems of the Turew landscape during vegetation period (March 21 to October 31).

		Ecosystem					
Normal year	**Parameter**	**Shelterbelts**	**Alfalfa**	**Sugar beet**	**Overwintering wheat**	**Pasture**	**Bare soil**
Weather conditions	Rn	1702	1555	1576	1592	1563	1594
Mean temperature	LE	1547	1246	1127	1120	1094	980
12.9°C	S	134	290	390	470	649	856
Precipitation 370 mm	ETR	632	509	461	458	447	400

Net radiation – incoming solar radiation minus outgoing radiation
Latent heat – energy used for evapotranspiration
Sensible heat – energy used for air heating
ETR – evapotranspiration in mm (litres of water per square metre)

season ranged from 980 MJ m^{-2} (bare soil) to 1547 MJ m^{-2} (shelterbelt). The shelterbelt uses more than six times less energy for sensible heat (S) than bare soil does. Also, the shelterbelt uses about 40% more energy for evapotranspiration than the wheat field does, while the wheat field diverts approximately more than three times more energy to air heating than the shelterbelt (Table 2.1). Hence, from the energetic point of view the cultivated fields could be considered as 'heaters or ovens' in landscape, and shelterbelts or forests can be called 'landscape water pumps'.

Comparing water balances in two contrasting terrestrial ecosystems of watershed, namely forest and cultivated field, under normal climatic conditions Kędziora and Olejnik (2002) found substantial differences in the surface runoff (10 mm in forest and 140 mm in cultivated field) and in evaporation (540 mm and 420 mm, respectively). Despite the fact that the infiltration is 470 mm in forest and 420 mm in cultivated field the input to subsurface groundwater was only 10 mm higher in forest than in cultivated field. The rate of water uptake by trees is more intensive than this is done by cultivated plants (wheat) with less developed root system and therefore with lower access to soil moisture. Thus, the water pumping effect is clearly seen in forests because of higher evapotranspira-tion and higher uptake of the soil water which affects, for example the formation of a flood wave. This is the reason why forests or shelterbelts are used for flood control.

In dry and normal years similar runoff is observed from forest and grassland landscape. With abundant precipitation trees control the runoff better than grasses (Table 2.2).

In the landscape composed of cultivated fields and shelterbelts one can observe two opposite tendencies in water cycling (Ryszkowski and Kędziora, 1995). The trees increase evapotranspiration rates. At the same time, the protecting effects of trees stimulate a decrease in wind speed and a lower saturation of vapour pressure deficits which decrease evapotranspiration. It is for this reason that fields between shelterbelts conserve moisture which can increase yields (Brandle *et al*., 2004; Grace, 1988; Ryszkowski and Karg, 1976) (Table 2.3).

The other important result of the landscape studies is the control of diffuse groundwater pollution caused by leaching of chemical compounds from soil of cultivated fields. The new insights on control mechanisms of diffuse pollution operating in permanent vegetation strips (biogeochemical barriers) located in agricultural landscapes were disclosed (Haycock *et al*., 1997; Muscutt *et al*., 1993; Ryszkowski, 2000; Ryszkowski *et al*., 2002).

The long-term studies carried out by the Research Centre for Agricultural and Forest Environment in Poznań, Poland indicated that shelterbelts, stretches of meadows, and small mid-field water reservoirs affect the chemistry of passing water (Bartoszewicz, 1994; Bartoszewicz and Ryszkowski, 1996; Ryszkowski and Bartoszewicz, 1989; Ryszkowski *et al*., 1997, 1999). Those landscape structures are called biogeochemical barriers because they control water chemistry.

Concentrations of nitrates leached from cultivated fields decreased substantially when ground water passed under biogeochemical barriers. Both shelterbelts and mid-field patches of small forests could decrease the nitrate concentration in influx from fields by 63 to 98%. In meadows the detected decrease of the concentrations of nitrates was similar and ranged from 63 to 98% (Ryszkowski, 2000).

The observed reduction of nitrates is caused by the following processes: plant uptake, denitrification, and release of volatile nitrogen compounds as well as by soil

TABLE 2.2. Precipitation and rate of runoff (mm y^{-1}) in different ecosystems (modified after Werner *et al.*, 1997).

Climate	Dry year	Normal year	Wet year
Precipitation	**627**	**749**	**936**
Runoff from:			
Cultivated fields	108	233	351
Grasslands	0	155	271
Forests	0	149	181

TABLE 2.3. Influence of shelterbelt network on evapotranspiration (mm or litters per square metre) during the plant growth season (21 March –30 October) with normal weather conditions (mean temperature 12.1°C and precipitation 440 mm), after Ryszkowski and Kędziora (1995).

Element of landscape	Evapotranspiration
Large wheat field	434
Large patch of deciduous forest	552
Landscape with shelterbelts covering 20% of area:	
total landscape	452
wheat field between shelterbelts	426

sorption-desorption processes. Conditions that influence those processes determine the efficiency of landscape structures to deliver ecosystem services (Ryszkowski *et al.*, 1997, 1999).

The significant influence of plant cover structure on the output of chemicals from watersheds was shown by Bartoszewicz (1994). The studies were carried out in two small watersheds located nearby. Cultivated fields covered 99% of the area in the uniform watersheds and in the mosaic one it was 83% while the rest of terrain was covered by a riparian meadow (14%) and shelterbelts (3%). The mean annual precipitation for both watersheds was the same and amounted to 514 mm. During three years of studies, the annual water outflow into drainage canal from the mosaic watershed was on average by 32 mm lower than from the uniform landscape because of the higher evapotranspiration of grasses and trees than from cultivated crops (Table 2.4).

In landscapes with mosaic structure (fields intersected by shelterbelts, stretches of meadows, small water reservoirs), higher doses of fertilisers can be applied without negative effects on water quality than in homogenous ones which are composed only of arable fields. This is a very important conclusion for the programmes for environment protection. Conscious use of the ecosystem services in the environment protection strategy will help to develop new environmentally friendly agro-technologies which at the same time allow reasonable intensive production balanced with the ability of natural systems to absorb the side effects of agriculture without being damaged. This is a good example for building up higher resistance of agricultural landscape against threats brought by the intensification of production which is needed to feed the growing human population.

Protection of water quality in rural areas should be based on technical, agrotechnical, and landscape measures. Improvement of water quality can be attained by the construction of various kinds of treatment plants in order to limit dispersion of communal and farm sewage. Agrotechnical means should be applied to reduce leaching and erosion, but the introduction of biogeochemical barriers will ensure a much higher efficiency of water pollution control. The application of environmentally friendly agrotechnologies can be facilitated by the stimulation of joint production effects due to multifunctionality of tillage activities. An example is the introduction of aftercrop (e.g. rye or wheat) which are ploughed into soil during spring as green manure, save farmer's expenses for mineral fertilisers and limit, simultaneously as joint product, the leaching of nutrients into the groundwater during late autumn and winter months, when rains could wash out chemicals if no plant cover exists (Ryszkowski and Karg, 2001). The efficiency of that joint effect could be substantially increased if the water cleansing service of shelterbelts is incorporated into measures of groundwater pollution control.

Semi-natural habitats maintained in the agricultural landscape can constitute important refuge for many plants and animals, thereby supporting biological diversity in farmland (Ryszkowski *et al.*, 2002b). It was found that a more diversified landscape stimulate a higher number of taxa, as well as the density and biomass of many invertebrates and vertebrates of animal communities. The same is true in respect to vascular plant communities. The studies indicate that in many plant and animal communities the impoverishment of biota due to intensive farming could be mitigated by altering the structure of the landscape through the introduction of a network of shelterbelts, hedges, small ponds, and other refuges. These results have important implications for the protection of living resources in the rural landscape.

2.6 Conclusions: intensification and diversification – the drivers of sustainable agriculture development

The intensification of food production is determined by the demand to feed the growing human population. The fulfilment of societal needs is the third very important pillar of sustainability. In 2000, the United Nations Organisation proclaimed that the elimination of poverty, hunger, and diseases is the Millennium Development Goal considering those calamities as the most significant social drawbacks to sustainable development. According to MEA (2005) there are more than 900 million people chronically hungry, some 1.1 billion still lack access to improved water supply and more than 2.6 billion people lack accesses to proper sanitation. The degradations of the environment curtail sustainable development, too.

The impact of future development of agriculture will have a major influence on the countryside not in terms of a change in landscape use patterns but in terms of more intensive methods of production. Thus, the interactions between society and environment will have to be intensified. The goal of sustainability is to create systems in which negative externalities are offset by joint production effects and the use of ecosystem services. To create such systems that reconcile nature protection

TABLE 2.4. Yearly mean nitrogen losses in discharge from two small watersheds (g m^{-2} y^{-1}) after Bartoszewicz (1994).

Watersheds	Precipitation	Water discharge to ditch	$N\text{-}NO_3$	$N\text{-}NH_4$
Mosaic	514	70 mm	1.0	1.2
Uniform	514	102 mm	16.3	4.1

with economic activity, it is necessary to change the attitude focused presently on object protection to a co-adaptation of production and processes supporting life.

World agriculture became more and more vulnerable ecologically, socially and economically and present trends are generally considered unsustainable.

In order to change this situation intensification should not be achieved by using increasing amounts of resources (e.g. fertilisers) but rather by using them more efficient. Strategies for sustainability should reduce the vulnerability of agriculture to various threats connected with inputs and use of resources and intensive agrotechnologies as well as stimulate greater preparedness and protection against natural disasters (e.g. against harmful effects of climate change). The very important objective of sustainable agriculture is diversification. Diversification will generally increase the resilience of agriculture and minimise production risks. Diversification may be achieved not only with respect to crops and animals but by the introduction of agricultural landscape structures which will increase ecosystems services that limit threats like groundwater pollution, water shortage, and so on. The challenge to introduce these strategies into practice is complex and multifaceted.

One of the obstacles to implement diversification is the public's perception that immediate revenues outweigh the influence of environment degradation or the long-term profits of diversifications.

The second problem is the choice of spatial scale for successful implementing environmentally friendly joint effects and enhancing ecosystem services. The services provided for groundwater cleansing by one shelterbelt have lower efficiency than those introduced by a shelterbelt network covering a watershed. The same is true in the case of raising after-crops during late autumn and winter in order to save money because of smaller consumption of mineral fertilisers. A linked positive non-commodity is the decrease of nitrogen compounds leaching because of the existing plant cover during winter but the efficiency of that joint effect depends on the area where that technology is applied.
The farm is a self-sufficient (autarkical) unit in respect to economic processes. But activities carried out within one farm may have too little effectiveness to curb environment deterioration. This does not mean that environmentally friendly technologies are not important. On the contrary, with regard to some degradation like soil compaction, decrease of soil organic matter, soil pollution, and other threats linked to local deterioration, the application of tillage methods restoring good soil conditions within farms is substantial. Environmentally friendly cultivation technologies can limit, to some extent, the rate of chemical leaching but can not eliminate the threats to groundwater by percolating water which washes chemical compounds out of the soil and spread them in the landscape.

The cycling of water or the spreading of pollutants through water and wind in agricultural landscape operate in much larger scales than a farm area (Ryszkowski, 2002). The same is true for the modification of microclimatic conditions or the protection of biodiversity. Hence, one has to be aware of that a spatial scale may be suitable for the optimal expression of one process, but it is often inappropriate for the others. Therefore the choice of spatial scale for the optimisation of various processes efficiency is complicated.

Besides that, a larger spatial scale than farm scale enables diversification of landscape structures, which support higher stability and resistance of landscapes to threats induced by agriculture intensification.

This analysis has significant implications for the use of joint production effects and ecosystem services. Joint effects linked to production are mainly appearing within farms, therefore their efficacy is much more limited than effects of ecosystem services within landscapes. Preliminary studies performed by experts of OECD, on a degree to which non-commodity outputs may be jointly produced with production output, indicated that the degree of jointing is weak in the case of cultural, heritage features, and agricultural employment. There is also a weak correlation between the provision of non-commodity outputs and the intensity of agricultural production (OECD, 2003). Thus, intensification of agricultural production probably will not result in higher efficiency of environmentally friendly joint outputs; although there is no doubt that negative non-commodities will be more intensive. In order to stimulate desirable joint outputs experts of OECD (2003) proposed the providing of targeted subsidies instead of broad production support as a main goal. The same situation concerns ecosystem services. The financial support should be directly supplied for the introduction of desirable landscape structures.

Studies concerning farmers' perception of environmental problems showed indications for a successful subsidies supply for developing environmentally friendly non-commodities or for managing landscape structures that enhance environment protection. Ryszkowski and Karg (2001) found that threats, which directly limit the economic situation of the farm are well recognised by farmers, while those with taking effect indirectly are mainly neglected. The water shortage, which limits yields, is noted by 71% of respondents, while only 7% bother about ground-water pollution, despite the fact that water quality in wells was not good. The protection of crops by shelterbelts against wind and frost is recognised by 24% of respondents. The higher the education level of farmers was the better they understood the protective services of shelterbelts. The reason for the introduction of secondary crops, which cover soil during late autumn and winter and are ploughed in spring as mentioned above, is saving costs connected with the purchase of mineral fertilisers. But farmers do not note the non-commodity effect of this agricultural technology that consists in the leaching control of chemical components (Ryszkowski and Karg, 2001). Thus, providing subsidies for activities that protect yields or save expenses are better accepted by farmers than financial support for the elimination of threats undermining environment quality.

It seems, that the elaboration of effective methods for a widespread introduction of ecological services, which substantially supplement joint production effects, are of uttermost importance if the goal to feed human population is observed. Economists closely co-operating with ecologists ought to develop new incentives at the farm and landscape level to increase production and revenues, which simultaneously rely on principles of interconnectivity, energy efficiency, matter recycling, and resilience.

The spatial design of various landscape elements providing ecosystem services is dealt in spatial planning which recently became one of the new dimensions of the EU policies of development (ESDP, 1999). The proposed ESDP policy is striving to elaborate strategies to minimise conflicts between different land users, e.g. farmers and nature conservationists, in order to implement the Natura 2000 programme with the establishment of a wide network of protected areas. According to the ESDP 'a broader land-use policy can provide the context within which protected areas can thrive without being isolated'. Thus, incorporation of spatial dimensions into relationships between economy, ecology and societal demands open up broader possibilities to moderate conflicts connected with food production intensification and nature protection.

Congruence of economy and life supporting processes is a fundamental prerequisite for the successful implementation of sustainable development. Before more specific guidelines for the practical implementation of this cornerstone of sustainable development will be proposed, the very general principle that characterises nature evolution should be observed. This principle consists of the diversification of system structures that enhance sustainability and resistance against threats.

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3. The assessment of landscape scenarios with regard to landscape functions

Olaf Bastian, Michael Lütz, Matthias Röder and Ralf-Uwe Syrbe
(Corresponding author: O. Bastian, email: Olaf.Bastian@mailbox.tu-dresden.de)

Abstract

Within a scenario analysis regarding the future development of a rural area in the 'Moritzburg small-hill landscape' north of Dresden (Saxony, Germany) we distinguished the following three scenarios:

1. increased cultivation of renewable resources for fuel (rape, rye, poplar);
2. abandonment of livestock keeping and withdrawal of large parts of grassland and poor arable fields from cultivation;
3. agriculture with a strong focus on nature conservation, basing on a landscape plan.

The three scenarios would influence the landscape and its functions (e.g. habitat function, water balance, resistance to soil erosion, recreation function) in a quite different manner. The ecological analyses were complemented by economic calculations (gross margin), which showed essential uncertainties concerning the influencing factors mainly depending on conditions and decisions on regional scales.

Key words
Agriculture, economic calculation, land abandonment, landscape functions, nature conservation, renewable resources

3.1 Introduction

For many centuries, agriculture has contributed to the development of our cultural landscapes essentially; rightly we can say that agriculture has shaped the face of most parts of Europe and other regions of the Earth. Agricultural land and forests cover about 80% of the territory of the European Union. Agricultural land alone covers more than 50% of the total land area in the region. In March 1998, the OECD stated:

"Beyond its primary function of producing food and fibre, agricultural activity can also shape the landscape, provide environmental benefits such as land conservation, the sustainable management of renewable natural resources and the preservation of biodiversity, and contribute to the socio-economic viability of many rural areas.... Agriculture is multifunctional when it has one or several functions in addition to its primary role of producing food and fibre"
(OECD Declaration of Agricultural Ministers Committee).

Currently, in industrialised countries agriculture is undergoing an intensive transformation process. It is accompanied by changing objectives of land use due to increasing demands for non-agricultural functions of the rural environment, e.g. recreation, nature conservation, protection of natural resources, non-agricultural economic goals, social issues. Changes in landscapes are not only restricted to land use and land cover, but they spread to the landscape as a whole, and they influence landscape processes and landscape functions.

Scenarios are not predictions; they describe trends that are likely under certain circumstances. Due to the uncertainties and erratic changes in nature and society and the wide variety of variables and influencing factors it is not possible to give exact prognoses. Scenarios can be a suitable alternative to describe the possible consequences of defined frame conditions and decisions (Haberl *et al*., 2003).

In order to analyse and to evaluate current and future landscape changes various landscape characteristics can be used, but also landscape functions that are especially suitable, complex indicators, especially to bridge from scientific to socio-economic issues, and to stress the consequences of changes for the human society. The term 'function' has particular meanings not only in mathematics and politics, but also in landscape ecology. Here, the term 'landscape function' stands on the one hand for fluxes of matter, energy, and species and on the other hand for the capacity of natural processes and components to provide goods and services which satisfy human demands directly or indirectly (De Groot, 1992). According to Haase (1991), the assessment of societal functions of a landscape is a pre-condition for relating the actual landscape state to socio-economic categories and processes. By the classification into economic (production), ecological, and social functions (Bastian, 1991; Bastian and Steinhardt, 2002), the concept of landscape functions can be linked to the sustainability concept with its established ecological, economic, and societal categories of development. Examples of such landscape functions are: biotic productivity, resistance to soil erosion, water retention capacity, groundwater recharge, groundwater protection, habitat function, aesthetic and recreation functions.

Below, on the example of a rural area north of Dresden (Saxony, Germany), a scenario analysis (with three different scenarios) will be presented. This scenario analysis is basing on different landscape indicators and landscape functions. For all three scenarios the future land use is simulated, and the ecological and economic consequences are calculated and discussed.

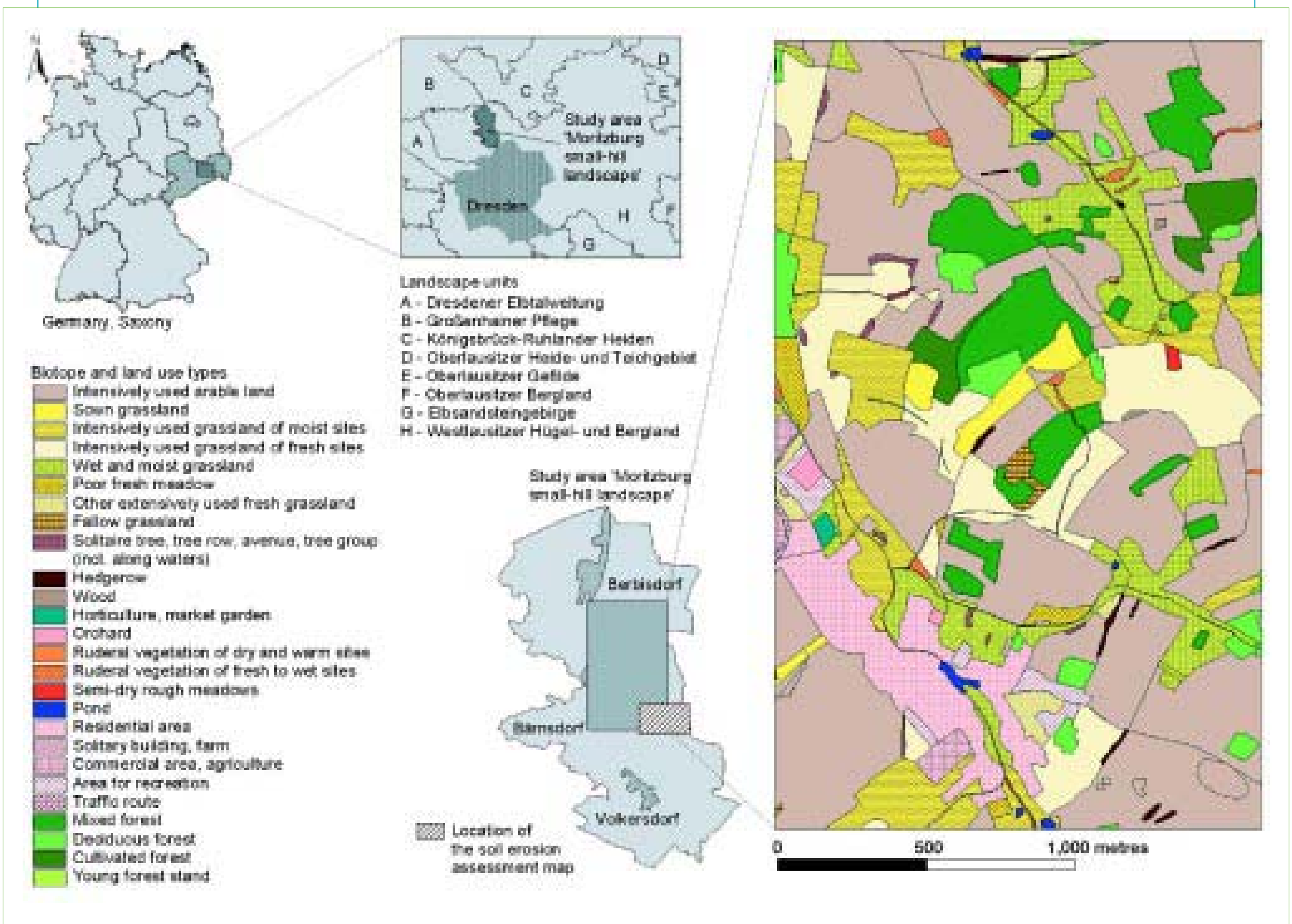
3.2 Methods

The study area (about 21 km²) covers the territory of three villages. It represents a characteristic part of the 'Moritzburg small-hill landscape' that is very attractive and almost unique in Central Europe from a geomorphologic and a landscape-genetical point of view. Similar landscapes are situated in southern Sweden. The average altitude of the area is between 170 and 190 m above sea level. Its peculiarities are the conspicuous relief forms, consisting of a small-scaled pattern of small hills and low ridges with rocks sticking out on the one hand and with flat hollows on the other hand. The bedrock consists of predominating monzonits, but also of granodiorite, sandy, and holocenic substrates. This basic pattern is responsible for the high diversity of soil, water, and climatic conditions as well as the vegetation cover and land use: essential contrasts and difficulties for an effective agricultural production are typical. Forests and coppices are concentrated on the tops of the rocky and stony hills, arable fields are found on slopes and grassland in moist hollows (Figure 3.1). Land improvements (especially drainage) had tried to diminish this natural heterogeneity but with moderate success. That is why, a rich-structured rural landscape with a considerably high biodiversity and interesting scenery survived up to now. Among flora and fauna, first and foremost plants and animals that are adapted to less intensive agriculture are worth-mentioning, e.g. some arable weeds, plants of field margins, birds breeding in hedges, coppices, grassland and arable fields; amphibians, reptiles and many insect species (cp. Bastian and Schrack, 1997).

For the future development of the agricultural landscape in the study area, three scenarios are in the bounds of probability:

1. Increased cultivation of renewable resources (rape, rye, poplar) for fuel;
2. Abandonment of livestock keeping, withdrawal of large parts of grassland and poor arable fields from cultivation;
3. Agriculture with a strong focus on nature conservation, according to a landscape plan from 1997 and to the prescription of the landscape protection area 'Moritzburg small-hill landscape.'

FIGURE 3.1. The geographical situation of the study area, and a section of the biotope and land use map.



In order to characterise landscape changes we analysed the following (state and pressure) indicators and landscape functions (description of the methods in Marks *et al*., 1992; Bastian and Schreiber, 1999; Bastian and Steinhardt, 2002):

- Habitat function (the function of landscape to supply suitable living conditions for wild plants and animals including their communities): esp. biotope assessment, vegetation records, floristical and faunistical analyses;
- Water balance: surface runoff, groundwater recharge (assessing the different influences of crops, and considering expected climatic changes);
- Morphology of running waters (influencing self-purification capacity);
- Resistance to soil erosion;
- Historical landscape elements, aesthetic values, and recreation function.

To ascertain the possible future proportion and distribution of crops we took the following parameters into consideration: the suitability of the site for the particular crop species (especially the soil fertility), the size of the parcels, the possibility to reach the fields (distance from the farm, barriers like highways).

To evaluate the economic effects of the different scenarios, a business management analysis was carried out. For each particular crop the variable margin (= gross margin) per hectare was calculated. The standard variable margin (= gross margin) per hectare was used as basis for the evaluation of crops (Lütz and Bastian, 2002; Figure 3.2). This was done by comparing the inputs and the outputs of each production method (difference between agricultural yield and the proportional special costs). Thus, the variable margin is: Agricultural yield (sum of market-prices, subsidies from the EU and the Saxon government, and compensations for deprived areas), less costs of production (seeds, fertilisers, biocides, costs for machines, and human labour).

We were working on the following assumptions:

- Economic value of field fodder is equivalent to the average variable gross margin per hectare of arable land (used capacity costs). (There is no market for field fodder. Its value can only be calculated as the profit that is missed, because field fodder parcels are lost for the cultivation of market crops.)
- The monetary assessment of grassland is basing on the equivalent of the arable land that would be needed for forage production (base for evaluation: metabolisable energy). (If the grassland is use for fodder production arable fields are saved for other crops).
- Market prices in all scenarios are equivalent to the actual prices.
- Consideration of current (until 2004) and predicted subsidies (from 2013). (Between 2005 and 2012 a step-wise transition from crop- and yield-oriented subsidies to area-related subsidies will take place. These transitional stages are not taken into consideration).
- No changes in animal keeping and management intensity for most crops (except 20% less fertilisers and biocides in winter rye and winter rape).

3.3 Results

The three scenarios are connected with partly essential changes in land use pattern (crop rotation) and land use intensity. Moreover, the environmental goods and services including the landscape functions are claimed and – sometimes also – impaired in quite different ways.

$$\Delta GM = \sum_{CS1+...CSX} \left[\frac{\left(\varnothing Y - (\varnothing Y \times YRF) \times MP - Diff_{Fert.+PPP} \right) \times CA}{CA_{total}} \right]$$

Abbreviation:

D GM	Alteration of the average gross margin / ha [€]
CA	Crop area (area of a particular crop) [ha]
CA_{total}	Total cultivated area [ha]
Fert.	Costs of fertilisers [€]
Y	Yield [dt]
YRF	Yield reduction factor (dependent on fertilisers and PPP application)
Diff.	Difference in costs [€]
CS	Crop species
MP	Market price / dt [€]
PPP	Costs of plant protection products [€]

FIGURE 3.2. Scheme for the calculation of the average gross margin per hectare for crops with special regard to the alteration of the management regime.

TABLE 3.1. Changes in land use and land use intensity in the three scenarios.

Agricultural land use	State %	State ha	Scenario 1	Scenario 2	Scenario 3
ARABLE LAND	**100**	**1002**	**983**	**700**	**920**
Winter wheat	17.15	172	↓	↑	↘
Rye	19.5	196	↘	↑	↘
Winter barley	12.6	126	↘	=	↘
Triticale	1.94	19	↑	↓↓	↘
Oats	1.84	18	↓	↓↓	↘
Summer barley	1.73	17	=	↓↓	↘
Rape	11.25	113	↑	↑	↘
Sunflower	3.7	37	↓↓	↓↓	↘
Flax	4.58	46	↓↓	↓↓	↘
Maize for silage	19.92	200	=	↓↓	↘
Maize (grain)	1.83	18	↑	↑	↘
Pea	2.31	23	=	↓↓	↘
Forage plants	1.66	17	↗	↓↓	↘
GRASSLAND	100	**674**	**607**	**150**	**685**
WOOD CHIPS (POPLAR)		**0**	**87**	**0**	**0**
FALLOW AGRIC. LAND		**0**	**0**	**827**	**0**
ESTABLISHMENT OF **OTHER BIOTOPES**					**70**

Legend	
Used area	
↘	decreasing slightly
↓	decreasing
↓↓	decreasing strongly
=	Constant
↗	Increasing slightly
↑	increasing
Land use intensity	
(grey)	constant
(grey/light green)	constant / decreasing slightly
(light green)	decreasing slightly
(green/dark green)	decreasing slightly, partly strongly
(green)	decreasing
(orange)	increasing

Regarding the proportion and distribution of crops (Table 3.1), scenario 1 leads to the intensification of grassland for fodder (in order to compensate losses in available parcels due to the cultivation of energy plants). Changes in crop distribution are depending on the soil quality (e.g. cultivation of wheat and rape on better sites, rye on poor sites). Wood plantations for energy purposes will be established mainly in wet hollows (former grasslands). In scenario 2, the majority of pastures and meadows will be abandoned. Hobby farmers will manage a major part of the remaining grassland. By emphasising nature conservation, scenario 3 aims at lower land use intensity, diversified crop rotations and a higher proportion of valuable biotopes.

The effects on the habitat function will be as follows: The decrease in grassland in favour of wood plantations and the increasing utilisation intensity of the total area in scenario 1 displaces plant species and communities of moist and wet meadows (e.g. *Holcetum lanati*, *Angelico-Scirpetum*, *Senecioni-Brometum racemosi*). Areas with high biotope values are reduced in favour of medium and low biotope values (Figure 3.3).

There is a general poverty in breeding birds (species diversity, population density) in maize and rape fields (George, 2004). The ortolan bunting does not brood in maize, rape or sunflower fields, and the skylark population is impaired by the extension of rape cultivation (Schrack, 2001). Wood plantations will increase the ϒ-diversity of bird species, but the share of wood species becomes higher and field species will be displaced. Big migrating birds (geese, cranes) are threatened because they prefer large fields for resting.

The transformation of arable fields and grassland to permanent fallow-land, in scenario 2, is partly favourable for some bird species (partridge, corn bunting), reptiles and insects, but unfavourable for field birds (ortolan bunting, skylark). With the increasing growth of shrubs and tall herbs the conditions for field birds and insects become worse (Flade, 1994).

Scenario 3 supports high biotope values and a wide spectrum of rare species and vegetation units, for example extensively used grassland. Several bird species like whinchat, red-backed shrike, corncrake,

FIGURE 3.3. Changes in the biotope values of the study area in the three scenarios.

lapwing and white stork but also insects such as the typical butterfly dusky large blue (*Maculinea* syn. *Glaucopsyche nausithous)* (an animal of EU-Community interest) profit from such meadows and pastures. Extensively used arable fields are positive for the corn bunting. More hedges would be favourable for whitethroat, barred warbler and red-backed shrike, whereas a general increase in the proportion of woods could reduce field birds in favour of ubiquists.

Many parameters of the landscape water balance are depending on land use (vegetation cover, drainage, soil compaction), but also on the climate. While arable fields show more evaporation in summer, on grassland the evaporation is higher in winter. Winter crops need more water than summer crops. That means consequences for water runoff and groundwater recharge. Afforestations (wood plantations for wood chips and for landscape management) and fallow-fields are representing dense vegetation cover that supports evaporation but reduces surface runoff and groundwater recharge. In general, all three scenarios are more or less unfavourable for the water balance. The predicted climatic changes, especially the higher temperatures in spring and summer, will increase evaporation and reduce groundwater recharge during these seasons.

Concerning the morphology of running water (small rivulets and ditches in the study area), no changes are connected with scenario 1. In scenario 2, the abandonment of grassland alongside water means higher degrees of naturalness. The same applies to scenario 3 that provides buffer strips and the revitalisation of running water.

On average, no changes in the potential soil erosion will occur in scenario 1 (Figure 3.4 see over). Admittedly, maize fields are prone to erosion, but less erosion distinguishes rape. More fallow-land and less maize cultivation in scenario 2 mean an increase in areas with low and very low potential soil erosion. In scenario 3, the potential soil erosion would be between the scenarios 1 and 2. Reasons are the (only) slight increase in grasslands and woods while on the overwhelming part of the area no modifications in land use affecting soil erosion are expected.

From aesthetic and educational points of view but also as historical documents, so-called culture-historical elements are important for rural areas, because they represent former agricultural and settlement activities, and they are still visible, at least in relic form. Examples for such landscape elements are: tree rows, hedges, small ponds, edges at fields, tracks, field terraces, stone walls, orchards, historical buildings (mills, stables). Damages can result from the ploughing of field edges, the deposition of wastes and rubbish, and from the abandonment (e.g. of orchards and historical buildings). Scenario 3 is the most favourable for culture-historical elements, whereas in the scenarios 1 and 2: their visibility may get lost due to tall and dense vegetation.

The varied surface (relief), the richness in biotopes and species, the diverse land use pattern, and the vicinity to the Saxon capital Dresden are important pre-conditions for the high recreation value of the 'Moritzburg small-hill landscape', especially for walking, cycling, and bird watching. Of course, scenario 3 is the most favourable for the recreation function due to the higher diversity and naturalness of biotope and land use types. Scenario 1 produces more woods but the character of an agricultural landscape is distorted, and the aesthetic value is lowered (e.g. by young poplar stands; rape is beautiful only when flowering). Scenario 2 causes more fallow-land, which is appreciated ambivalently, according to different stakeholders and personal aesthetic sensitivities.

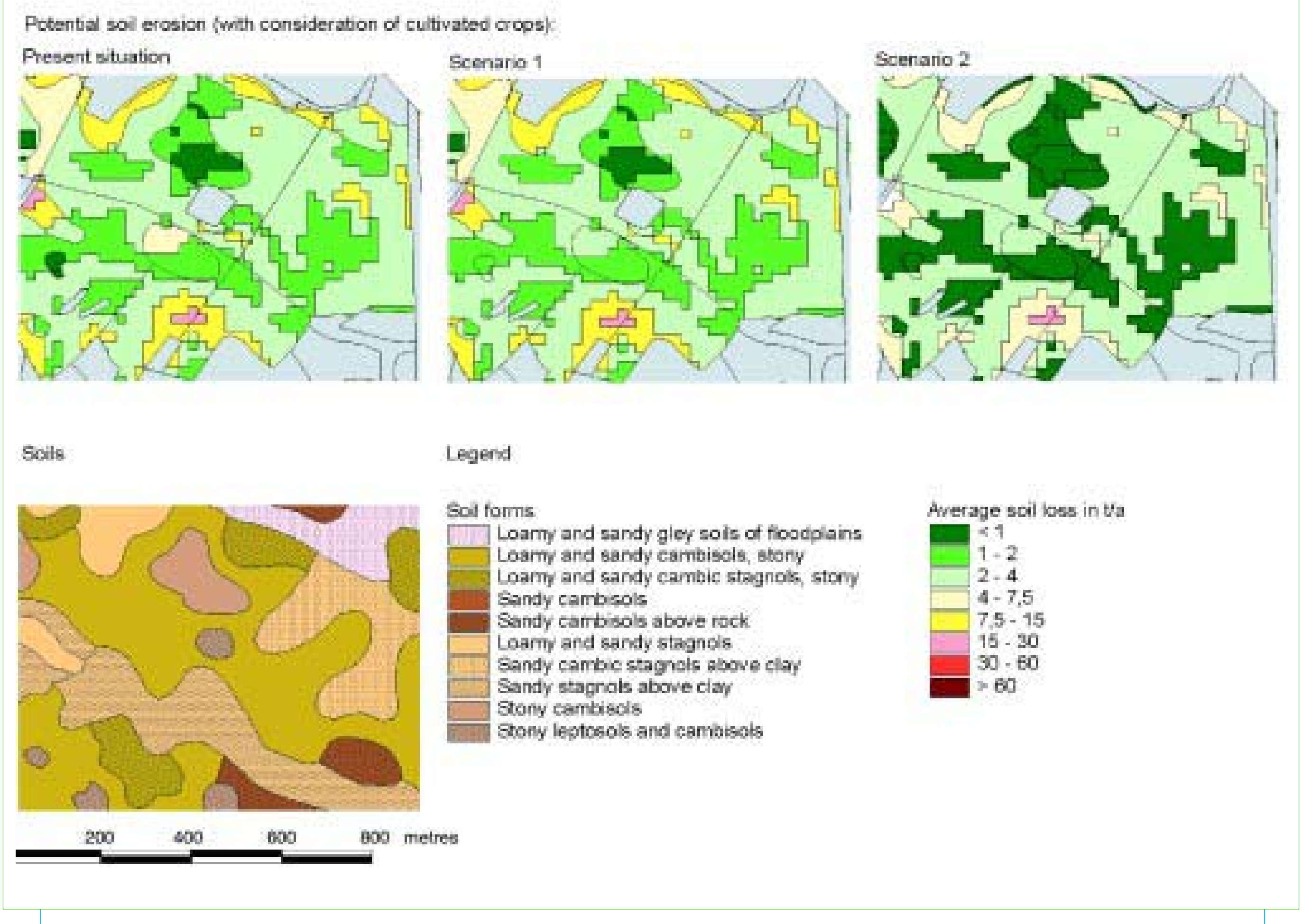
Finally, the economic consequences of the three scenarios shall be compared. In scenario 1, the annual income of farmers will rise from 500,000 € to 616,000 € (= 123%). It depends on subsidies paid for agricultural fields and grassland. It is, however, uncertain if woody stands will be supported by the government or the EU. The abandonment of cattle breeding in scenario 2, permanent fallow on grassland and less total agricultural area will reduce the income from 500,000 € to c. 284,000 € (= 66%). If, however, financial supports will be paid for fallow-land, the total income would rise to 520,000 € (= 110%).

The costs of several measures in scenario 3 (establishment of new woods and hedges, revitalisation of waters) are not included in the calculation (gross margin) because the farmers do not pay them. Only losses in agricultural land are considered. Despite of the diminution of agricultural land (by 10%) thanks to subsidies for grassland and landscape management, farmers' income can rise to 510,000 € (103%).

3.4 Discussion

Comparing the ecological and economic consequences of the three scenarios, the following facts are obvious (Table 3.2). Naturally, scenario 3 does well in the complex 'species and biotopes (habitat function)'. Due to the heavy transformation or intensification of grassland, scenario 1 is the less favourable. Scenario 2 must be regarded as ambivalent because some species would profit and others are disadvantaged. All three scenarios are worsening the water balance. Both, the morphology of running waters and the situation concerning potential soil erosion become better in the scenarios 2 and 3; scenario 1 is – on average – indifferent. For the cultural landscape and for recreation purposes, scenario 1 is the less favourable, while scenario 3 is the best one.

FIGURE 3.4. Soils and potential soil erosion by water at present and in the scenarios 1 and 2 in a part of the study area (calculation method of soil erosion after Schmidt in Marks *et al*., 1992, modified; soil map from Mannsfeld, 1963; crops: own mapping).



The economic consequences strongly depend on the agri-economic policy. Thus, a definite calculation is not possible. If subsidies for nature conservation and landscape management will also be paid in future, the income situation in scenario 3 is similar to the present state. In scenarios 2 and 3 both, income gains and losses are possible. Thus, the total ecological and economic balance turns out in favour of scenario 3. The last-mentioned should be preferred, because it supports the peculiarities and the high values of the 'Moritzburg small-hill landscape' the best.

As mentioned above, nobody knows absolutely which scenario will come true. There are a lot of uncertain factors and influences (driving forces), especially the global and European economic development. Thus, the total liberalisation of global food markets can favour scenario 2, because in this case agriculture in the study area would hardly be able to compete, which would result in essential land abandonment. As the present development shows, it is, however, more likely that traditional crops are not replaced by fallow-land but by plantations of energy plants (Röhricht, 2005) (scenario 1).

Only scenario 3 has more binding force in the form of the landscape plan from 1997. That is why it is interesting to study to what extent the demands fixed in this document have been implemented, and which problems and obstacles are standing in the way. A repeated mapping of land use biotopes in 2004 revealed that only a minor part of the demands fixed in the landscape plan were realised, among them the maintenance of valuable biotopes (e.g. dry meadows, hills, edges) and the total landscape character. Almost no running waters have been revitalised, and only very few new (or former) small ponds have been established. The creation of buffer strips and edges at woods and along field-tracks did not take place; existing ones were reduced or removed by ploughing. Several measures for threatened arable weeds and animals of the fields were carried out. Only very few stone walls, fruit-trees, and extensively used grassland were established or developed.

The reasons for this rather poor balance are: the lack of payments and the limited obligatory nature of landscape plans. The majority of measures were realised by volunteers (NGOs for nature conservation), by agri-environmental programmes, and by environmental compensations (e.g. for the widening of a motorway nearby).

Many biotope types, very rich in plant and animal species, so-called semi-natural communities, are a result of the historical agriculture and they are dependent on the maintenance of moderate land use or management practices. Land abandonment and plantations of energy plants (accept of rye and partly of rape) would also go against the main purpose of the protection of the 'Moritzburg small-hill landscape' to 'maintain typical plant and animal communities of rich-structured agricultural landscapes' (prescription about the landscape conservation area from 12.02.1997).

3.5 Conclusion

The present growing interest of human society in productive, multifunctional, and ecologically 'healthy' countryside, also as part of regional cultural heritage, is a powerful driving force for the development of rural landscapes. It is necessary to find and to implement such forms of land use that guarantee the maintenance of ecological functions to the largest extent, and which integrate a sustainable, resource-protecting development as much as possible. It is, however, obvious that the economic situation of the farmers managing the landscape is the crucial point for the future of rural landscapes. At the moment, no definite statements concerning the future financial situation of agriculture are possible. Essential uncertainties (unexpected changes in political, economic, and ecological frame conditions) can influence the development drastically. That is why, the likelihood of the particular scenarios cannot be calculated. Nevertheless, the scenario analysis is a suitable way to estimate in which frames the landscape will develop in future, and what could be the ecological and economic consequences. It could be shown that landscape functions represent a suitable approach to bridge from ecological to societal issues in order to show the consequences of landscape changes for the human society.

TABLE 3.2. Comparison of ecological and economic effects of the three scenarios.

Parameter / function	Scenario 1	Scenario 2	Scenario 3
Habitat function	-	?	+
Water balance	-	-	(-)
Running water morphology	0	+	+
Soil erosion	0	+	+
Recreation function	-	(-)	+
Economic consequences	+ / 0 123 % / 100 %	-/+ 66 % / 110 %	(+) 103 %

+ = positive, - negative, 0 – no effect

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4. A proposed tool to discern how farming activities contribute to environmental functions in a landscape

Helene Rapey, Etienne Josien, Sylvie Lardon, Gerard Servière and Cécile Fiorelli
(Corresponding author: H. Rapey, email: helene.rapey@cemagref.fr)

Abstract

In areas where a large proportion of the land is used for farming, such as in European countries, evaluating links between farming activities and landscape multifunctionality is delicate and complex. In the last 15 years, social demands and policy orientation have evolved and now voice greater and more varied expectations concerning landscape characteristics, which are frequently linked to farming activity. However, it is still difficult to clearly identify and understand the contribution of farming to landscape multifunctionality because of the many interlocking forms of farm activities and land uses present in a given landscape. In assessing the contributions of farming land use to multifunctionality, research focuses most often on farm units and less frequently on landscape units, and rarely takes into account the complementarity of different farm types. In addition, it usually ignores combinations of non-productive functions in a landscape. Our research objective was thus to devise a framework that could successfully take into account and appraise complementarities among different farms and multiple functions in a landscape entity. We chose a geo-agronomic viewpoint to address the spatial organisation and complementarities of farming practices in a landscape. After methodological proposals an exploratory practical case study was developed in a small diversified livestock farming area on two sensitive environmental functions (preservation of surface water resources and preservation of a mosaic pattern of vegetation).

The main finding of this study was the multiform contribution of the farms to these two environmental functions, both in the overall landscape and on each farm. Two main spatial configurations appeared: 1) large farms with a spatially limited and disseminated contribution to the two landscape functions, and 2) medium and small farms with a relatively large localised contribution to the two functions.

Improvements are now necessary, e.g. in the identification of land users expectations, in the identification of the fulfilment conditions of various function sets, and in the simplification needed to make comparisons between many and larger landscapes. The ultimate aim is to produce tools and references at landscape scale for policy and decision making concerning agriculture and multifunctionality.

Key words
Multifunctionality, method, case study, farm, spatial pattern

4.1 Introduction

In the last 15 years social demand and policy orientation in rural areas have evolved; more varied and extended functions are required of landscapes, especially those with a large proportion of farming area, such as in European countries: preserving water resources, helping vegetation and land maintenance, supplying and preserving long-term employment, etc. These social and policy trends generally bring changes in the conditions of farming (rules, subsidies, user conflicts, etc.). Because of the often large and long-standing farming land uses in rural areas, farmers are considered essential actors in the fulfilment of these functions. However, precise qualitative and quantitative assessment of their contributions is generally complex because of their close dependence on other environmental and local conditions, and the resultant variability (Benoit *et al*., 1998; Hayo *et al*., 2002; Monestiez *et al*., 2004). Such assessment has also become a very sensitive issue owing to its increasing importance for subsidy entitlement.

Recent research on land use contributions to multifunctionality focuses more frequently on the farm unit and less frequently on the landscape unit, and rarely takes into account the complementarity of different farm types (Lardon *et al*., 2004). In addition, this research usually concentrates on the link between the farm productive function and a single non-productive function for the landscape concerned, with a methodology suited to this function, but ignores the varied interactions of non-productive components in the landscape. Evaluating the links between farm activities and landscape multifunctionality is thus currently a delicate and complex issue, requiring new tools, new references, and a new approach in agriculture (OCDE, 2001; Hervieu, 2002; INRA, CEMAGREF, CIRAD, 2002).

Accordingly, our present research objective was to develop a tool that takes into account and evaluates complementarities among different farms and multiple functions in a landscape entity marked by the diversity of farm land users, and of biotic and abiotic conditions (Rapey *et al*., 2004).

Because of our agronomic experience, we first centred our approach on the functions that are most directly linked to farm practices on land, such as environmental and productive functions. We chose a geo-agronomic viewpoint that considered the spatial pattern of farming practices in a landscape, and we were attentive to the location of the different farming areas and practices. Using references from the environmental sciences, we undertook an enlarged agronomic characterisation of the farming area with data on the ecological status of practices and environmental vulnerability of the land support. We tested this approach on a small landscape case study, and we propose a methodological framework for the qualitative assessment and comparison of agricultural contributions to landscape multifunctionality.

4.2 Framework of the data collection

Our principal working hypothesis was that the fulfilment of the environmental functions for a land unit depends on the 'patchwork' of farm practices and natural conditions in that land unit.

This hypothesis generalises the results shown for some of the most frequently studied functions (e.g. soil erosion and its link to the location of tilled fields in a river basin) to sets of environmental functions.

- our approach required a set of specifications for data collection and analysis in a landscape;
- identification and knowledge of the functions that depend locally on the farming activity;
- inclusion of all the farmers present in the land unit, irrespective of their economic role;
- full information on the farming practices on which the fulfilment of the functions depends; and
- consideration of the location of the practices in relation to their bio-physical conditions, and to the surroundings practices.

This approach was implemented in a first case study in a border zone of the French Massif Central. A small entity of 350 ha in the hilly part of a rural commune totalling 1,034 ha of utilised farm area was studied. It displayed a pronounced diversity of farming land uses and land users with mixed crop and livestock farming orientations.

4.2.1 Identification of the functions

This step required defining landscape functions and their links with farming activity. In the literature on multifunctionality, the basis of the function is either the expression of a specific social demand or the statement of a particular impact noted on landscape characteristics. Given our initial hypothesis and our agronomic viewpoint, we assume that a function exists when there is a relation between an expressed expectation of land users, whether farmers or non-farmers, and a spatial entity modified by farming practices. For example, when anglers' expectation of water quality in an area depends on the land cover and practices on the farm fields bordering the rivers in a landscape, then agriculture has a water quality preservation function (fulfilled to varying degrees).

To select the relevant functions for the landscape studied, we used two sources to extract expected effects of agriculture: documents on local environmental regulations for agriculture and the opinions of several members of the commune council. Two main functions emerged for our case study: the preservation of the quality of the surface water resources, and the preservation of the diversity of the mosaic land cover.

4.2.2 An enlarged definition of farmers concerned by the functions

An appraisal of the agriculture functions in a landscape requires to include in the analysis all the farms and fields present, irrespective of their productive or non-productive role. We take this position because some previous studies pointed out the significant impact of concentrations of small non-professional farms in parts of a landscape due to their specific practices and geographical location (Rapey *et al*., 2002). Hence we chose to enlarge the common definition of farmer and farming practice which is generally limited to a productive role (Laurent and Mouriaux, 1999).

In the landscape studied, the 25 farms surveyed, using 94% of their utilised farm area, comprised 54% full-time, 12% part-time, 16% retired, and 16% hobby farms (i.e. with no financial product), accounting for respectively 77%, 6%, 8%, 3% of the entire studied farming area. In a 'classical' approach to farming activity, these last two categories would not have been included, which would have ignored the contribution to landscape functions of 32% of the land users and 11% of the farming area.

4.2.3 Targeted information on farming practices conditioning the function fulfilment

First, this stage required identifying and detailing:

1. the farming practices; and
2. the spatial entity concerned by the functions, because of their potential role in the function fulfilment.

Some points emerged from a literature analysis of agri-environmental studies and measures:

1. types of practices in farm fields with potential effect on each function fulfilment; and
2. criteria and conditions concerning these farming practices that are relevant to their favourable or unfavourable impact on environmental components.

The different practices, criteria, and conditions actually observable in the study landscape were recorded and used as indicators of the ecological status of farm field practices. In this work stage, our objective was to construct tools essential for differentiating farming practices that made favourable or unfavourable contributions to each environmental function, rather than for the evaluation of function fulfilment.

In the study landscape with its functions, the significant practices identified concerned fertilisation and treatments, grazing and land maintenance. For the 'water' function, the selected indicators of the ecological status of practices in each farm field were the estimated annual surpluses of N and P_2O_5 according to the field apparent balance and the declared number of pesticide treatments at certified doses in a year; for the 'landscape' function, the indicators were the observed

FIGURE 4.1. Qualification, in the case of the 'water' function of 1) the favourable or unfavourable character of farming practices on environmental components, 2) environmental vulnerability, and 3) the field contribution to the function fulfilment.

1. Qualification of the ecological status of farming practices / field:
/ 'water' function
- High surplus of N apparent balance
- High surplus of P apparent balance
- High number of pesticide treatments at certified doses

→ 'Unfavourable' practices when at least one condition is fulfilled
→ 'Favourable' practices in other cases

X

2. Qualification of the environmental vulnerability / field:
/ 'water' function
- Proximity of rivers (< 35 m from a field border)

→ 'Unfavourable' bio-physical condition when the condition is fulfilled
→ 'Favourable' condition in other cases

3. Practices × Environment Conditions / field	**'Unfavourable environment'**	**'Favourable environment'**
'Unfavourable practices'	Unfavourable conditions ➘ Potential low contribution	Medium conditions ➘ Potential medium contribution
'Favourable practices'	Medium conditions ➘ Potential medium contribution	Favourable conditions ➘ Potential high contribution

Relevant example for the studied area / 'water' function	'Unfavourable environment'	'Favourable environment'
'Unfavourable practices'	Continuously grazed paddock in an alluvial plain	Continuously grazed paddock on a plateau
'Favourable practices'	Rotational grazing paddock unfertilised in an alluvial plain	Rotational grazing paddock unfertilised on a plateau

presence of bush and/ or tree edge in each plot and the degree of similarity of cover type to that of surrounding plots. After data collection, on each farm field in the landscape each indicator value set was inspected and a classification and frequency analysis of the values relative to an indicator were made. This differentiated the favourable or unfavourable status of practices for the function fulfilment and the landscape studied (Figures 4.1 and 4.2).

4.2.4 A specific view of farming practice location

To consider the interactions of the farm practices with the environmental conditions, information on the ecological status of practices must be combined with data on local environmental vulnerability. A literature analysis gave us:

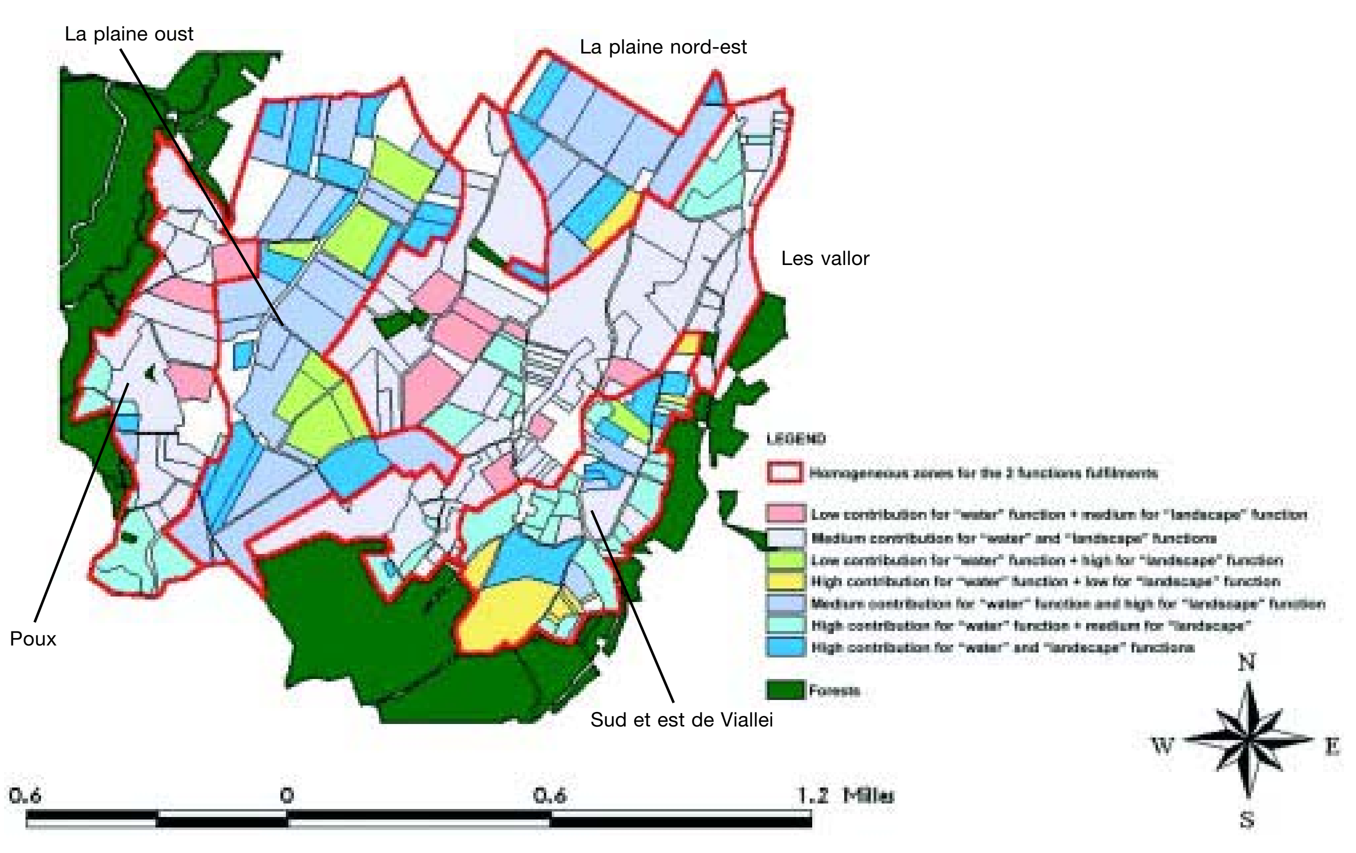
1. certain bio-physical conditions that are determining for the environmental function fulfilment; and
2. criteria and conditions concerning farms fields that are relevant to their environmental vulnerability. The actually observable and variable conditions in the studied landscape were recorded and used as the indicators of environmental vulnerability of farm fields.

As previously for the practices, the differentiation of the environmental vulnerability in all the farm fields in the landscape aimed to show the relative role of bio-physical conditions in the fulfilment of each environmental function, rather than to evaluate the function fulfilment.

On the landscape studied, the bio-physical condition for the 'water' function was proximity of a river to the field; for the 'landscape' function, the condition was the frequency of visibility from the highest points around the studied perimeter. All these indicators were estimated from GIS data bases and tools. After the estimation for each farm field in the landscape, the indicator value set was inspected. As previously done for practice characterisation, a classification and a frequency analysis of the values for each indicator was made to differentiate favourable and unfavourable bio-physical conditions for the function fulfilment in the landscape studied (Figures 4.1, 4.2).

Finally, the collected and used data in this approach to landscape functions covered a larger domain than the more usual field in the farm approach used by agronomists:

FIGURE 4.2. Map of the potential fields contributions to the two function fulfilments in the case of the 'water' and 'landscape' functions for the studied area.



- for the data sources: farms surveys, landscape maps and photographs, etc.;
- for the data: observed values and indicators;
- for the farming activities: full-time and part-time farmers, professional and hobby farmers, crops and livestock, etc.; and
- for the environmental characteristics: topography, hydrography, etc.

These data covered and allowed linkage within various spatial determinants of the function fulfilment.

4.3 Main results

Because of the limited extension of the study area and non-comparison with other landscapes, the findings emerging from the data analysis have no generic scope. Nevertheless, the various agricultural conditions inside the landscape enable us to make certain comparisons and discern certain linkages between function fulfilment and farms and to test the operability and utility of the methodological framework described above.

4.3.1 Inside the landscape; varied conditions for function fulfilment

The 350 ha of farming area studied presented a wide diversity of land-cover: 219 ha of grassland, 93 ha of arable land, 14 ha of fallow and bush, and 2 ha of garden and orchard spread over 240 farm plots. The land users varied in terms of farming labour force and capital invested in farming activity: full-time farmers with more than 100 ha of average total Utilised Area, part-time with about 20 ha of UA, retired with about 20 ha of UA, and hobby farmers with less than 5 ha of UA. Thus, the farming land uses and practices presented a complex pattern in the landscape studied.

After collecting and combining the environmental and practice characteristics of each field (Figure 4.1), we found that the conditions for the function fulfilment were highly varied in the landscape. However, it was possible to discern homogeneous parts of the landscape that formed new spatial and specific entities with similar contributions to the environmental functions (Figure 4.2).

There also appeared a complex mix of conditions for the function fulfilment within and between farms (Table 4.1). A large number of farms were included in the 'favourable' or 'medium' conditions for function fulfilment. In 'unfavourable' conditions, the number was lower. Hence, a large proportion of the farms made different contributions to the functions inside the limited study perimeter and inside their own farm area.

These findings suggest a hierarchy of areas and farmers in terms of aptitude to preserve or increase function fulfilment.

4.3.2 Farm groups with common characteristics in terms of contribution to functions

The conditions for the two function fulfilments in each farm present in the landscape showed some similarities, apparently correlated with common characteristics on farming activity and structure. The 'full-time' and 'part-time' farmers presented the widest-ranging conditions for the function fulfilment (respectively 7/7 and 6/7 of the configurations listed in Table 4.1), the 'retired' and 'hobby' farmers were less widely diversified in their conditions for the function fulfilment (respectively 5/7 and 3/7 of the configurations listed in Table 4.1). The qualities of the conditions were also different: 'retired' and 'hobby' farmers stood out with no unfavourable conditions for the 'water' function, and with favourable conditions for this function for a significant part of their area (> 1/3 of the UA); for the 'landscape' function, most of their used area presented favourable conditions. On closer examination, this high environmental 'performance' was seen to derive not only from extensive practices but from the close fit between the field practices and bio-physical conditions. At the landscape level, these favourable conditions for function fulfilment were not extensive, but were still important because of their relative extension over small sensitive parts of the landscape.

These first findings revealed links between the function fulfilments and the farm type: full-time farmers with a large extension and various locations of their fields ➔ varied conditions and contributions to the function fulfilments with irregular fit between the field practices and bio-physical conditions; retired and hobby farmers with a small extension and similar location of their fields ➔ similar conditions and contributions to the function fulfilments, with frequent fit between the field practices and bio-physical conditions.

Further close inspection of the differences between farms revealed another important factor concerning their potential impact on function fulfilment: recent changes in farm sizes and practices. As regards practices and farms a few years before the CAP 2000 changes (year of survey -8), the 'full-time' farmers contrasted with the others; they presented large changes in farm size (area and livestock) and practices. Concerning their former conditions for function fulfilment, 69% of their area underwent changes during the period 1994–2002, in contrast to the relative stability of the 'part-time', 'retired' and 'hobby' farmers (respectively 24%, 34%, 42% of their area changed during the period 1994–2002).

Thus, spatial and temporal variability were the characteristics of the 'full-time' farmers as regards their contribution to the environmental functions studied. This shows the need to survey full-time and non-full-time farmers specifically and differently to understand and act on function fulfilment in a landscape.

4.4 Discussion and conclusion

This partial approach to landscape multifunctionality, based on a geo-agronomic viewpoint, displays some major strengths and limits.

It proposes a first basis for a structured and operational approach to the characterisation and comparison of the agricultural contribution to landscape multifunctionality. Some improvements are necessary, in particular on the following points: identification of land user expectations conditioned by farming practices, definition and characterisation of the main conditions for the different function fulfilments, a method for combining multiple indicators for practices and bio-physical conditions, and reasoned methodological simplification to allow comparisons between many and larger landscapes.

This proposed approach reveals and can be used to appraise the role of the regulation of diverse practices and farm locations inside a landscape. This viewpoint also discerns and helps to understand how size, complementarities and changes in the different type of farms influences function fulfilment; in the case-study presented, the full-time farmers displayed a high variability in their practices and environmental conditions that induced a wide variability in their contributions to function fulfilment.

TABLE 4.1. Qualification of the global conditions for the 'water' and 'landscape' function fulfilment in all fields in the study area.

Field conditions for 'landscape' function fulfilment	Field conditions for 'water' function fulfilment	Area concerned (ha)	Number of farmers concerned
Favourable	Favourable	37	17
	Medium	75	11
	Unfavourable	17	4
Medium	Favourable	37	16
	Medium	128	20
	Unfavourable	19	5
Unfavourable	Favourable	12	6
	Medium	0	0
	Unfavourable	0	0

The next steps in our approach will be to transpose this framework to larger areas corresponding to administrative and political units of management in order to produce tools and references to support public policy decisions on agriculture and multifunctionality.

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5. Supporting multifunctionality of agriculture in intensively used urban regions – a case study in Linz/Urfahr (Upper Austria)

Rainer Silber and Hans Karl Wytrzens
(Corresponding author: R. Silber, email: rainer.silber@boku.ac.at, wytrzens@boku.ac.at)

Abstract

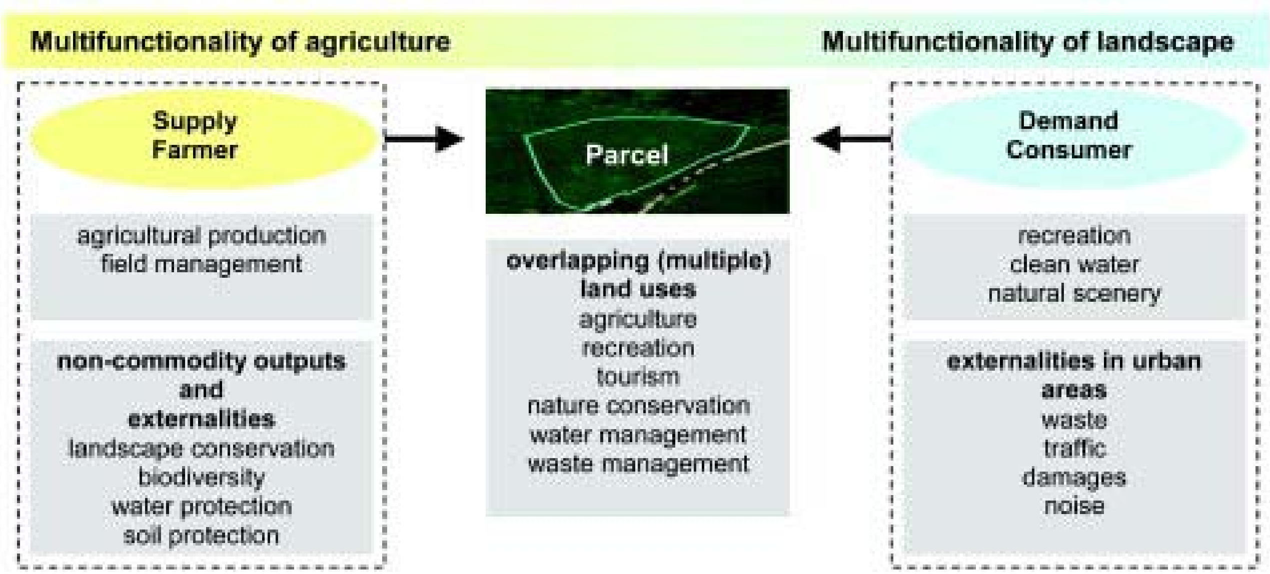
In urban regions, the agricultural business and farmland fulfil multiple functions, e.g. production of food, supply of recreation areas, or nature conservation. Farmers supply land (multifunctionality of agriculture) for various purposes that are demanded by consumers (multifunctionality of landscape). A case study in Linz/Urfahr (Upper Austria) shows how local policy can assess, compensate, and preserve agricultural multifunctionality in urban regions and how farmers perceive multifunctionality of landscape. The city of Linz assigns the multifunctional use of farmland in its local development concept and it compensates nature and multifunctional values of agricultural land by paying a special subsidy to urban farmers. Interviews with farmers proved that they are conscious about their role for urban quality of life although a majority of the farmers pointed out the negative effects of multifunctional use of farmland, e.g. waste, dog excrement, damages. Results of the case study showed that a restrictive green belt policy and special payments help maintaining urban farmland, but an explicit assessment of multifunctionality of agriculture by the local policy needs further efforts.

Key words
Multifunctionality of urban agriculture, multifunctional urban landscapes, land use, GIS

5.1 Introduction

Landscape is a result of spatial activities and their externalities. Multifunctionality of landscape can be regarded as the potential of landscape to satisfy various claims of consumers. Agriculture is one part of a multifunctional landscape making a considerable extent of land use. Multifunctionality of agriculture contains the multiple non-commodity outputs and positive externalities of agriculture. Figure 5.1 shows that the spatial reference unit of an agricultural parcel is the connecting link between supply of multifunctional agriculture and social demand for multiple benefits of farmland. In recent years, assessing, modelling and developing of multifunctional landscapes, multifunctional land use and multifunctional agriculture has been frequently object of scientific research (Brandt *et al*., 2000; Brandt and Vejre, 2003; Van Huylenbroeck and Durand, 2003; Helming and Wiggering, 2003; Vanslembrouck and Van Huylenbroeck, 2005). An explicit study on multifunctionality of agriculture in urban regions was carried out in Belgium (N.N., 2003; Boulanger *et al*., 2004). However, researchers mostly focus on development strategies to preserve multifunctional urban agriculture or multifunctional farm activities (diversification), but less on the assessment of multifunctional agricultural land use.

FIGURE 5.1. Relationship between multifunctionality of agriculture and landscape.



There is a special situation in urban regions as they are characterised by a high density of overlapping different land uses. Thus, urban farmland is usually required for several purposes (like production of crops and vegetables, ecological buffer area, recreation area, etc.) in a multiple manner (Wytrzens and Silber, 2004). Non-developed areas (i.e. open landscape, green belts or green ways in the urban fringes mainly consisting of farmland, forests or water courses) provide scenic, natural and recreational value for urban people (Fábos and Ahern, 1996).

While the extent of agricultural area (supply) decreases due to urban development, non-agricultural pressure on the residual farmland increases. Urban agricultural land is evolving from a production area towards a consumer-oriented space (N.N., 2003). This development turns farmland in (peri-)urban regions into a meeting point of interests of several stakeholders like farmers, nature conservationists and environmentalists, inhabitants, consumers, planners, or building industry. Land use conflicts are a result of opposed interests, e.g. economic and urban development may clash with the maintenance of nature and environmental quality, heavy recreational use may pose a threat to agriculture, but also to ecology. Urban communities sometimes have problems to maintain a sustainable multifunctional agricultural land use as desired by the inhabitants (Boulanger *et al*., 2004; Ryan and Walker, 2004; Sullivan *et al*., 2004; Wagner, 2005). If urban municipalities want to deal with multifunctionality of agriculture and landscapes they need to have concepts how to assess, how to preserve and how to support these aspects. This paper attends several questions with regard to the study area of Linz/Urfahr:

- How can multifunctionality of agriculture and landscape be assessed?
- By which means can local policy compensate and preserve agricultural multifunctionality?
- How do urban farmers perceive agricultural multifunctionality?

5.2 Materials and methods

5.2.1 Study area

The study area Urfahr is the northern part of Upper Austria's capital Linz. Urfahr has got a total extent of 26 km². It could be divided in three main landscape areas:

1. the hilly green belt mainly consisting of small-structured grassland, dominated farmland, and wood;
2. a centrally located green area which is important for ground water protection, but also for recreation; and
3. the green way of the Danube valley being essential for urban climate (Magistrat der Landeshauptstadt Linz, 2003).

Generally, the district of Linz/Urfahr is intensively used for leisure purposes; it is an urban ecological sensitive area that has remained its agricultural appearance. The municipality of Linz protects farmland located in the green belt against urban expansion by a restrictive spatial policy. The number of agricultural holdings is decreasing. In 2003 about 50 farms were located in Urfahr (1988: 87 farms) with an average size of less than 15 ha utilised agricultural area; more than 50% are part-time farmers. Traditional livestock farming is declining whereas pluriactive farming (e.g. leasing of buildings, communal services) is increasing. At 75% of the farm holdings succession is insecure. Most of the farmers' children have non-agricultural education and jobs because of worse income opportunities and missing future perspectives in agriculture. So cultivation of agricultural land, which is a precondition for multifunctional use of farmland, is insecure (Wytrzens and Silber, 2004).

5.2.2 Survey of local farmers and analyses of a municipal subsidy for urban farmers

Results on multifunctionality of agriculture in Linz/Urfahr are particularly based on a survey (2003) of 40 local farmers. The interviews provided information about farm structure, agricultural land use changes, future expectations of the farmers but also about multifunctional landscape and its impacts on farming. The questionnaire used a combination of scaled response, open-ended questions, and multiple response options. After summarising and transforming those answers given at open-ended and multiple response questions, variables were coded and data were analysed by using SPSS. Finally descriptive statistics and statistical analysis methods were conducted.

Additionally secondary data about a special municipal subsidy for urban farmers (so-called 'Stadtbauernförderung') were analysed. Having data of all applicants since 1994, long-run analysis of the payments and the overall development could have been done. Ecological and economic effects of the subsidy were assessed by evaluating expert opinions and by comparing the communal payments with other agricultural aids.

5.2.3 GIS analyses of data

In order to gain information about multifunctionality of agricultural land use and landscape in the study area survey data as well as contents of the local development concept of Linz ('Örtliches Entwicklungskonzept/ÖEK') – which is a central policy guideline that is dealing with future urban and landscape development – were spatially analysed by using GIS (ESRI ArcGIS 8.3). For creating a map about multifunctional farmland (Figure 5.4 see page 33) two main steps were carried out.

Assignments of multifunctional use of agricultural land conducted by the municipality of Linz were derived from a special map ('Freiraumkonzept') within the official local development concept (ÖEK). Agricultural land with additional (non-agricultural) functions was systematically classified into four categories:
(i) nature conservation and biotope pattern;
(ii) urban climate and natural scenery;
(iii) water protection; and
(iv) recreation.

Further agricultural land, green space, developed area, forest and water were displayed according to the land use plan of Linz.

Statements of the interviewed urban farmers about disturbances caused by recreational use of farmland were analysed. Problem areas of such damages were digitised by hand.

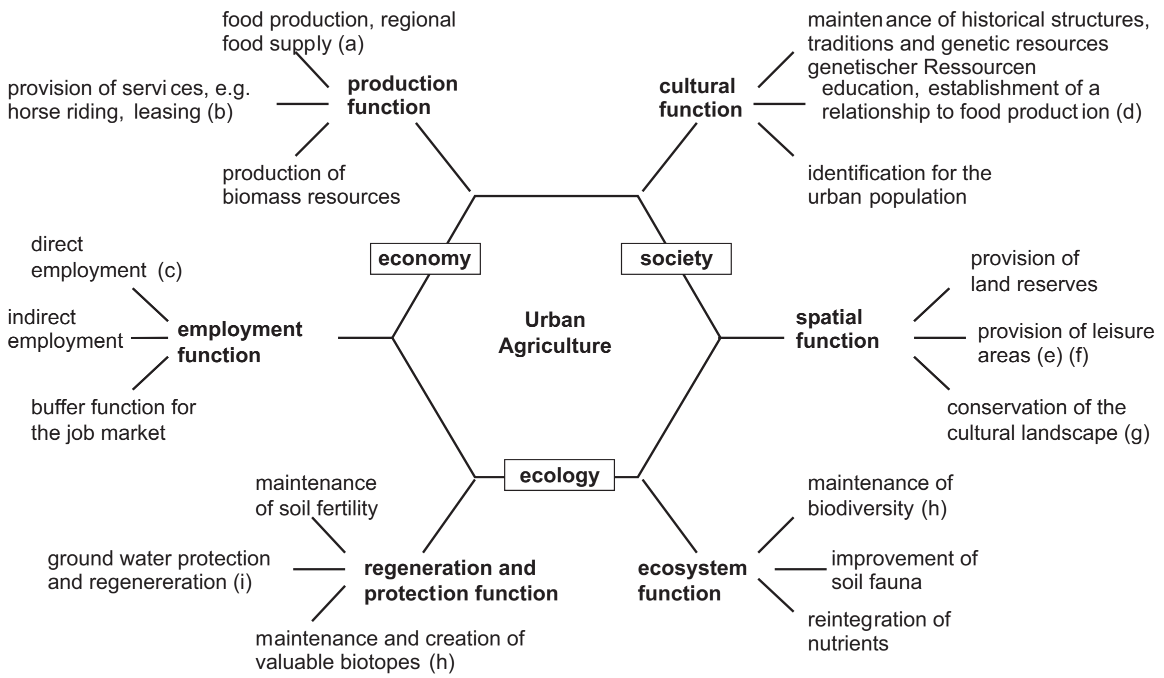
5.3 Results

5.3.1 Assessment of multifunctionality of agriculture and landscape

There is no official and explicit assessment of multifunctionality of agriculture and landscape in local policy although local representatives use this term frequently. Nevertheless, an estimation of agricultural and non-agricultural functions, fulfilled by local farmers and their land could be done by considering the results of the farmers' survey and assignments of the municipality in the ÖEK.

The overall impression of the interviewer was that the local farmers generally are conscious of their importance for the municipality of Linz and the urban society. Not because of producing local food but because of maintaining the cultural landscape. Beside landscape conservation, farmers and their land fulfil different functions about which farmers are commonly not aware of (Figure 5.2). By screening specific literature about multifunctional agriculture and landscapes as well as urban farming (Bastian and Röder, 1998; De Groot *et al*., 2002; Wytrzens and Silber, 2004) six main functions of urban agriculture following the concept of sustainability (economy, ecology and society) can be derived: production, employment, regeneration and protection, ecosystem, spatial and cultural function. According to the survey results and assignments in the local

FIGURE 5.2. Multifunctionality of urban agriculture.



Farm structures and diverse activities of local farmers with multifunctional effects according to survey results:
a) Altogether about 50 farmers and 900 ha farmland in Linz/Urfahr; five direct marketers, seven organic farmers
b) Ten farmers leasing agricultural buildings, two horse farmers, five farmers working for machinery ring, one farmer keeping an inn.
c) 129 persons working on the farms making about 60 full-time jobs.
d) Six holdings co-operating with local schools or offering educational services.
e) Two farmers leasing their land for golf courses, three farmers providing allotments.

Additional functions of farmland assigned in the local development concept:
f) About 180 ha of agricultural land with priority for recreation (20% of total agricultural land in Urfahr).
g) 390 ha of farmland being specifically relevant for urban climate and natural scenery (42%).
h) More than 100 ha with specific importance for nature conservation and biotope patterns (12%).
i) About 90 ha of farmland located in water protection zones (10%).

development concept figures can be attributed to some specific functions.

Several farmers take benefits of the urban location as they currently carry out (semi)-agricultural activities which have multiple direct or indirect benefits for urban people (local food supply, recreation, education, entertainment, services) for gaining (additional) income. Especially leasing of agricultural buildings, organic farming and co-operation with local schools are popular. A considerable number of farmers could imagine to provide communal services (landscape and path maintenance, tree care) or to take part at (supported) nature conservation and environmental projects in future, which would further enhance agricultural multifunctionality.

Farmers reported that they had to face with specific constraints resulting from a multifunctional use of their land. Usually there is open access to private farmland; only special crops and pastures are sometimes fenced in. According to the farmers especially recreational use (like hiking, running, biking, mountain-biking, riding, walking the dogs, barbecuing, camping) has negative impacts on farming, e.g. waste, people destroying or stealing crops, dog excrement (Figure 5.3). Waste thrown into fields can cause damage at machinery but it can also injure livestock by feeding polluted fodder (glass shards, metal). Fodder contaminated with dog excrement (pathogenic germs) may cause diseases and abortions. Such constraints could lead to higher production costs than in other regions; farmers may have to face financial loss and extra work. Problems resulting from recreation are concentrated to specific areas that are most intensively frequented because of good infrastructure (paths, inns) and nice scenery (see Figure 5.4). Altogether 40% of the farmers had to deal with complaints of urbanites because of impacts of agricultural activities (noise, dust, smell).

Only five (of 40) farmers stated that usage of farmland by urbanites for leisure purposes has positive impacts on agriculture, e.g. for direct marketers or because people get in contact with agriculture.

5.3.2 Integration of agricultural multifunctionality in local policy

Generally a restrictive green belt policy sets limits to urban development in Linz/Urfahr in order to create adequate conditions for the maintenance of agricultural land use and to provide urban recreation zones and ecological buffer areas. Furthermore this spatial policy has an aesthetic target too as it shall preserve an undisturbed view from the hills of Urfahr to the city centre of Linz and vice versa. Local policy tries to integrate aspects of multifunctional urban agriculture in different official guidelines and aims, particularly assigning specific additional functions of agricultural land required by society in the local development concept (Figure 5.4). Location of the farmland (proximity to settlements or protection areas) and natural conditions were considered when making classifications of additional functions, e.g. over 40% of the agricultural area has a prior function for urban climate and natural scenery and 20% of the farmland is predominantly relevant for recreational use. When developing and implementing the ÖEK a lot of farmers were sceptical. During public participation the classification of farmland as being highly important for recreation particularly implicated conflicts between farmers and local authorities. Farmers worried about even more constraints and disadvantages for agriculture resulting from leisure activities.

By comparing the negative impacts of recreational use of urbanites according to the statements of local farmers with non-agricultural functions of farmland identified by the local authority it could be shown that generally recreation takes place especially close to urban settlements, two areas which are important for ground water protection are intensively used by visitors, the heaviest demand for recreation and generated constraints occur at areas with an attractive natural scenery, areas which are relevant for nature conservation and biotope pattern are hardly used for recreation (may be these areas are used by sensible visitors that do not cause damages).

According to the green space plan of Linz (Magistrat der Landeshauptstadt Linz, 2002) urban green space (in Urfahr the majority of it is agricultural land) generally has five main functions for the municipality with different importance for agricultural land depending on the site: urban climate compensation function, ecological function, psycho-hygienic function, recreation function, structuring and shaping function. However, local policy does not assess these functions regarding to farmland in the green space plan.

5.3.3 Municipal compensation of agricultural multifunctionality

The municipal compensation subsidy for urban farmers for ecologically valuable measures (‘Stadtbauernförderung’), comprehends itself as a political instrument to preserve nature and agricultural multifunctionality in areas with high pressure on agriculture. These payments have a total budget (Linz) of Euro 100,000 p.a.; in 2003 over 340 ha of extensive meadows and pastures managed by 49 local farmers were supported. This subsidy should be an incentive to keep marginal land in agricultural production. The farmers are motivated to maintain agricultural land use; i.e. they keep the landscape open. At the same time they provide their fields for nature conservation or recreation purposes. Without subsidies afforestation or complete land abandonment would increase because of predominantly negative agricultural ground rents in this region. From the farmers’ perspective this aid represents an important part of their income. Farmers have understanding for the intentions of this measure, as 90% answered that the aim ‘maintenance of cultural landscape’ is very important or important.

5.4 Discussion and conclusions

The diversity of functions that society demands from open land suggests careful dealing with urban agriculture

FIGURE 5.3. Negative impacts of recreational use of farmland by visitors according to the farmers (n = 40) of Linz/Urfahr (2003).

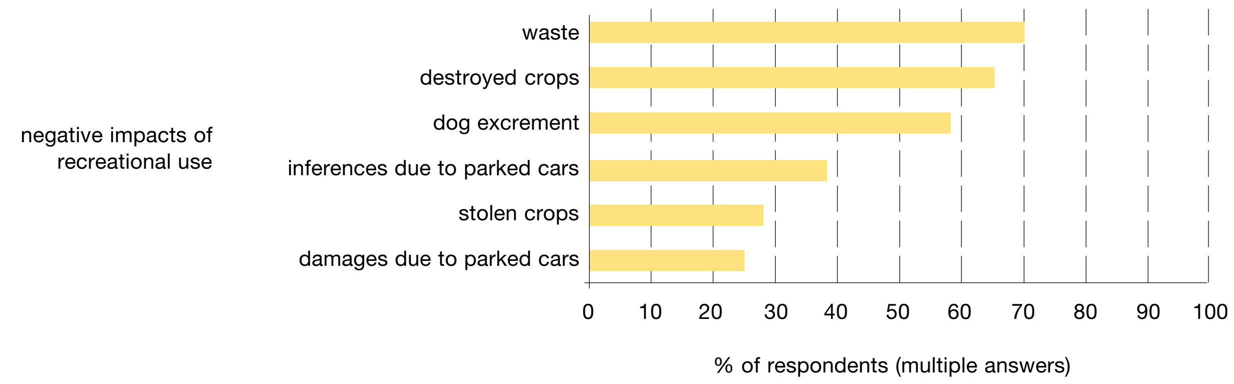
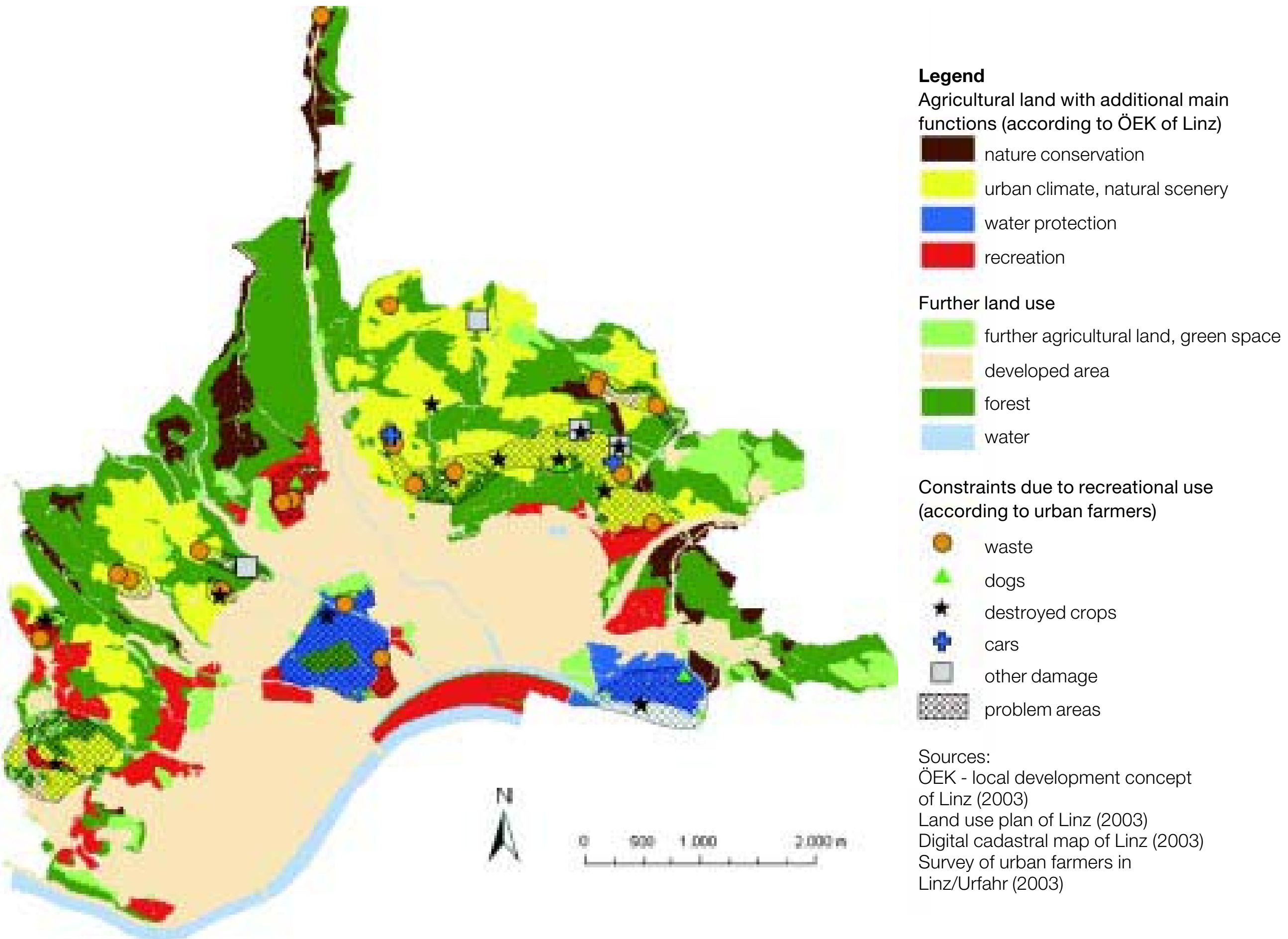


FIGURE 5.4. Additional functions of agricultural land assigned in the local development concept of Linz and local concentration of constraints due to recreational use of urbanites.



Specific functions of agricultural land according to ÖEK	area (in ha)	% of total farmland
nature conservation, biotope pattern	105.5	11.6
urban climate, natural scenery	387.0	42.4
water protection	87.7	9.6
recreation	182.3	20.0
no specific function	149.8	16.4
Total agricultural land in Linz/Urfahr	912.2	100.0

and farmland. (Peri-)urban communities try to safeguard the survival of farms or at least they want to maintain agricultural land use (Wagner, 2005). Strategies and policy instruments like farmland retention programs (Heimlich and Barnard, 1997) are developed to achieve different public goals like balanced land use, adequate open space, containment of urban expansion or protection of urban nature, e.g. by installing stringent environmental measures and regulations in spatial planning. Especially where multiple functions compete local policy and planners either have to set clear priorities or reach sustainable compromises.

Analyses in the study area of Linz/Urfahr showed that measures of the local policy like a restrictive green belt policy or a special subsidy for urban farmers have positive effects on farmland preservation. Particularly the farmers' aid helps maintaining and improving multifunctionality of agriculture and hence the multifunctionality of landscape in the city region of Linz. Furthermore, in future this instrument may be extended to an information basis and monitoring system of urban agriculture as annual data of local farm holdings and their land use are available. According to a study in Salzburg (Nindl, 1998) landscape conservation subsidies are more efficient if they are spatially explicit, e.g. related to parcels like the subsidy in Linz. For creating more favourable conditions for local farmers additional steps beside subsidies should be taken, e.g. public relations projects to communicate the importance of urban agriculture, minimisation and compensation of the damages caused by recreational use, measures to improve the communication and co-operation between urban farmers and the local authorities (Wytrzens and Silber, 2004).

Assigning additional functions of farmland in local policy concepts as done by the city of Linz, may be a first step to assess multifunctionality of urban agricultural land. For developing a method to assess multifunctional urban farming in an explicit way (maybe also in terms of money) further research has to be done. Literature research showed that this field has hardly been subject of scientific studies or policy programmes.

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6. Indicators and assessment of multifunctionality – operationalising the concept for planning applications in landscapes

Beate Jessel (email: jessel@tum.de)

Abstract

In ecologically oriented planning the term 'multifunctionality' has gained high importance as it helps to represent the complexity of landscapes, of their constituents and services. When being used for planning applications and assessments, the term usually refers to the different services a certain landscape unit should provide from a human perspective and thus reaches beyond the field of pure analysis, but is still essentially connected with normative aspects. Two examples serve to illustrate the application of the concept in spatial planning and the related problems of finding appropriate indicators:

- multifunctionality as a sectoral concept being used in nature conservation to determine and to assess impacts on ecosystem functions and to develop functionally related compensation measures; and
- multifunctionality as an integrated, goal-oriented concept that, within spatial planning, is used to determine distributions of land use following the superior overall concept of sustainability.

It can be concluded that it is difficult, if not impossible, to find appropriate indicators to picture 'multifunctionality' itself adequately, but it may be a powerful concept for defining complex targets and integrated guidelines for landscape protection and development, and also to reconcile ecological with economic and social aspects. Thus, attention should be paid on how to interrelate different functions and to link different indicators to come to interpretations on multifunctionality within defined target systems.

Key words
Multifunctionality, indicators, impact regulation, land use, landscape planning, spatial planning

6.1 Introduction

The function model represents an important base that allows for connecting landscape-ecological and planning approaches within landscapes. Despite function is a concept that is already widely spread for analyses and assessments in landscape and regional planning, 'multifunctionality' is often used as a kind of 'umbrella term' that is attributed to the distribution of land use and its expected benefits but nevertheless remains rather vague.

The term 'multifunctionality' has deep roots in the agricultural policy, being associated with particular characteristics of the agricultural production process and its outputs that can be differentiated into commodity and non-commodity goods (OECD, 2001). In this context multifunctionality is first and foremost related to the different outputs of economic activity that may be intended or unintended. It has been applied predominantly to rural landscapes and spread into land use planning, being used as an analytical tool as well as becoming a means to design planning objectives. But beyond rural areas multifunctionality can also be related to any land use pattern, as e.g. urban or forest dominated landscapes should also provide different living, recreation, and aesthetic values (for implementing multifunctionality in urban and suburban areas see e.g. Rode and von Haaren, 2005).

The paper will start with a terminological discussion pointing out the various meanings of the term 'multifunctionality' with relation to spatial units which, as a consequence, may require different indicators. It follows the hypothesis that, when being used for planning applications and assessments, the term usually reaches beyond the field of pure analysis and is essentially connected with normative aspects. In this context, within ecologically oriented planning, assessing multifunctionality and finding suitable indicators usually take place on at least two levels: In nature conservation planning the concept is used to analyse and assess the internal functioning of landscapes as ecological units and to adjust the different ecological functions within one single unit, as different functional characteristics, relating e.g. to species distribution and soil characteristics do not necessarily coexist without conflicts. Beyond this, multifunctionality also serves to reconcile ecological with economic and social aspects. This application can be found in spatial planning and is closely related to the concept of sustainability (see also OECD, 2001, p. 6). Two examples will serve to illustrate these two aspects and also to make clear the practical problems of applying the concept in land use, landscape and spatial planning:

- Multifunctionality as a sectoral concept being used in nature conservation to determine and to assess impacts on ecosystem functions and to develop functionally related compensation measures.
- Multifunctionality as an integrated, goal-oriented concept that, within spatial planning, is used to determine distributions of land use following the superior overall concept of sustainability.

6.2 Dimensions of 'multifunctionality' and consequences for the determination of indicators

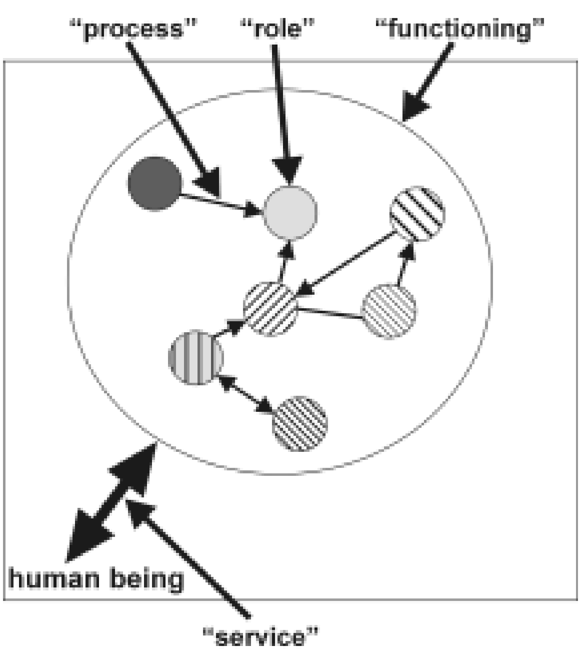
An indicator is defined as a certain parameter value of an object that has a high correlation to another certain parameter value of the same or another object (Arndt *et al.*, 1987, p. 13; Schubert, 1991, p. 22). This correlation can be a quantitative or a qualitative one but at any rate has to be distinct. The difficulties, however, that come up for the definition of those indicators that shall picture multifunctionality become clear as soon as the requirements for simple, i.e. one-dimensional indicators are visualised (see e.g. Zehlius, 1998, p. 11). Basic requirements for indicators are:

- an unequivocal definition of the characteristic that is to be indicated;
- an unequivocal relation between indicator and indicandum ('validity of the indicator');
- a highly stable relation between indicator and indicandum with different representatives of the same indicator, for large spaces, and over a long time ('validity' and 'reproducibility' of the indicator).
- an easy and quick registration of the indicator and consequently a minor effort for the registration compared to the third measurement of the individual parameters for the description of the object ('efficiency' of the indicator).

Beyond this, indicators of multifunctionality are preferably required to represent several functions reliably and simultaneously, fulfilling for each attribute they indicate the above-named criteria. It appears that these requirements are not easy to fulfil, if at all.

Moreover, within the environmental sciences the term 'function' is used in various meanings (see Figure 6.1): First of all it may denote the relations between components of an ecosystem that may be referred to – in a descriptive manner – as 'processes'. Within complex ecological systems that comprise a certain number of processes function may describe the 'roles' which particular single elements play within the system. Regarding the whole system from outside it may also refer (in an analytical way) to the 'functioning' of the system, or, taking into consideration human needs and attitudes, to the 'services' which are provided by the ecological system (Jax, 2000, pp. 8 ff.). The latter usually implies normative aspects, as the kind of services that are attributed to a certain system usually refer to those that are also much valued from a human perspective.

FIGURE 6.1. Different approaches to define the term 'function' (Jax, 2000).



These difficulties of giving a clear definition increase when 'multifunctionality' is addressed: it can be regarded as the different roles one single element can play within a certain system, and as the different processes that relate one element to others. It can also relate, in a descriptive manner, to the different function principles one system can fulfil or, implying normative aspects, to the different services one and the same system maintains for human beings. At any rate, the respective meaning in which 'multifunctionality' is used has to be clearly defined, as it may require different indicators to represent it.

Thus, when picturing such relations, multifunctionality can be used in a descriptive and in a normative manner (see also OECD, 2001, p. 9): In a descriptive way, multifuctionality can be considered as an analytical framework to study complexity (Cairol *et al*., 2005, p. 7). Within ecologically oriented planning, functions have gained high importance as they serve as a means of reducing complexity to its relevant essentials and to handiness for the planning level. They help to represent the complexity of landscapes as 'landscape' itself is a concept representing a spatially explicit entity that cannot be measured itself, but needs to be dissected into measurable entities (Jessel, 1998, p. 11 ff.). In landscape planning, the meaning of 'function' is usually 'the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly' (De Groot, 1992, p. 7; see also De Groot *et al*. 2002) or 'the actual and potential functioning of a landscape for a sustainable fulfilment of human needs, concerning natural as well as aesthetic requirements' (v. Haaren, 2004, p. 81). In this planning context also two different meanings of the term 'function' have to be distinguished. It may represent

a) if the landscape is used actually by the society (external function) or if it plays an actual role just for the ecosystem (internal function);
b) the potential, i.e. the capacity of the ecosystem to fulfil human needs without necessarily using it at the moment.
c) These landscape functions result from interacting factors such as climate, soil, water and land use / land cover. The satisfaction of human needs and at least the potential functioning of a landscape both imply implicit notions that landscapes should fulfil certain services for humans and that they should function in a certain way that has to be described by defining reference conditions. Thus, the notion multifunctionality proves to be symptomatical for the present language use in ecology, in which only an insufficient differentiation between the determination

of facts and the valuation statements is made. At any rate, multifunctionality thus, scrutinised or not, reaches beyond the field of pure analysis and tends to become a planning objective.

As landscapes cannot be pictured by single functions, usually multiple functions are needed to represent a spatial entity called 'landscape' (see e.g. Marks *et al*., 1992; Bastian and Schreiber, 1999). Thus, within landscape planning the unequivocal relation to multiple functions makes clear that it is not only a matter of a sectoral protection of single natural assets but deals with intermedia considerations.

The mixture of descriptive and normative aspects e.g. becomes apparent in the fact that landscape functions in planning procedures are prevalently assigned two dimensions, which both require different indicators: Their 'suitability' (to fulfil certain human needs, which directly implies a normative dimension) and their 'sensitivity' (to changes of that functions, which may represent an analytical dimension but which also becomes normative when it has to be valuated if the respective change has to be considered as an impairment). With respect to ground water for instance, 'suitability' may represent the capacity for the renewal of groundwater resources, indicated by the mean groundwater recharge. Input parameters usually are mean annual precipitation, type of land cover (representing the potential evapotranspiration), soil parameters (field capacity, soil texture), and ground water level. One main aspect of the 'sensitivity' is the protective function of a landscape unit against groundwater pollution that can be derived from a combination of parameters, such as soil permeability, groundwater level and geological stratification. A widespread planning tool that results in combining both aspects, sensitivity and suitability, by overlapping their spatial specifications and deducing an integrated 'ecological risk' is the so-called ecological risk analysis (Bachfischer, 1978).

If one takes a step forward and now explicitly denominates multifunctionality as a planning objective, consequently the securing and development of diverse, reciprocally overlapping functions in the landscape shall not be made so high priority that other functions are neglected. With the discussion of the indicators the question arises which thresholds or standards are to be observed so that 'the functioning of the ecosystem and its services' – a term that is also written in the German Federal Nature Conservation Act – is guaranteed and no impairment limits will be trespassed. In particular, in densely populated countries environmentally sound measures will have different regional significance depending on the specific landscape potentials and with respect to different competing utilisations with variable intensities of their impacts. Thus, multifunctionality necessarily implies a spatially or regionally variable differentiation of the individual environmental functions. Not for nothing, in land use planning multifunctionality is closely connected with the concept of integrated land use, which implies a certain variety of land use within the meso-scale landscape units and with the question about regional thresholds for the upkeep of definite services (see Chapter 4).

Thus, for the application of multifunctionality for analysing and assessing landscapes we can come to the conclusions (see also Jax, 2000) that:

- a clear definition of which specific meaning of 'multifunctionality' is addressed is required in any case the term is used and applied;
- a designation of the respective reference area or reference units must be given, since biotopes, ecosystems as well as landscapes in no way are given or predetermined units but are always defined by the contemplator;
- when used in a planning context (in the sense of 'functioning' of a landscape or its compartments) the concept necessarily cannot remain purely analytical (as it is required e.g. by Cairol *et al*., 2005, p.2) but involves normative aspects;
- these normative aspects have to be assigned clearly and require the definition of respective reference conditions.

6.3 The function concept in the German impact regulation

6.3.1 Legal requirements

In ecologically oriented planning, the function concept is often used for environmental impact assessments considering and evaluating the impacts of certain projects on the respective ecosystem functions. This is especially true and also legally required for the German impact regulation according to the Federal Nature Conservation Act. It refers to interventions in nature and landscape, i.e. to changes to the shape and appearance or utilisation of land that may significantly impair the ecosystem or the natural scenery (Par. 18 (1) of the Federal Nature Conservation Act). If significant impairments on the ecosystem or the natural scenery do occur, they primarily have to be mitigated or avoided. For the remaining impairments the intervening party is obligated to primarily endeavour to offset any unavoidable impairment through measures of nature conservation and landscape management (compensatory measures) or to offset them in some other way (substitute remediation). The Federal Nature Conservation act then explicitly refers to the function concept to define when compensation or substitute remediation is obtained: According to Par. 19 (2) an impairment shall be considered to have been compensated for as soon as the impaired functions of the ecosystem have been restored; it shall be considered to be offset in some other way (= substitute remediation) as soon as the impaired functions of the ecosystem have been substituted in an equivalent manner. These legal specifications thus require that the impacts of projects shall be analysed with regard to the different ecological functions. At any rate, within the impact regulation the term 'function' is used in the sense of 'capacity' or the ability of ecosystems to produce certain goods and services. The major portion of the compensation measures apply to agricultural areas the agricultural use of which is partially continued. However, the agricultural use is imposed the obligation that certain functions for nature preservation are fulfilled as well.

Within the impact regulation, considerations of multifunctionality have to refer to the different functions of the areas that have been disturbed or destroyed. This may concern several functions existing or overlapping on the same site, such as habitat functions for certain species, recharge of groundwater resources and aesthetic functions. These impaired functions then have to be put in relation in each case to the functions possible compensation areas may fulfil to obtain compensation. Compensation sites have to be identified that are suitable for re-establishing the impaired functions and thus to obtain an upvaluation of their natural values. Each impaired function has to be analysed and assessed severally; but to obtain effective compensation it should be tried to establish as many functions as possible on the same site.

These legal provisions meet some practical problems when put into practice.

6.3.2 Lack of a consistent model for ecosystem functions

The function model and the aim to obtain multifunctionality on compensation sites play a great role for impact regulation. Every year all over Germany thousands of hectares for compensation sites have to be determined to fulfil the legal requirements. But so far, no consistent model for picturing the different ecosystem functions is applied. A lot of guidelines exist in the federal states, and also for different administrative districts and municipalities that vary in the functions they specify (Table 6.1 presents an example, showing the functions that have to be assessed, from the official guideline for impact regulation for the federal state of Brandenburg; see MLUR, 2003). Above all, the single functions that are used to picture the different characteristics and interrelations within the natural goods soil and visual landscape vary considerably. This may lead to misunderstandings and to different resulting area sites for compensation measures to be carried out. Furthermore, despite from legal provisions, that require to consider all ecological functions likewise, in practice, abiotic functions and the aspects of natural scenery are often neglected.

Generally, in the ecologically oriented planning, no uniform theoretical concept and a model based on this and understood as 'functions of nature' exists. No doubt, certain existing core functions, that regularly appear in lists and codes of practise, can be found, however there are major differences in the denotation of the functions as well as in the attributed meanings.

6.3.3 Biotope types as proxies for multifunctional units

Another aspect considers the functional units that are the basis for the forming of individual functions. Functional units may be, e.g. watersheds (for groundwater recharge), soil types (that represent certain site conditions), or visual landscape units (i.e. spaces with visually homogenous character that present themselves as living space from the perspective of a person that operates within the landscape and that may serve to picture aesthetic functions; see Jessel, 2006). Within the impact regulation it is above all biotopes that are taken as integral functional units. They primarily serve to picture the general habitat function but furthermore are widely used as proxy for other functions. Regarding

TABLE 6.1. Application of function models in impact regulation: Ecological functions that are suggested to be assessed for impact regulation in a guideline for Brandenburg (MLUR, 2003, pp. 20 ff.).

Natural Assets	Functions
Soil	Buffer / filter function
	Infiltration
	Erosion protection
	Habitat function
	Natural capacity for production of biomass
	Function of soils as raw material deposits
	Archive of natural and cultural history
Water	Renewal of groundwater resources
	Protective function against groundwater pollution
	Surface water protection
	Water and matter retention
Air/climate	Bioclimatic balance
	Protection against immissions
Species/habitats	General function for species and habitats (species, populations, habitats, biotopes)
	Special functions for certain species or within habitat networks
Visual landscape	Function for experiencing nature and for recreation
	Documentation and information function

biotope types it is assumed that they integrate other nature assets, e.g. by reflecting characteristics of the soil and water balance or allowing to draw conclusions concerning the existence of individual species. Moreover, biotope types offer the advantage that usually area-wide data are available or easy to investigate. Though not being functionally defined they are able to incorporate several functional aspects but neglect others. For instance, with the focus on biotope types beyond species especially the population level is often not addressed; the same is true for the overall visual character of a landscape that cannot be pictured by a simple conglomeration of single biotopes.

6.3.4 Determining the necessary amount of compensation

After having been investigated and assessed, the different functions have to be interrelated to determine the resulting amount of compensation, which is usually a certain area where certain measures have to be carried out.

The focus on biotopes here also promotes the application of certain pragmatic models that are based on these units and are applied widespread when assessing impacts and determining the resulting amount of compensation, but do not cover all functions. One model are monetary equivalents that are based on biotopes: The fictive costs of a full restoration of the impaired biotopes are determined; the resulting amount of money is taken to determine the necessary area and amount of compensation. Another approach is so-called biotope value points: The single biotope types are valued by certain criteria such as species richness, rarity, efforts for restoration; and by aggregating these criteria an integrated 'biotope value' is determined. This basic value can be modified by additional factors, representing e.g. soil and water-related aspects or a certain function within habitat networks. The resulting value points are multiplied by the size of the area. These value points are calculated for the biotopes on the impaired area but also for those which exist and which can be obtained on a possible compensation site. The difference between the amounts is crucial for the extent of the area where compensation measures have to be carried out.

The approach to use biotope valuation procedures and monetary equivalents as additional standards of value reveals the problem to not only measure but also interrelate the individual functions. By means of biotope value points or the translation to monetary equivalents a reduction of different functionalities that can hardly be compared as such, to analogous units is made. Thus, it becomes evident that the issue of aggregation of different indicators, that is a problem for all indicator systems, is even more crucial with multifunctionality because different types of dimensions exist that have to be merged.

6.3.5 Spatial relations to picture multifunctionality

Eventually there is the question which spatial relation can be decisive for the attribution of functional compensatory and substitute remediation taken in consideration of the consequences of impairment.

At any rate, according to the legal requirements unavoidable impacts shall be compensated for in functional relation to the respective impacts. Thereby, it is essential for the compensatory measures that they retroact to the place of interference. As a consequence, a comparably close interrelation between the compensatory measures and the place of impairment is predetermined. For the substitute remediation it is required that the impaired functions of the ecosystem have to be substituted in an equivalent manner. For the federal state of Brandenburg the convention was made that substitute remediation has to refer to the same large-scale physical unit (Figure 6.2). Ultimately, this is a convention that reaches beyond the direct spatial interrelation but focuses on preventing that the total balance of the ecosystem continues to aggravate.

Consequently, the impact regulation reveals the problem to determine reasonable spatial units in which definite functions can be attributed and interrelated. The necessary decision which alteration scope is to be still considered as a substitute remediation has the character of a convention in the end.

6.3.6 Lessons from example 1

Thus, the example of the impact regulation shows some typical technical and methodological problems when assessing multifunctionality that are common for impact regulation as well as for the application of the multifunctional concept in ecologically oriented planning in general:

- the lack of a common and consistent functional model to be applied in ecologically oriented planning. Within impact regulation, this may lead to different results about possible compensation measures;
- the problem of measuring and quantifying any function with appropriate methods and according to legal requirements;
- the fact that often biotope types are taken as proxies for spatial units to picture multifunctionality;
- the question which spatial relations can be accepted for certain functions; and
- the problem of interrelating and aggregating different indicators and their related functions to deduce integrated planning (or compensation) measures.

6.4 Indicators for multifunctionality in spatial planning

6.4.1 Functional concepts in spatial planning

Spatial planning includes the tasks to manage land use and spatial functions using the instruments of spatial planning. In Germany, by its legal provisions, spatial planning is also dedicated to the function concept: Par. 1 of the Spatial Planning Act defines as a basic task for spatial development to provide for individual spatial functions and land use. For this purpose different concepts were developed in spatial planning (see

Figure 6.3 see over): The concept of 'balanced functional areas' is related to a small scale differentiation of spatial units and aims at integrating different functions that are compatible to each other on the same site, whereas the concept of 'spatial segregation of functions' implies a broad scale differentiation of spatial functions and is connected with a spatial segregation into priority functions. Both concepts also include a normative dimension. The first concept is also closely related to the landscape ecological model of 'differentiated land use' and the objective of multifunctional landscapes. It has been widely adopted for spatial planning and is explicitly recommended for application e.g. by the German Advisory Council on the Environment (1987, p. 563, 1996, p. 16).

The concept of differentiated land use (Haber, 1972, 1998) is based on the assumption that each spatial unit should secure all basic ecosystem functions. These are its functions for production (e.g. biomass) and regulation

FIGURE 6.2. Large-scale physical units as a base to allocate multifunctional remediation measures in Brandenburg (MLUR, 2003).

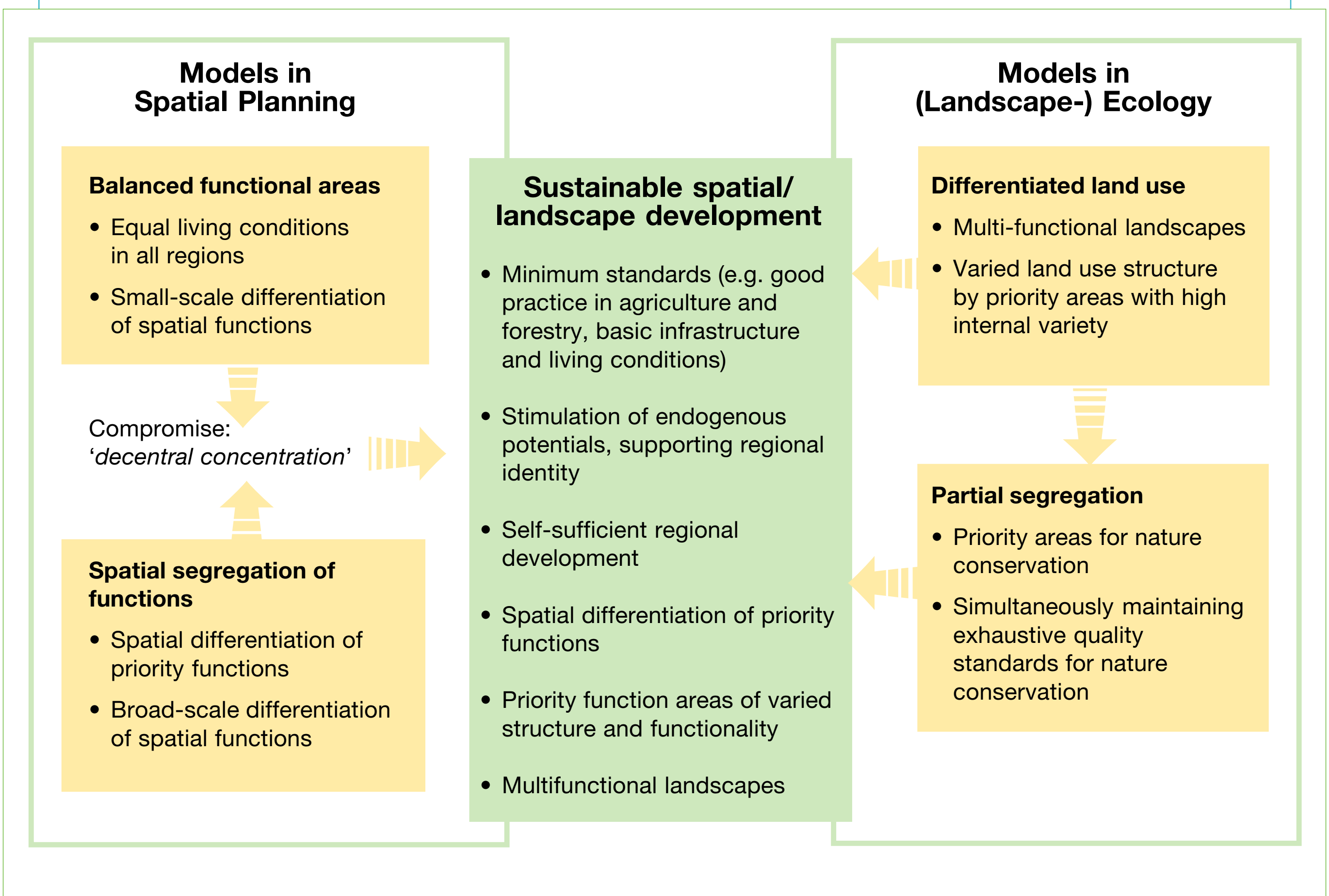
(e.g. the ability of water bodies for self purification), its information function (which comprises also aesthetic values), and its carrier function (for different human activities). It is assumed that the fulfilment of these basic functions must be guaranteed even with different spatial emphases. The concept comes with a spatial differentiation of the utilisations or utilisation concepts which shall guarantee that certain limits of impairment are not exceeded anywhere in the ecological balance. For this purpose the respective prevailing land use (urban-industrial, agrarian-forestal, or near-natural) is to comply with definite standards (SRU 1987, p. 159): within one spatial unit, the land use impairing the environment must not cover 100% of the area. On average, 10–15% of the area is to be reserved or made available for recovery or as a buffer that should be distributed in a network pattern. Furthermore, the respective prevailing land use must be diversified, e.g. with respect to space (by appurtenant spatial sizes) or to time (e.g. by an appropriate crop rotation) in order to avoid the development of large, uniform swathes of land (agrarian or forestal monocultures, monotonous urban areas).

In doing so, it shall be avoided that sensitive resources over large areas are exposed to utilisation impairments and irreversible harm at the same time. Furthermore, the development towards a uniform land use in increasing areas over the last decades shall be slowed down. The concept of differentiated land use is broadly applied in spatial and land use planning, but it is important that it represents not a strict planning principle but a frame for self-organisation without determining a certain fixed pattern of land use. Implementing the concept of differentiated land use in spatial planning has to be based on a systematic analysis and assessment of the different ecological functions by means of indicators. Figure 6.4 demonstrates how the concept can be used for an integrative functional analysis that results in the derivation of functional units covering multiple functions and altogether representing graduated quality standards for the maintenance of natural services: the analysis of the individual landscape functions (such as habitat functions, functions for climatic balance or groundwater recharge, etc.) is taken as a basis.

Thereby, for each resource a separate target concept is deduce, e.g. for the groundwater the areas with a special and general significance for the protection of the groundwater against inflows and for the recharge and with the implication of special requirements for the land use are shown.

The sectoral target concepts must overlap then and a comparison of the sectoral targets is to be performed.

FIGURE 6.3. Models of differentiation of spatial functions in landscape ecology and spatial planning (according to Petry 2004, p. 255).



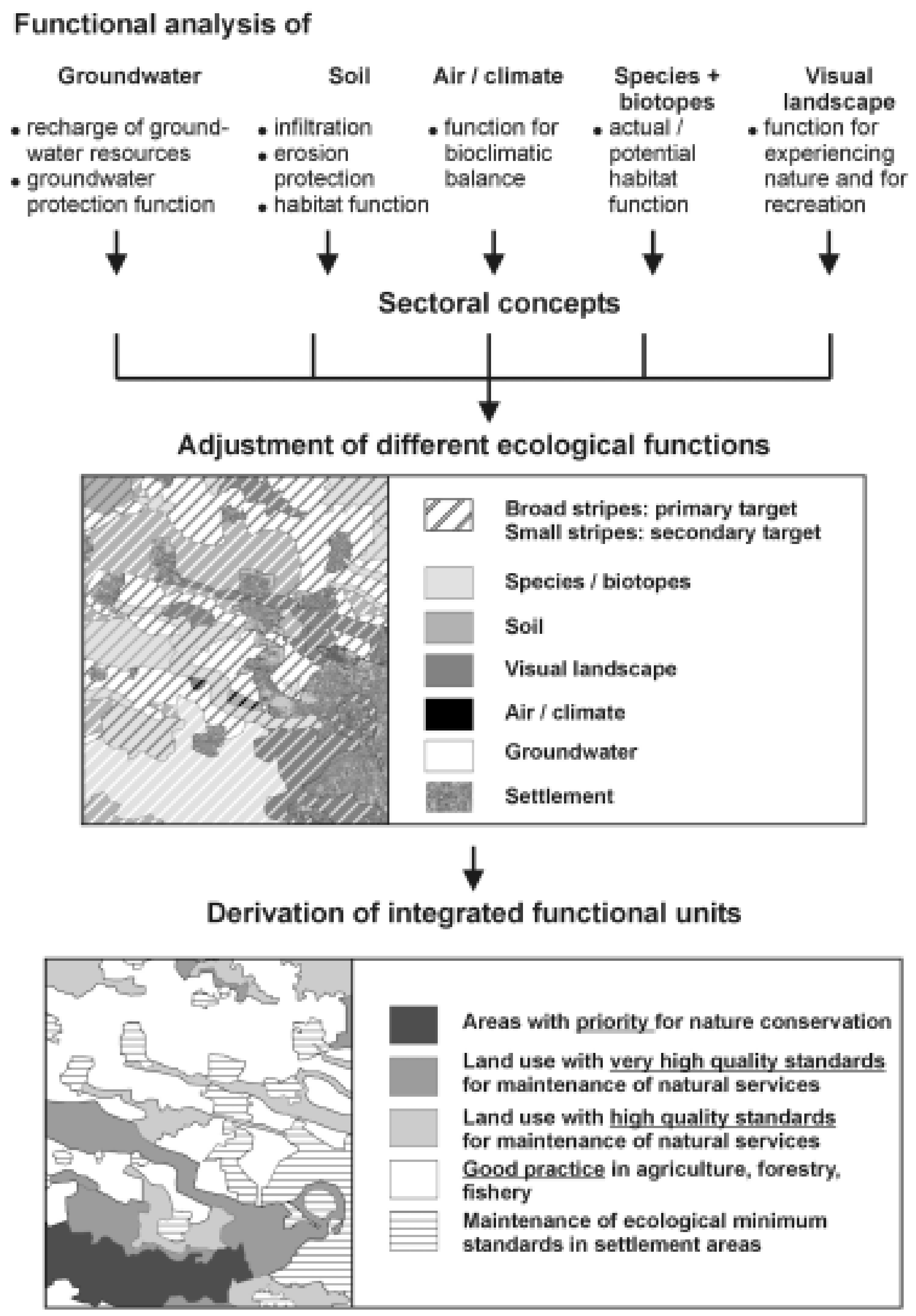
For each resulting spatial unit one main target (first priority) and a subordinate target (second priority) will be determined respectively.

From the overlapping targets the functional spaces will be deduced. They represent functional ecological units where ecological aspects have to be taken into account with different importance but where, nevertheless, certain minimum standards have to be secured anywhere.

The elaborated results serve as a discussion basis in the comparison with other concerns.

This shows that the analysis of individual functions can extend over a wide spectrum, however the complexity that can be shown for the overlap of different functions is limited. Therefore, in this case, main and subordinate targets are determined respectively that have to be taken into account in the resulting functional units (see Figure 6.4).

FIGURE 6.4. Derivation of integrated functional units, based upon functional analyses.



6.4.2 Integrating multifunctional land use into the overall concept of sustainability

Differentiated land use is a concept that is closely related to ecological multifunctionality but in order to obtain a development that can be called sustainable still has to be integrated with social and economic needs.

The German Advisory Council on the Environment that advises to apply the concept of differentiated land use and proposes it for the spatial planning takes the line that certain minimum levels (SRU 1996, p. 26) are to be fulfilled, that:

- include ecological minimum standards for the long-term protection of abiotic and biotic resources as well as the safeguarding of the functioning of the ecological systems (ecological aspect);
- secure the land users an adequate income (economic aspect), and
- maintain minimum standards of social and cultural infrastructure in the rural areas.

Thus, the concept of differentiated land use and ecological multifunctionality gets integrated into the broader discussion on how sustainable development can be achieved. Table 6.2 lists some common indicators that are used so far to picture a 'sustainable development' in spatial planning. It becomes clear that as yet most of these indicators are one-dimensional, being related to one single dimension of sustainable development but not being able to characterise 'sustainability' or 'multifunctionality' itself.

Up to now, one main principle in German regional planning has been the principle of maintaining equal living conditions in all regions. This principle is laid down not only in the Spatial Planning Act but also in the Basic Law of the Federal Republic of Germany (art. 72 (2)). It was one main task of regional planning to assure preferably the same standard in, e.g. provision with infrastructure, access to education, and living quality in all regions. To obtain this objective area-wide minimum standards were established by spatial planning.

Due to the rapid structural transformations within land use and economy but also to the German Unification that reinforced the structural differences within the country, at least in Germany, spatial disparities have grown in recent years and also will further increase in the future (BBR, 2005; ARL 2005). These disparities appear not only between urban / suburban and rural regions but it is also the rural regions that turn out to be rather distinct. Furthermore, it becomes more and more obvious that the complexity of the spatial constellations and the

TABLE 6.2. Some common core indicators that are used to picture 'sustainable development' in spatial planning (BBR 2005, p. 93).

Target	Indicator
Economic competitiveness	
Economic performance	Gross value added per inhabitant (15–65 years old), in Euros
Improvement of innovative ability	Employees in research (per 1,000 inhabitants)
Establishing seminal professions	Employees with higher qualification (UAS or university degree), portion of all employees
Social justice	
Adequate income	Average gross income per employee, in Euros
Increase of employment	Percentage of employment (portion of employees, 15–64 years old)
Increase of women's employment	Percentage of employed women (portion of employees, 15–64 years old)
Adequate provision of jobs	Rate of unemployment
Improvement of education	Persons without school-leaving certificate (portion of all school-leavers, in %)
Improved integration of young foreign citizens	Rate of foreign students on secondary schools
Adequate provision with housing space	Housing area per inhabitant (in sq. m)
Stabilisation and adequate funding of public authorities	Municipal debts
Protection of natural living conditions	
Reduction of sealed areas	Development of the housing and traffic area (in %)
Protection of endangered species	Protected areas (share of national parks, nature conservation areas, SAC and SPA in %)
Reduction of the use of limited resources	Final energy consumption of industries and private households
Reduction of material flows	Municipal solid wastes, in kg per inhabitant and employee
Preservation and improvement of water quality	Share of water courses with water quality class II

development of functions as such cannot be covered by a uniform model.

Thus, recently the awareness has grown that the principle of equal living conditions cannot be preserved any longer and has to be modified or newly interpreted respectively (BBR, 2005, p. 107 f.).

Because of these trends and because area-wide equal living conditions are no longer feasible there is an ongoing discussion to substitute the equivalence of living conditions by spatially differentiated minimum standards. These standards are designed to secure a set of basic functions which have to be defined variably from region to region. As, according to this philosophy, every distinct region has its specific set of functions and demands, methods will have to be developed to determine these key functions and sets of indicators are necessary that may variably integrate ecological, social, and economic aspects (so called inter-linkage indicators; see e.g. Heiland *et al*., 2003, p. 89). Besides, one main question is about who it will be to assign these minimum standards and which leeway will be given to the members of local communities to influence the process of determining them: on the one hand it is clear that these minimum standards cannot be established by the stakeholders themselves in a certain region because it can be supposed that the local people would all claim that they have to get the highest possible standard of infrastructure and services. On the other hand it is also evident that it will not be possible to define those standards without the involvement of the local people. Here, the rules for the respective decision-making processes still will have to be established so that the standards (and indicators) to be introduced will be accepted.

6.4.3 Lessons from example 2

Thus this second example demonstrates that ecological concepts of multifunctionality have to be put into a broader context considering also economic and social aspects for a sustainable development. The need of integrating ecological as well as socio-economic aspects into common indicators for multifunctionality becomes evident. But, at the same time there still is a lack of exactly such so-called 'inter-linkage indicators' at present. Furthermore, the question comes up how participation in the determination and assessment of the resulting spatially differentiated minimum standards could work.

6.5. Conclusions

What follows from that for the application of 'multifunctionality' for planning purposes, in particular for indicating and assessing multifunctionality?

In opposition to the attitude of Cairol *et al*. (2005, p.2) who claim that multifunctionality should be used as a purely analytical framework, the term necessarily includes normative aspects when being applied for planning purposes. Because here, usually the aspect of services that certain spatial units fulfil or may fulfil for purposes defined from a human perspective plays an important role. This requires clear reference conditions and targets that have to be defined, including integrative guiding principles as well as a clear description of the different functions that are referred to respectively.

Another issue is how to register the multiple dimensions of spatial units that are considered as being multifunctional. As for landscapes (that represent complex spatial units) it is also true for multifunctionality that it cannot be measured directly. It is difficult, if not impossible, to find appropriate indicators to picture 'multifunctionality' itself adequately and reliably.
Thus it becomes clear that multifunctionality seems particularly suitable for defining complex targets and integrated guidelines for landscape protection and development. Beyond purely ecological approaches, it may be a powerful concept to reconcile ecological with economic and social aspects, but it seems inappropriate for the level of indicators and their assessment as it is difficult to define indicators that cover several functions likewise, meeting for any of them all demands that have been cited for reliable indicators.

In fact, attention should be paid to address the problem how to interrelate different functions and link different indicators to come to interpretations and assessments on multifunctionality within defined target systems and reference conditions.

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7. Making the multifunctionality concepts operational for impact assessment

Annette Piorr, Sandra Uthes, Yuca Waarts, Claudia Sattler, Kathrin Happe and Klaus Müller
(Corresponding author: A. Piorr, email: apiorr@zalf.de)

Abstract

Multifunctional land use is related to multiple concepts, policies, rural development objectives, and agricultural land use realities. For the assessment of impacts on multifunctionality, a consistent and operable framework has to be developed that refers to all of these different aspects. It also has to integrate those functions and criteria that are addressed in existing concepts for sustainability and multifunctionality and their assessment.

The EU's 6th Frame Programme (FP 6) research project 'MEA-Scope'[1] develops a tool for the ex-ante assessment of policy impact on the multifunctionality of agriculture. Connected to this task is the challenge to develop an operational framework that consistently integrates theoretical multifunctionality concepts with the practical impact assessment requirements. We describe a multilevel approach that integrates the different conceptions and policy levels of multifunctionality into an indicator framework applicable for impact assessment. Both, the demand side of multifunctionality, from the rural development perspective, as well as the supply side of multifunctionality, from the agricultural production perspective, are considered.

Key words
Multifunctional agriculture, sustainable rural development, impact assessment, NCOs, multifunctionality indicators, modelling tool

7.1 Introduction

The promotion of multifunctional agriculture has been set as an explicit goal of European agricultural policy. Especially the latest reforms of the Common Agricultural Policy (CAP) emphasise the role of multifunctional agriculture as an instrument to support sustainable rural development. Since rural areas in Europe vary a lot in terms of geo-physical conditions and urban-rural settings, it becomes highly complicated to assess existing policies or potential future policy options regarding their impacts on multifunctionality. To cope with this challenge, special tools are required that reduce complexity and help focusing on the substantial.

The central issue of the FP6 project MEA-Scope is to develop an ex-ante multifunctionality impact assessment tool on a microeconomic farm approach. Connected to this task is the development of an operational framework that is expected to link in a consistent way theoretical multifunctionality concepts to practical policy impact assessment requirements. This paper describes the structural development of such an operational framework and is organised as follows:

In Section 7.2, a conceptual analysis is presented, which compares the relevant multifunctionality theories, considers the relationship between multifunctionality and sustainability, and determines the scope of policies, which affect agricultural land use and the production of commodities (COs) and non-commodities (NCOs).

In Section 7.3, we present the MEA-Scope operational approach, which distinguishes between a demand side of multifunctionality by policy makers and society as a whole and a supply side of multifunctionality represented by the agricultural production of seven case-study regions. Our approach is based on existing impact assessment methods and indicator frameworks adapted according to the project's requirements, workshops with policy makers to identify their needs and expectations concerning impact assessment tools, expert surveys in our case study regions and a modelling part, to investigate agricultural joint production.

Since multifunctionality demand and supply do not necessarily correspond, we discuss in Section 7.4 how a potential gap can be closed by further research.

7.2 Conceptual analysis

7.2.1 Theoretical multifunctionality concepts

Existing theoretical multifunctionality concepts show a differentiation between a supply-oriented or positive, and a demand-oriented or normative view to analyse multifunctionality (Casini *et al*., 2004). The positive view on multifunctionality recognises agricultural activity as a multioutput activity involving the joint production COs and NCOs with some of the NCOs having the characteristics of externalities or public goods. This approach analysing multifunctionality from the joint production view has been widely adopted, e.g. by OECD (2001), Blandford and Boisvert (2002), Boisvert (2001), or Romstad *et al*. (2000). It stresses multifunctionality as an inherent characteristic of rural

1 MEA-Scope: Micro-economic instruments for impact assessment of multifunctional agriculture to implement the Model of European Agriculture. Project (SSPE-CT-2004- 501516) funded by the DG RTD of the European Commission, FP6 *Policy oriented research* www.mea-scope.org

landscapes with an emphasis on the specific production relationships between COs and NCOs.

On the other hand, there is also a normative component to the analysis of multifunctionality in the sense of maximising positive and minimising negative externalities of agriculture. In this particular point of view, agriculture is given the objective to fulfil certain functions that society demands. This approach is put forward mostly by FAO (FAO, 2000a, 2000b) and the European Commission (e.g. COM, 2004). Following this view on multifunctional agriculture, three main functions of agriculture can be distinguished: the economic, the environmental and the social function. The concept is based on the assumption that agricultural systems are intrinsically multifunctional and have always fulfilled more than just their primary aim of producing food, fibre and fuel (Maastricht, Netherlands, 12–17 September 1999).

Multifunctional agriculture refers to the multiple goods and services that are provided by both, the agricultural sector itself and land use related other sectors. The multifunctional role of agriculture is understood as the entire range of associated environmental, economic and social functions of agriculture.

7.2.2 Multifunctionality and sustainability

From the conceptual perspective the question comes up how to describe the relationship between multifunctionality and sustainability. The MULTAGRI project e.g. analysed this question by pointing out the dependencies between the need and capital oriented and normative paradigm based sustainability concept and the demand, activity and jointness oriented and analytical concept of multifunctionality (Caron and Lecotty, 2005). '...multifunctionality can make an important contribution to sustainability but does not necessarily have to be sustainable … EU policy acknowledges that multifunctionality is an important contributor to sustainability' (Cairol, 2005). Hagedorn (2004) even refers to 'multifunctionality as a tool for achieving increased sustainability'.

7.2.3 Multifunctional agriculture, CAP und Rural Development objectives

To accompany the further reform of market policy, Agenda 2000 explicitly introduced rural development as the second pillar of the CAP. In this sense, the role of agriculture is redefined within the framework of rural development (van Huylenbroeck and Durand, 2003). In particular, the second pillar recognises farmers as the producers of public and private goods in their environmental and social function in rural areas by providing financial support to engage in non-commodity production (COM, 2004). With the introduction of the Midterm-Review-Reform of the CAP the complementary position of rural development became even more accentuated with the introduction of decoupling, modulation, and cross-compliance.

The latest reform of the CAP is expected to provide EU farmers with a clear policy perspective: to go towards integrated rural development with the financial framework until 2013 for agricultural expenditure, to make European agriculture more competitive and market oriented, to promote a substantial simplification of the CAP as well as to facilitate the enlargement process and to better defend the CAP in the WTO. Further, it shall allow maximum flexibility in farmers' production decisions while removing or improving environmentally negative incentives of the current policy to provide encouragement for more sustainable farming practices (COM, 2003). This overall policy development underlines the position of farming as being of overriding importance within the scope of an integrated rural sustainability development (COM, 2004). In order to continue and improve this development according to the situation in rural areas the measures under the EU´s future rural development policy will be build around three thematic axis, namely competitiveness, environment and land management, quality of life in rural areas and diversification. Additionally, the LEADER axis will be integrated as a cross sectional area.

7.3 Operational framework for multifunctionality impact assessment

7.3.1 Requirements

Given the objective of developing a tool for impact assessment of multifunctional agriculture, first a suitable analytical framework is required. Such an analytical framework on the one hand should be operable for more or less specified models working at different scales with data sources at different levels of aggregation. On the other hand, the framework has to meet the existing and envisaged demands for ex-ante policy evaluation. It should comply with the international trade negotiation requirements without sacrificing its normative basis in sustainable development and the promotion of rural areas.

The MEA-Scope project opted for a framework that differentiates between the demands on the supply side of multifunctionality. Hence, our framework consists of two parts: a demand based theoretical approach based on the functions of agriculture to find the demanded NCOs and the representative indicators on the one hand and a supply oriented economic modelling approach on the other hand.

7.3.2 The framework structuring concepts, policies and models

Based on the analysis of existing concepts and theories (*see Section 7.2*), the MEA-Scope project holds the following view. The overall frame for agricultural policy as well as for rural development policy in the EU is formed by the concept of sustainability. The concept of multifunctionality itself is subordinated to it. It is expressed through the policy measures divided into the first and second pillar introduced by the Agenda 2000 reform and the Midterm-Review Reform of the CAP with the main focus on agriculture, increasingly integrated into rural development (Figure 7.1).

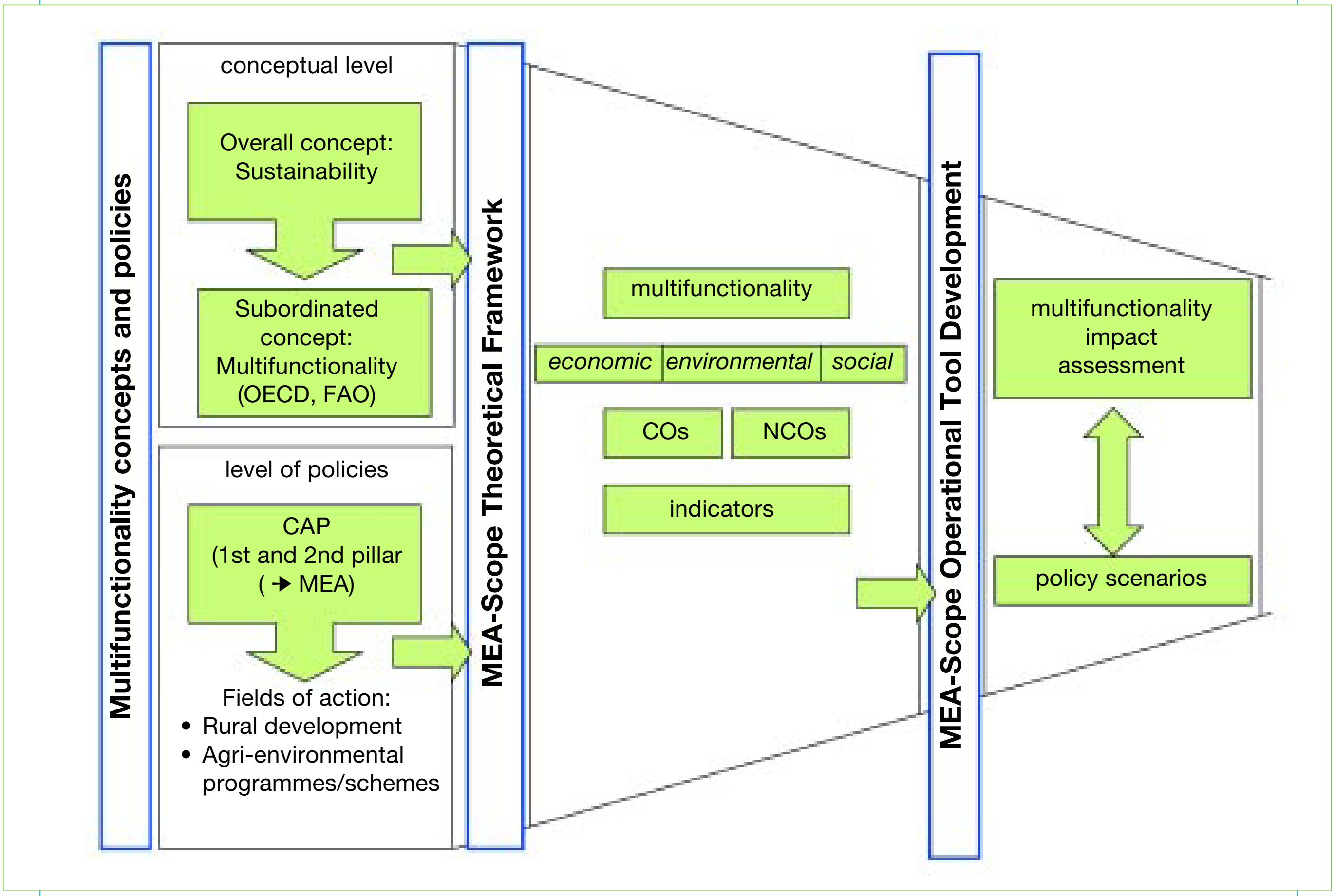
7.3.3 The modular features for demand and supply oriented analysis

The demand for ex-ante assessment of future policies is a specific interest of policy makers in the European Commission. Not only because the policy programmes underlie an evaluation process, of which the ex-ante assessment is a key element, but also because a kind of governance is more and more implemented, which intrinsically builds upon the principle of bottom-up driven national, respectively regional implementation. As outlined, the new policy strategies for 2007–2013 give even more emphasis to the integration of agriculture and rural development.

Thus, also the assessment of the societal demand for multifunctionality becomes an increasing field of interest. Specific regional rural development priorities emerge depending on the given land use structures, the involved sectors, and the development objectives by varying groups and regional policies. We refer to this issue as 'societal demand', and differentiate between the 'potential' demand, which stands for development objectives and priorities, e.g. as seen by regional stakeholders, and 'revealed demand' which expresses itself by subsidies, e.g. agri-environmental programmes (AEP) (Figure 7.2).

The supply of multifunctionality by agriculture can be defined as a function of the joint production of COs, which are typical market products (e.g. cereals …) and NCOs, which are products and functions of the landscape jointly generated by agricultural production which fulfil public or private needs (e.g. biodiversity, fertile soils…) (Barkmann *et al*., 2004; Piorr *et al*., 2005; Wiggering *et al*., 2003). Depending on the diversity and intensity of production structures (e.g. mixed farm, crop production farm), production systems (e.g. conventional, organic) and/or production schemes (e.g. soil tillage system, amount of fertiliser) the ratio between CO and NCO production and the degree of jointness varies (Sattler *et al*., 2006; Piorr *et al*., 2006). Thus, in intensively used agricultural areas due to farm economic reasons the CO/ NCO production ratio is clearly weighted on the production of CO. Contrary, NCO production is rather prevailing in extensively used areas. Regarding the amount of payments for agri-environmental measures (AEM) as a proxy for NCO production, the example of Brandenburg country shows, that given a ratio of arable land/ grassland of 80/20 the related payments for AEM per ha are 13% of total for arable land respectively 55% for grassland, whereas round 50% of payments for AEM on arable land refer to organic farming (Matzdorf *et al*., 2005). Organic farms again are usually located at sites with a lower fertility

FIGURE 7.1. The MEA-Scope theoretical framework integrating multifunctionality concepts and policies and the operational task of tool development.



index, have a higher share of grassland, and a lower yield per hectare (MLUV, 2005).

Also the supply side view differentiates between the 'potential' supply, which refers to the general capabilities and potentials of a specific region, and the 'actual' supply that reflects the real situation, regarding the currently applied agricultural management practices as well as the present environmental conditions.

7.3.4 Hierarchically structured NCOs

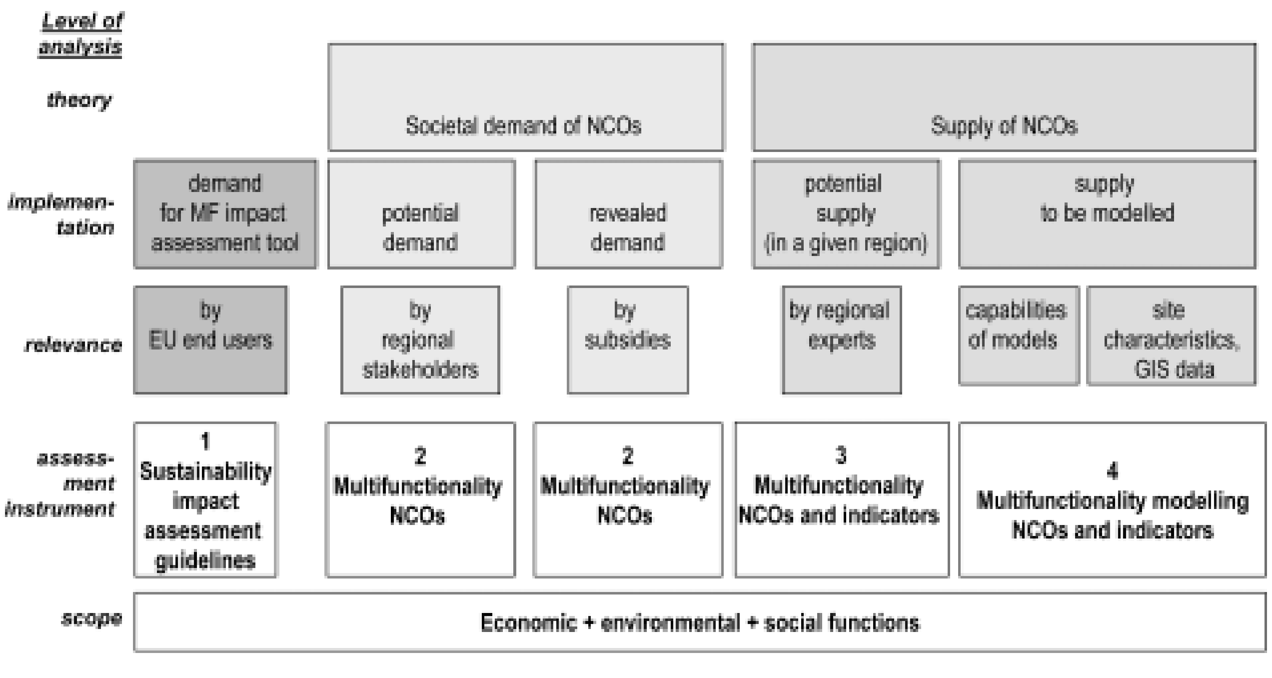
In a stepwise procedure a framework for the assessment of multifunctionality impacts was developed on the basis of established impact assessment and indicator systems. For the selection of the NCOs and indicators, the structure of the MEA-Scope theoretical framework according to Figure 7.1 was taken up.

For the initial framework an assessment system was chosen that allowed for an analogous understanding of the concept of multifunctionality as integrated within the concept of sustainability: The Impact Assessment Guidelines (COM, 2005), a handbook which sets procedural rules for the impact assessment in the Commission, developed to identify whether an issue is related to the EU's sustainable development strategy. The guidelines provide a list of possible economic, environmental and social impacts and name relevant key questions on these issues. Thus, it expresses the policy demand. This list is already in practical use by the potential end-users of the MEA-Scope tool.

In a first step such impacts and key questions which are related to multifunctional agriculture have been selected from the impact assessment guidelines list (COM, 2005) and paraphrased into NCOs. In a second step, this list was narrowed down to adapt it to the assessment needs from the regional demand side. It refers to potential NCOs which can be delivered by the agricultural sector respectively by activities of farmers or by other sectors respectively by activities of other participants than farmers. In the MEA-Scope project the list was used in face to face interviews with stakeholders (representatives from institutions, organisations, and societal groups) in case study regions in Denmark, Italy, Germany and Poland. The stakeholders were surveyed about the regional rural development priorities, the ranking of various NCOs, and about the role which agricultural sector or farmers play in this context. In parallel, step three was carried out for the assessment of the supply side. At this level the NCO list was joint with a compilation of indicators which have been selected from the most relevant (mainly environmental) indicator systems in use. Details on this procedure are described in Waarts (2005). In the MEA-Scope project this list was used for a selection of the NCOs from the scientific experts´ view to the specific problems and potentials of seven European case study regions (in Denmark, France, Italy, Germany, Poland, Hungary and Slovakia).

In step four, the multifunctionality NCO and indicator list was linked to the capabilities of existing models, specifically to the modelling approach applied for the development of the MEA-Scope tool. With this modelling

FIGURE 7.2. The MEA-Scope operational approach for NCO identification and assessment.



approach we refer to the actual supply side. The tool is built on three existing micro-economic models, AgriPoliS (Happe *et al*., 2004), MODAM (Zander, 2003) and FASSET (Hutchings and Gordon, 2001). AgriPoliS is a multi agent model for the calculation of structural change, working at regional scale, using FADN data and considering interactions between different farm types. MODAM is a linear programming model for the calculation of economic-environmental trade-offs for a high variety of management practises at farm level. Trade-offs between farm economics and the achievement of environmental goals are determined in order to assess the degree of jointness of COs and NCOs. FASSET is a dynamic model for matter flow calculations on farm level. First results on the application of the linked tool for a case study region in Brandenburg (Germany) have been published (Happe *et al*., 2006).

All three models were developed for the agricultural sector and from a CO production oriented view, which has been enlarged first to environmental issues and subsequently to the wider range of NCOs. Oriented towards joint production, the modelling approach refers to the supply side. For the selection of feasible NCOs and indicators it was differentiated between the given situation of models capabilities and the NCOs and indicators that can be or will be integrated in further development of the models. As a result, a framework was set up that provides different levels of specification for NCOs and indicators related to economic, environmental and social functions. Examples are presented in Table 7.1.

7.3.5 The indicators for multifunctionality

For the basic structure of the multifunctionality assessment framework, we set up categories for economic, environmental and social functions in analogy to the sustainability concept and the multifunctionality concept by the FAO. By selecting suitable indicators for these three functional categories, the interface for the analysis of the practical meaning of the multifunctionality approach was created. A compilation of indicators from the most relevant indicator frameworks and of those used in relevant projects was set up. As well scientifically oriented policy evaluation frameworks were analysed (Table 7.2).

The indicators were first classified into functional groups (considering the FAO concept) and in a second step to NCOs (considering the OECD concept). In a well structured reduction procedure the basic indicator list was adapted to the different levels of use on the demand and supply side analysis of the project. Due to the comprehensive compilation, Table 7.2 only lists the level of NCOs and the related subcategory. For the assigned lists of indicators with units of measurement we refer to Waarts (2005).

7.4 Conclusions

In spite of several efforts in defining the scope of 'multifunctionality' and 'sustainability' of 'agriculture' or with a broader perspective 'land use', an explicit classification has not yet been agreed on. Generally, the term 'multifunctional agriculture' is mainly used from the suppliers' perspective (the agricultural sectors' view), whereas 'sustainable land use' is referred to from the demand perspective (the broader rural development view). Overlaps are unavoidable as multi'functional' agriculture is related to landscape functions that form a central part of the sustainability concept. *Vice versa*, non or non-exclusively agricultural land use options (e.g. traffic, energy production) that support sustainability of rural regions are more and more supplied by suppliers from different sectors. Cairol *et al*. (2006) confirm in this context that 'multifunctionality is considered as a consequence of the changing needs and demands of consumers and society at large towards agriculture and rural areas…parallel to the evolution of demand, many farmers have engaged in new activities, through new strategies such as diversification, pluriactivity'.

In the MEA-Scope project we considered the difference between the 'potential' and 'revealed/actual' side of

TABLE 7.1. Hierarchically structured impact assessment framework related to economic, environmental and social functions.

Level	Impact assessment framework	Economic functions	Examples for environmental functions	Social functions
1	Sustainability Impact Assessment Guidelines	'Change the level of employment?'	'affect emission of harmful air pollutants?'	'Impact on animal health and welfare?'
2	Multifunctionality NCOs	Employment in the region	Abiotic resources (water, soil, air quality)	Animal welfare
3	Multifunctionality NCOs and indicators	Employment/ labour (DK, D, F, I, PL, SV)	Air quality - ammonium emissions (DK) - greenhouse gas emmissions (DK, D, PL)	Agricultural farming practices: Animal welfare (F, D, HU)
4	Multifunctionality modelling NCOs and indicators	salaried/unsalaried labour - farm labour - field labour - livestock farming labour	- ammonium emissions - greenhouse gas emissions	Animal welfare

demand and supply, depending on the more or less focused role of the agricultural sector, or in terms of participants, the farmers, in the rural development context. From the 'potential' perspective agriculture offers its activities towards multifunctional outputs competitively to other sectors/ participants, e.g. forestry, nature conservation groups or tourism. Competition does not only mean others might reach the same impact with higher effectiveness or efficiency, but also that others might be better integrated in networks competing for the same funds. From the 'actual' perspective the agricultural activities are focused because the current NCO oriented policies, as the agri-environmental programmes (AEP) of the Agenda 2000 only refer to agricultural farms. This situation will change in the period 2007–2013. The funds for AEP, now located in the second axis of the European Agricultural Fund for Rural Development (EAFRD), are forecasted to decrease about 30%. Environmentally sound forestry systems are supposed to receive payments from this axis, too. In parallel, the third axis aiming at promoting life quality and diversification, in terms of starting trans-sectoral activities, opens the range to participants from beyond traditional agriculture. Finally, the budgetary integration of the LEADER axis points out that only network oriented activities with a strong linkage to local action groups hold a promising position for receiving future payments.

TABLE 7.2. Categorisation of selected NCO by functions (Waarts, 2005).

Functional category	Selected NCO	NCO subcategory
Economic	Generation of income Employment Rural entrepreneurial activities	
		- water quality
		- water availability
		- soil quality
		- air quality
		- pesticide use
Environmental	abiotic resources	- energy use
		- biodiversity
	biotic resources	- habitats
		- landscape management
		- landscape pattern
		- landscape amenities
		- abandonment of farmland
		- farming systems (in protected areas)
		- grassland management
	landscape and land use	- management practices
		- maintaining cultural landscape
		- maintaining buildings
Social	Cultural heritage	- traditional (farming) practices
		- nature conservation
		- educational services
	Non-farming activities	- care activities
		- population characteristics
		- labour use
	Social infrastructure	- health
	Recreation in rural areas	
	Healthy food/food safety	
	Animal welfare	

The MEA-Scope indicator list is based an the analysis of the following indicator frameworks/references:
The Baltic Environmental Forum, 2000; The BIOGUM project, 2004; Bösch, P. and E. Söderbäck, 1997; The Commission of the European Communities, 2000, 2001; EEA (European Environmental Agency), 2001a, 2001b, 2004; The ELISA project, 2000; The ELPEN project, 1999; The ENRISK project, 2004; European Commission and Eurostat, 2001; EU, 2003; Eurostat, 2001; FASSET, 2004; The IRENA project, 2003; McRae, T. and Smith, C.A.S. (eds). 2000; OECD (Organisation for Economic Co-operation and Development), 2001a, 2001b, 2004, 2004; The PAIS project, 2004; Prescott-Allen, R., Moiseev, A. and MacPherson, N. 2000; Reid, W.V., McNeely, J.A., Tunstall, D.B., Bryant, D.A. and Winograd, M. 1993; The SAFE project, 2004; UNDP/UNEP/World Bank/WRI (World Resources Institute), 2000; UNEP (United Nations Environmental Programme), 1999, 2001; Wascher, D.M. (ed.). 2000; WHO (World Health Organization) Europe, 2004.

The models of the MEA-Scope modelling approach do not allow to simulate the processes between demand and supply of NCOs, as well as they do not integrate trans-sectoral activities of farm households. The first analyses of surveys on the societal demanded NCOs show distinct differences between the kinds of NCOs demanded in different regions (case study areas) located in different European countries and the NCOs which are supplied by the current agricultural practice. NCOs related to environmental and landscape functions, for example are more demanded in extensively used areas, whereas NCOs providing for economic and social functions, e.g. the prevention from migration of young people, are rated extremely important in intensively used areas. The specification of the gap between both sides – demand and supply – is expected to be one important result of the framework in use (Figure 7.3).

In this context the issue of scales of the tool becomes an interesting question. While the administration often demands a multifunctionality impact assessment at a regional scale (districts, landscapes), the production side asks for an assessment at single farm level. Therefore, the requirements of a multiscale approach in the development of impact assessment tools can be deduced. The MEA-Scope tool works at this multiscale level. Resuming the considerations about complexity of transactions and properties (e.g. 'resource and actors characteristics, that often have no clear boundaries, and positive (intended) effects and negative (non-intended) side effects materialise in different environmental media and different geographical areas' (Hagedorn, 2006) new challenges for adaptations arise.

From our view also methodological and monitoring related tasks should be taken into account. For a full implementation of multifunctionality assessment frameworks as the presented one, some effort remained unsatisfactory. This is especially due to the insufficient availability of data on the social NCOs and indicators. Thus, currently both research and policy advice have to cope not only with the lack of social impact assessment criteria, indicators and data. Even the discussion on the definition and assessment of social externalities of multifunctional agriculture is ongoing (Mann and Wüstemann, 2005). There is definitely a need for monitoring systems that better integrate social NCOs or indicators in the existing European agricultural databases or vice versa specifically refer to agricultural activities respectively to farmers in rural development related databases.

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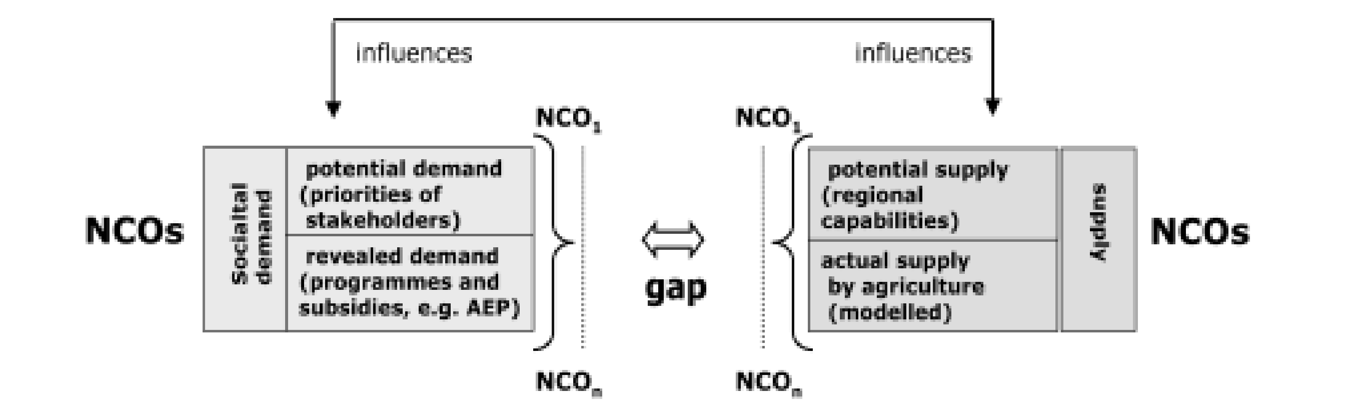
FIGURE 7.3. Conceptual background for NCO demand/supply identification.



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8. N and P flows and balances in Wielkopolska farms

Jerzy Bieńkowski and Janusz Jankowiak
(Corresponding author: J. Bieńkowski, email: bienkowjerzy@poczta.onet.pl)

Abstract

Within the strategy of sustainable agriculture development, attention is given to the necessity of limiting the nutrient balance surpluses in farms. Nutrient excess in farms is a potential source of environmental pollution through leaching to water or volatilisation to atmosphere. The aim of the study was to determine the flow and balances of nitrogen (N) and phosphorus (P) in different farming types. The research was carried out in a group of 30 farms representing three agricultural types: milk production, pig production and crop production (10 farms each). The highest production surpluses of N and P were on farms of milk production type (127.7 kg N ha^{-1} and 21.3 kg P ha^{-1}). The farms specialising in crop production were characterised by the lowest values of N and P production surplus (39.2 kg N ha^{-1} and 5.9 kg P ha^{-1}). The average levels of N and P soil surpluses were as follows: 56.5 kg N ha^{-1} and 21.3 kg P ha^{-1} in farms with milk production; 42.6 kg N ha^{-1} and 20.5 kg P ha^{-1} in farms with pig production; 33.2 kg N ha^{-1} and 5.9 kg P ha^{-1} in farms with crop production. The results of the research indicate that, while maintaining the existing farming intensity, a decrease in nutrient surpluses would be possible through the efficiency increase in N and P utilisation in animal feeding and higher crop productivity.

Key words
Nutrient balance, farming type, farming intensity, gas emission, environment pollution

8.1 Introduction

Positive mineral nutrient balances could be generated in intensified agricultural production areas, which constitute threats to the environment. In places of intensive farming the most important problem for human health can be a risk of water pollution with nitrates (NO_3). The leaching of NO_3 to water to a large degree would depend on physiochemical soil properties, local climate conditions, vegetation cover and landscape structure (Hoffmann and Johnson, 2000; Ryszkowski, 1992).

Agricultural activities are accompanied by nitrogen (N) and phosphorus (P) emissions to the environment (Hoffmann and Johnson, 2000; Jankowiak *et al*., 2003; Ryszkowski, 1992; Tilman, 1999). The places and directions of infiltration of these elements are diverse, for example run-off to surface and ground waters and N volatilisation in the form of ammonium (NH_3), nitric oxide (NO) or nitrous oxide (N_2O) (Jarvis *et al*., 1994). Through identification of critical places, together with the flow paths of mineral elements and assessment of their losses, the priorities for undertaking protection actions can be properly set, aiming at modification of agricultural practices, introduction of organisational changes in farms as well as establishing biogeochemical barriers absorbing pollutants from surface and ground water.

Better understanding of nutrient stocks and flows at farm level helps to focus on the sources of their emission to the environment. That emission is interpreted as a loss from the whole farm. The characteristic feature of an element flow system in the farm is its modular structure (Halberg *et al*., 1995). Its distinguishing parts are animal feeding, storage and application of organic fertilisers, and plant growth (Granstedt, 2000). The losses of elements occur in each module. Types of farming in which animal husbandry is present are in an analytical respect more complicated. The reason is interrelationship between the animal and crop enterprises.

In Poland, most intensive forms of agricultural production occur in Wielkopolska Region. This Region has the highest share in total production of main agricultural products (Mieroslawska, 2001). Farms within this area show a strong orientation in livestock production, with stocking density of pigs and cattle being equal to 262 and 39.1 animal heads per 100 ha, respectively. Up to now, there have not been sufficient efforts to estimate nutrient balances in commercial, individual holdings with intensive production organisation in Wielkopolska farms. Because of dissimilarities of production processes in animal and crop production systems it is also important to recognise if and to what degree they differ in respect of nutrient balances and accumulation in soils. The aim of our study was to determine the balances and flows of N and P in different farming types of Wielkopolska Region.

8.2 Materials and methods

8.2.1 Population and sampling procedure

Analysis of N and P balances and flows were carried out during the years 2002–2004 in a population of 30 commercial privately-owned farms representing three types of farming: milk production, swine fattening and crop growing, classified according to EU farm typology (Augustyńska-Grzymek *et al*., 2000). From each type 10 farms were selected randomly, allowing only one farm per county to assure even distribution over the region.

8.2.2 Nutrient flow model

The difference between N and P quantities flowing to a farm and their retention on the level of animal production, together with their uptake by plants, is described as net balance (Sveinsson *et al*., 1998). The detailed description of element flow in farms can be helpful in formulating specific advice aimed at reduction of emitted quantities of elements and at the same time at an improvement in the use of mineral nutrients from farm inner sources. The analysis of N and P flow was performed based on Granstedt's model designed for an assessment of NPK flow in conventional and organic farms in Sweden (Granstedt, 2000). That model presents in an integrated way the flow of nutrients through all parts of a farm production system (Figure 8.1). In our study, each type of farming was featured by three segments of production system, i.e. a whole farm, subsystem of animal production, and environmental subsystem embracing soil and crops, also described as a subsystem of plant production.

8.2.3 Methodology of N and P balance research

At the beginning of the analysis there was an estimated nutrient balance for the whole farm 'at the farm gate'. The calculation method for nutrient balance, in kg nutrient ha^{-1} of agricultural land (AL), based on Granstedt's model (Granstedt, 2000), is given below:

$$NB = (IN1 = IN2 + IN3 + IN4 + IN5 + IN6 + IN7 + IN8) - (OUT1 + OUT2) \quad (1)$$

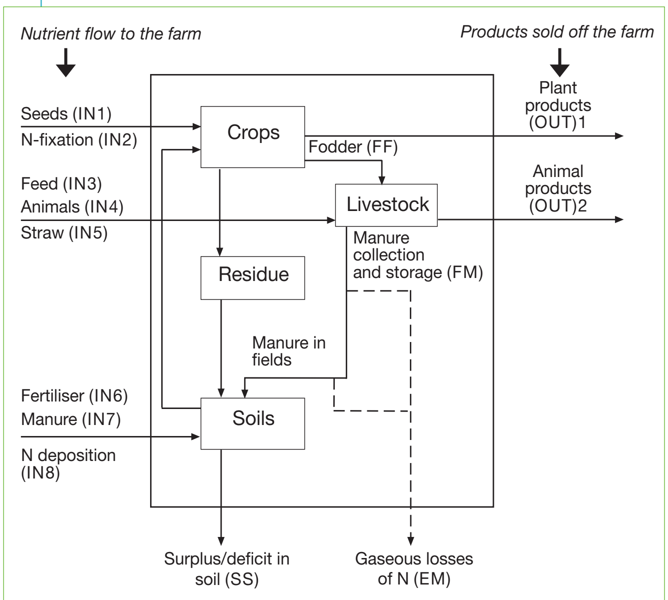
where: NB – nutrient balance at farm level, explanation of the remaining symbols is presented in Figure 1.

Besides nutrient balance, N and P surpluses in soil are also calculated by this model. N surplus in soil (kg ha^{-1}) on a farm level is assessed in the following way:

$$SS = NB - EM \quad (2)$$

where: SS – N surplus in soil, explanation of the remaining symbol is presented in Figure 1.

FIGURE 8.1. N and P inputs and outputs flows at farm level.



This pool of N in soil is also prone to losses in a process of leaching. P compounds are not subjected to gaseous losses, therefore positive values of P balance in farms are equivalent to its surplus in farm soils.

Concentrations of N and P in main yields and residues were taken from literature (Fotyma and Mercik, 1995; Kujawiak, 1994; IZ-INRA, 2001). Quantities of nutrients in soils available for plants are determined by summation of nutrient contents in mineral fertilisers, N deposition from the atmosphere, and elements introduced into the soil with plant residues and manure.

For the flow analysis of nutrients in the animal production branch, information on type and quantity of own and purchased forage used in feeding, as well as type of animal from outside the farm acquired for production purposes, was necessary. Flow of nutrients in animal production in a simplified form is presented by the following equations:

$$FM = NIA - OUT2 \quad (3)$$

where: NIA – nutrient inflow to animal production, explanations of the remaining symbols are presented in Figure 1.

$$NIA = IN3 + IN4 + IN5 + FF \quad (4)$$

where: FM – manure collected, explanation of the remaining symbols are presented in Figure 1 and in Formula 3.

N and P amounts in animal products exported outside the farm (livestock, milk) were estimated as a product of sold quantities by separate product groups and the average concentration of N and P in those products based on literature (National Research Council, 2003; Rotz *et al*., 2002). Extent of N emission in the form of NH_3 and N_2O was assessed separately for each animal species, considering various forms of faeces collection (deep litter, shallow litter, slurry) based on the emission coefficient accepted by the Atmospheric Emission Inventory Guidebook (UNECE/EMEP Task Force on Emission Inventories and Projections, 2002).

8.3 Results and discussion

8.3.1 N balance

The N balances for different farming types are presented in Tables 8.1 and 8.2. Balances were calculated for three elements of production system: whole farm, animal production and plant production. Large variations of accounted nutrients occurred both within farm production types, as reflected by values of standard deviation, and also between analysed types of farms. It could be assumed that such effects were caused by different animal stocking rate, crop rotation, high variability of the level of inputs flowing to farms and technology of animal feeding. The lowest N balance (39.2 kg ha^{-1}) at the farm level was found in farms of

TABLE 8.1. Annual N balance for three farming types of studied farms in Wielkopolska Region (kg ha-1) at the whole farm level.

No.	Balance components	Farming types: Dairy		Swine fattening		Crop production	
1	Inflows into the farm, of which:	168.8	(50.4)[1]	164.4	(57.8)	139.6	(27.8)
	purchase of feedstuffs	50.6	(27.5)	69.0	(49.4)	5.1	(8.6)
	mineral fertilisers	102.7	(31.0)	81.1	(19.8)	119.0	(22.8)
	seeds	0.8	(0.8)	1.3	(0.9)	1.2	(1.0)
	atmospheric deposition[2]	10.5		10.5		10.5	
	biological N-fixation	0.6	(1.7)	0.0		0.0	
	purchase of animal for production	0.9	(1.8)	2.5	(3.6)	0.3	(0.7)
	purchase of straw and manure	2.7	(6.0)	0.0		3.5	(7.6)
2	Outflows from farm, of which:	41.1	(16.2)	51.7	(24.0)	100.4	(17.9)
	sale of slaughtered animals and milk	32.1	(8.9	36.2	(18.5)	2.5	(4.8)
	sale of plant production[3]	9.1	(10.4)	15.5	(15.0)	97.9	(18.8)
3	*N balance* (1–2)	127.7	(47.1)	112.7	(39.5)	39.2	(26.6)

1. Standard deviation in brackets, 2. Fotyma *et al.* [6], 3. Main crop and by-product.

Table 8.2. Annual N balance for three farming types of studied farms in Wielkopolska Region (kg ha-1) at the subsystems of animal and plant production.

No.	Elements of production system	Farming types: Dairy		Swine fattening		Crop production	
I	**Subsystem of animal production**						
	1 Inflows into the animal production, of which:	194.9	(53.2)[1]	156.9	(62.1)	13.1	(17.9)
	purchase of feedstuffs	50.6	(27.5)	69.0	(49.4)	5.1	(8.6)
	own feed and bedding	140.7	(27.4)	85.4	(21.5)	7.7	(10.1)
	purchase of animal for production and straw	3.6	(7.8)	2.5	(3.6)	0.3	(0.7)
	2 Outflows from animal production, of which:	32.1	(8.9)	36.2	(18.5)	2.5	(4.8)
	sale of slaughtered animals and milk	32.1	(8.9)	36.2	(18.5)	2.5	(4.8)
	3 *Balance* (manure and slurry, 1–2)	162.8	(48.9)	120.7	(45.7)	10.7	(13.9)
	4 N gas losses	71.1	(24.9)	70.1	(26.9)	5.6	(7.2)
	5 *Balance after accounting for gas losses* (3–4)	91.7	(27.7)	50.6	(18.8)	5.1	(6.6)
II	**Subsystem plant production (soil and crop)**						
	6 Inflows, of which:	212.2	(54.6)	159.0	(31.7)	179.5	(37.7)
	manure and slurry[2]	91.7	(27.7)	50.6	(18.8)	5.1	(6.6)
	purchase of manure[2]	0.0	0.0	3.1	(6.8)		
	mineral fertilisers	102.7	(31.0)	81.1	(19.8)	119.0	(22.8)
	seeds	0.8	(0.8)	1.3	(0.9)	1.2	(1.0)
	ploughed-in residues	5.9	(11.8)	15.5	(12.5)	40.6	(14.4)
	atmospheric deposition	10.5	10.5	10.5			
	biological N-fixation	0.6	(1.7)	0.0	0.0		
	7 Outflows, of which:	149.7	(30.2)	100.9	(14.9)	105.6	(16.2)
	sale of plant products and feed intake	149.7	(30.2)	100.9	(14.9)	105.6	(16.2)
	8 *Balance* (6–7)	62.5	(42.4)	58.1	(28.6)	73.9	(30.9)
	N surplus in soil[3]	56.5	(39.1)	42.6	(20.5)	33.2	(21.7)

1. Standard deviation in brackets. 2. Applied to soil. 3. Difference between N balance at farm level and gas losses.

plant production type. Several-fold higher N balances in the same segment of production system were generated by farms oriented towards milk production and pig fattening (127.7 kg ha^{-1} and 112.7 kg ha^{-1}, respectively). Large differences in N balances between farms with animal production and ones specialising in crop growing can be associated with higher inflows of that nutrient to animals from external sources and at the same time with higher export of N from crop farms. The average sum of N imports to farms with milk and pig production was equal to 168.8 and 164.4 kg ha^{-1}, respectively, while in crop farming it was 139.6 kg ha^{-1}. Quantities of N outflows were in reverse order. In the crop growing group, the average export from a farm was 100.4 kg N ha^{-1}. In groups with swine fattening and milk production, nutrient exports were lower by 49 and 59%, respectively.

As was already mentioned, applying Granstedt's model through the possibility of getting insights into the internal structure of nutrient cycling helps to identify modifying factors of N and P utilisation, both on the farm level and within the frame of the main components of the production system (animal production, soil and plant environmental system).

The N balance in animal production was highest for the dairy farms (162.8 kg ha^{-1}), mainly as a result of own forage applied in large amounts. The swine fattening type had a 26% lower N balance compared with dairy. A very low N balance was recorded in farms specialising in crops. In that group, cows or pigs were of marginal importance and therefore nutrient quantities delivered with manure were small.

Taking into account gas emission the final N balance was significantly decreased. For dairy farms that balance was equal to 91.7 kg ha^{-1}, while for pig farms it was 50.6 kg ha^{-1}. Larger percentage differences of N balance can be linked with a higher degree of gas losses from pig excrement (58%) in comparison with N emission from cattle ones (44%).

High animal stocking density in dairy farms created a requirement for the production of large amounts of own forage of which firstly, bulky feed, as reflected by N quantity leaving the environmental system, equalled 149.7 kg ha^{-1}. In pig farms N outflow ran at a lower level since own cereals were commonly used for pig feed. Cereals prevalence in cropping pattern (92%, data not presented) can be an explanation for low N outflow from the environmental system. Cereals contain average protein content (9–14%) and at the same time deliver lower yields compared with other forage plants. In an environmental system of pig farming, total N inflow was 159 kg ha^{-1}. This effect was influenced by low N fertilisation and lower quantities of N manure. Higher N inflows, by 20.5 kg ha^{-1}, were observed in the crop farming type. Farms of that group compensated for lack of N from manure with higher mineral N fertilisation and ploughed-in crop residues.

According to a concept of the model, the difference between N balance and its gas emission is considered as N surplus in soil. It represents approximately that amount of soil nutrients that leaves the agricultural system, thus contributing to an increase in the pollution load to environment. Nitrogen surplus in soils of the investigated farm types was in the range 33.2 to 56.5 kg ha^{-1}.

8.3.2 P balance

P balances for all farming types were positive for each component of production system (Tables 8.3 and 8.4). Farm level P balances were similar for farming types with animal production. In dairy and swine fattening types they amounted to 21.3 and 20.5 kg P ha^{-1}, respectively. In the farm group with plant production, P inflow exceeded the outflow side of the balance by 5.9 kg ha^{-1}. The low P balance was on the one hand a consequence of its low inflow from the purchased concentrates, because only a few farms here had little animal stock and others raised no animals at all, and on the other hand P amounts exported with sold crops were high. P is not lost by volatilisation therefore its excess in soil is equal to its balance in the farm. Estimated values of P balance for pig and dairy types of production were relatively high. In the Netherlands, studies on monitoring environmental effects of an introduced nutrient registration programme showed that in the years 1997–1999 P surpluses for 114 dairy farms and 15 crop farms were 23.6 kg ha^{-1} and 8.3 kg ha^{-1}, respectively. Before that, in the year 1990, average P surplus in Dutch agriculture was 32.7 kg ha^{-1} (De Boer *et al*., 1997). In the Wielkopolska Region of Poland, average P surplus, calculated by the Macrobil model, in 36 large output farms (company holdings) of different farming type was 5.2 kg ha^{-1} (Fotyma *et al*., 2001). Higher balance of P in the analysed farms compared to the cited above P balance values could presumably in significant part result from differences in stocking density (the average stocking density in that study was of 0.58 LU ha^{-1}, while in ours it was equal to 1.4 and 1.0 LU ha^{-1} for dairy and pig farms, respectively, data not presented).

Table 8.3. Annual P balance for three farming types of studied farms in Wielkopolska Region (kg ha^{-1}) at the whole farm level.

No	Balance components	Farming types: Dairy	Swine fattening	Crop growing
1	Inflows into the farm, of which:	29.0 (11.7)[1]	31.9 (14.2)	24.6 (8.0)
	purchase of feedstuffs	10.6 (5.8)	15.5 (10.5)	0.7 (1.2)
	mineral fertilisers	17.5 (7.1)	15.6 (6.9)	22.8 (8.7)
	seeds	0.2 (0.2)	0.3 (0.2)	0.2 (0.2)
	purchase of animal for production	0.3 (0.5)	0.5 (0.8)	0.1 (0.2)
	purchase of straw and manure	0.4 (1.0)	0.0	0.8 (1.8)
2	Outflows from farm, of which:	7.7 (2.9)	11.4 (5.2)	18.7 (3.1)
	sale of slaughtered animal and milk	6.2 (1.7)	8.5 (4.5)	0.5 (1.0)
	sale of plant production[2]	1.5 (1.8)	2.9 (2.9)	18.2 (3.3)
3	*Balance* (1–2)	21.3 (11.2)	20.5 (11.6)	5.9 (7.2)

1. Standard deviation in brackets. 2. Main crop and by-product.

Table 8.4. Annual P balance for three farming types of studied farms in Wielkopolska (kg ha^{-1}) at the subsystems of animal and plant production.

No.		Elements of production system	Farming types		
			Dairy	Swine fattening	Crop growing
I		**Subsystem of animal production**			
	1	Inflows into the animal production,	35.6 (10.6)[1]	32.1 (12.8)	2.1 (2.8)
		of which: purchase of feedstuffs	10.6 (5.8)	15.5 (10.5)	0.7 (1.2)
		own feed and bedding	24.3 (7.2)	16.1 (3.8)	1.3 (1.6)
		purchase of animal for production and straw	0.7 (1.5)	0.5 (0.8)	0.1 (0.2)
	2	Outflows from animal production,	6.2 (1.7)	8.5 (4.5)	0.5 (1.0)
		of which: sale of slaughtered animals and milk	6.2 (1.7)	8.5 (4.5)	0.5 (1.0)
	3	**Balance** (manure and slurry, 1–2)	29.4 (9.8)	23.6 (9.0)	1.6 (1.8)
II		**Subsystem plant production (soil and crop)**			
	4	Inflows,	47.7 (16.7)	42.0 (12.6)	31.0 (9.1)
		of which: manure and slurry[2]	29.4 (9.8)	23.6 (9.0)	1.6 (1.8)
		purchase of manure[2]	0.0	0.0	0.8 (1.8)
		mineral fertilisers	17.5 (7.1)	15.6 (6.9)	22.8 (8.7)
		seeds	0.2 (0.2)	0.3 (0.2)	0.2 (0.2)
		ploughed-in residues	0.6 (1.1)	2.5 (2.1)	5.6 (1.4)
	5	Outflows,	25.9 (7.9)	19.0 (2.4)	19.4 (2.9)
		of which: sale of plant products and feed intake	25.9 (7.9)	19.0 (2.4)	19.4 (2.9)
	6	**Balance** (4–5)	21.8 (11.7)	23.0 (10.9)	11.6 (7.8)

1. Standard deviation in brackets. 2. Applied to soil.

8.3.3 N and P management in animal and plant production subsystems

N and P plant uptake in farms specialising in swine fattening was lower than in other farming types (Table 8.5). Those farms in principle grew cereals in monoculture. They did not tend to maximise production effects from cereals, which is shown by lower N and P amounts from external sources incorporated into the soil.

According to data in Table 8.6, mineral fertilisers were the most important source of N and P inflow to farms. Dairy farms and pig farms differed significantly in terms of N and P percentage share from purchased concentrates. In the dairy group, N and P in concentrates made up 30 and 36.6% of total nutrient inflow, while in pig farms it was 42.0 and 48.6%, respectively. So, swine fattening farms were to a considerable degree dependent on an external transfer of nutrients in concentrates. The results suggest that production level of own feed is still insufficient for feeding requirement, despite a high cereals share in crop rotation. Reserves for the increased feedstuff production should be looked for by an increase in plant productivity. The moderate rate of mineral N inflow to those farms of 81.1 kg ha^{-1} may indicate that the soil productivity is yet not adequately utilised.

Swine fattening farms used per livestock unit (LU) 173.1 kg N and 33.0 kg P from external sources (Table 8.7 see over). In dairy farms there was 115.6 kg N and 19.8 kg P per LU. N and P quantities from purchased feeds in swine fattening farms were more than twice those in dairy ones.

8.3.4 N balance and stocking density

Changes in N balance in relation to stocking rate in the farms studied are shown in Figure 8.2. There was a tendency to a steady, linear increase in balance together with stocking rate. At two LU per ha the amount of N balance was 200 kg ha^{-1}. In Denmark, in research on nutrient cycling in 16 conventional dairy farms with a range of stocking 1-2 LU ha^{-1}, N surplus ranged from 150 to 300 ka ha^{-1} (Halberg *et al*., 1995). This was

FIGURE 8.2. Total N balance in the studied farm group in relation to stocking rate.

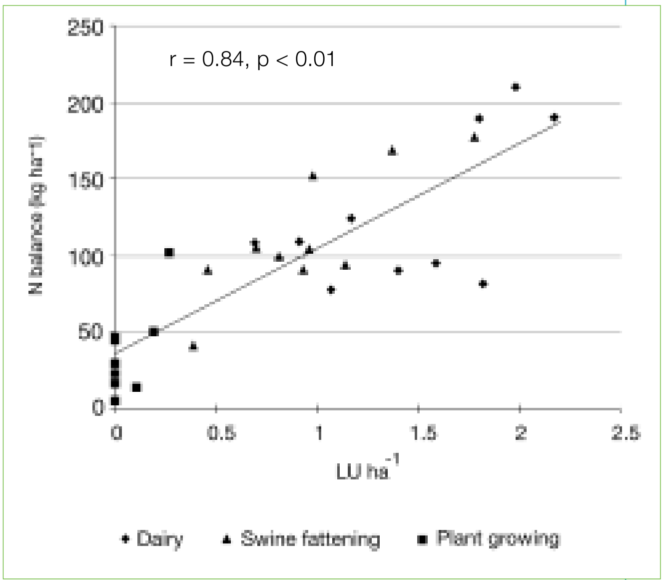


TABLE 8.5. N and P surpluses in soil for three farming types of studied farms (kg ha^{-1}).

No	Specification	Farming types: Dairy N	P	Swine fattening N	P	Crop growing N	P
1	N and P inflows into soil from different sources at the field level	210.8	47.6	157.7	41.7	178.3	30.8
2	Total nutrient uptake by crops and crop residues	155.7	26.5	116.4	21.5	146.3	25.1
3	Plant uptake decreased by nutrients contained in seeds and N fixation	154.3	26.3	115.1	21.2	145.1	24.9
Nutrient surplus in soil (1–3)		56.5	21.3	42.6	20.5	33.2	5.9

TABLE 8.6. Share of different N and P sources in total inflow into farm for the studied farming types (%).

N and P external sources	Farming types: Dairy N	P	Swine fattening N	P	Crop growing N	P
Purchased feed	30.0	36.6	42.0	48.6	3.7	2.8
Mineral fertilisers	60.8	60.3	49.3	48.9	85.2	92.7
Other sources	9.2	3.1	8.7	2.5	11.1	4.5

TABLE 8.7. Quantities of N and P imported to farm for dairy and swine fattening farming types (kg LU^{-1}).

N and P external sources	Farming types: Dairy N	P	Swine fattening N	P
Purchased feed	34.7	7.3	72.6	16.3
Mineral fertilisers	70.3	12.0	85.4	16.4
Other sources	10.6	0.5	15.1	0.8
Total	115.6	19.8	173.1	33.5

explained by a high level of total N inflow assessed at 170–183 kg LU^{-1}. In comparison, in the analysed farms this amounted on average to 115.6 kg LU^{-1} (Table 8.7). Above 1 LU ha^{-1} the amplitude of N changes became wider. In the lower part of the graph, below the tendency line, a cluster of farms could be found in which N balance was relatively low and changed only slightly at the stocking range 1-1.8 LU ha^{-1}.

The results presented here indicate that an increase in production intensity cannot in every case lead to a growth of N surplus. Proper solution in feeding and fertilisation strategies in farms can thus be regarded as important elements decreasing nutrient surpluses (De Boer *et al*., 1997).

8.4 Conclusions

1. N and P balances were markedly dependent on types of farming. In view of higher nutrient surpluses within dairy and pig farms it is expected that nutrient loading on environment could be substantially higher in those farms compared to plant production ones. Attention should be given to nutrient management allowing for limiting the accumulation of nutrient excesses in soils because they pose a risk of infiltrating into surface and ground waters.
2. Threat of higher relative N gaseous emission from manure to atmosphere was associated with pig production farms. Comparative size of N volatilised related to the unit of animal density was much greater in pig farming compared to dairy.
3. Some of the farms with large livestock densities were characterised by especially high N balances. It seems that introducing the proper changes in the production management processes could assist them in improving N use efficiency.
4. Results of N and P balances in the studied farms indicate that a decrease in N and P surpluses could be achieved mainly through proper feeding systems stimulating better retention of these elements in animal products. This process should be accompanied by optimisation of fertilisation with the aim of improving manure utilisation and increasing mineral elements uptake with plant yields. As a consequence, this would allow a reduction in the import of nutrients from outside the farm. When setting a general fertilisation level equally important is to take into account possibly all sources of these

nutrients in soil. This should also be correlated with realistically assessed uptake of these nutrients by plants in given soil conditions.

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9. Pricing opportunity costs to meet soil quality concepts in matters of heavy metal inputs into agricultural soils

Wolfgang Reiher, Bernd Weinmann, Rolf-Alexander Düring and Stefan Gäth
(Corresponding author: W. Reiher, email: wolfgang.reiher@agrar.uni-giessen.de)

Abstract

There is reasonable concern that agricultural management restrictions may be imposed, when fertiliser application will lead to failure of heavy metal sustainability criteria. Any management restriction reduces a sites land rent compared to the maximal achievable land rent. A methodology is presented that calculates site-specific opportunity costs when sustainability criteria of heavy metals will be exceeded using the models ProLand and ATOMIS of the model network ITE^{2}M. The methodology enables the economic comparison of different sustainability criteria. The importance of permissible additional heavy metal loads in case of the German soil protection legislation is demonstrated.

Key words
Heavy metals, integrated modelling, land use modelling, opportunity costs, sustainability criteria

9.1 Introduction

Agriculture has intensified dramatically in many regions in Europe during the last decades, leading to a revolutionary change in economic, social, ecological, and political concerns. There is now a need for concepts that address all these aspects of developing culture and support stakeholders, politicians, and decision makers. As an overall assessment of every parameter in a social-economic-ecological system is not possible, especially on regional areas, there is a need for indicator parameters which incorporate protection of ecological resources while maintaining an acceptable level of local economy and achieving satisfactory social conditions (Jessel, 2005) especially when non-sustainability is a slow process and adverse effects are likely unnoticeable, but nearly irreversible such as large-area soil degradation.

With the ITE^{2}M model network (Integrated Tool for Ecological and Economical Modelling) the Collaborative Research Centre 'Land Use Options for Peripheral Regions' develops an integrated methodology towards the achievement and appraisal of economic an ecological sustainable options for regional land use which are site-specific and economically differentiated (Frede, 2005). The spatially explicit approach of ITE^{2}M allows a detailed view on different parts of a region. Areas can be identified where any ecological quality criteria is affected due to non-sustainable agricultural management practice. Methods are developed to estimate costs for a sustainable practice.

This work shows a methodology for pricing opportunity costs to meet soil quality concepts in matters of heavy metal inputs into agricultural soils and therefore focuses on the interrelationship of the two models ProLand (Prognosis of Land Use) and ATOMIS (Assessment Tool for Metals in Soils). Scenarios are developed demonstrating the calculation of opportunity costs from site-specific land-rent estimation for a region and testing the precautionary concept of the German soil legislation.

9.2 Background

Considering ecological aspects of sustainability several environmental laws and conventions appoint requirements and sanctions on agricultural management. One example is the application of organic wastes, which is prohibited in Germany when certain reference values for heavy metals in soils are exceeded (BioAbfV, 1998). Thus, ecological criteria, regulated by law, may have influence on land use and management options.

The German Federal Soil Protection and Contaminated Sites Ordinance (BBodSchV, 1999) states so-called precautionary values which, if exceeded, shall normally mean there is reason that concern for a harmful soil change exists (BBodSchG, 1998). For the inorganic pollutants Ni, Cu, Zn, Cd, and Pb the precautionary values are the same as the above mentioned reference values in the German Ordinance on the Utilisation of Organic Wastes on Agricultural, Forest and Horticultural Used Soils (BioAbfV, 1998). Precautionary values are deliberately low compared to trigger and action values, which emphasises their importance as indicators for multifunctionality. They are particularly suited to protect integratively the different ecological pathways soil – plant, soil – soil organisms, and soil – ground water (BBodSchV, 1999). If exceeded there is a reasonable concern that sustainability and therefore multifunctionality is harmed. Table 9.1 provides an overview on the texture- and pH-differentiated precautionary values. Because precautionary values can be easily exceeded by geogenic reason in some areas, permissible additional heavy-metal loads have been added to the precautionary values. These additional loads are permissible when the precautionary values are exceeded on a site by geogenic reason.

Agricultural management practices such as fertilisation are the major inputs of heavy metals into topsoils beside atmospheric deposition (Nicholson *et al*., 2003). Liming has a main influence on heavy metal solubility and bioavailability by steering soil pH-value, usually the most important factor for heavy metal sorption (Alloway, 1995). The type of fertilisers has a main influence on the heavy metal load and which specific elements may put a risk to the soil. On the one hand potentially high Cd concentrations in mineral P-fertilisers is a well known problem. On the other hand even organic fertilisers from animal husbandry may exhibit high contents of Cu and Zn (Thiele and Leinweber, 2001; Nicholson *et al*., 2003). There is reasonable concern that agricultural management constraints may be imposed on particular sites, when precautionary values are exceeded in the future, to accomplish sustainability criteria.

9.3 Methodology

9.3.1 ProLand

The bio-economic simulation model ProLand is a comparative static model predicting the explicit spatial allocation of land use systems (Kuhlmann *et al*., 2002). The main assumption is that the land use pattern is a function of the natural, economic, and social conditions and therefore the focus of the model is to analyse the consequences on the allocation of agricultural and forestry systems as these general conditions change (Möller *et al*., 2002). The basic behavioural function of ProLand is maximisation of land rent. It is assumed that land users will maximise the land rent under the precondition that the opportunity costs of capital and labour would reach a certain minimum level, set by spatially variant realistic values for the region (Kuhlmann *et al*., 2002; Weinmann *et al*., 2006).

Calculating the land rent takes several steps (Weinmann, 2002). The first step is estimating the site-specific maximum realisable yield). Therefore specific conditions like soil type, accumulated temperature, and precipitation in growing season are used as inputs to determine this yield. The second step is the calculation of the production costs adjusted to natural and site conditions such as slope or field size. For this reason a calculative approach is applied to reproduce the influence of the local characteristics on several elements of costs (KTBL, 2002). The land rent maximisation is carried out for every decision unit, in this case the grid units of a grid map. The output of ProLand includes land rent, land use and in particular management information (e.g. crop rotation or fertiliser application) for each site.

9.3.2 ATOMIS

The Assessment Tool for Metals in Soils (Reiher *et al*., 2004) prognoses site-specific potential Ni, Cu, Zn, Cd, and Pb long-term accumulation. The heavy metal sorption is calculated using general purpose Freundlich isotherms according to van der Zee and van Riemsdijk (1987) and Horn (2003). These sorption equations are parameterised by soil sorption characteristics like pH-value, clay-content, content of soil organic carbon, and heavy metal content of the soil. They estimate the element concentration in soil solution which can be removed from the topsoil by leaching and plant uptake. Predicted total concentrations in topsoils are compared to the sustainability criteria at each yearly time step and the time to precautionary value exceedance is calculated. In this study a land use and management system is considered to be sustainable, when simulated heavy metal concentration in topsoils do not exceed these legal values within 100 years. Assumed pH-target-values vary between 5.8 and 6.8 for arable land and 4.9 and 5.8 for grassland depending on clay content; beside soil texture, they determine the effective precautionary value. Beside atmospheric deposition (HLUG, 2001), heavy metal input is calculated by ProLand information on the amount of P-fertilisation. The amount of P-fertilisation is equal to the amount of P-removal by harvested plant parts.

9.3.3 Backcoupling of ATOMIS and ProLand

In case ATOMIS prognoses exceedance of any precautionary value within 100 years on a specific site, it reduces the amount of P-input onto that site iteratively during repeated simulations to an amount which ensures that there will be no exceedance within this period of time. This sustainable P-input is a new input parameter in ProLand to calculate a new, sustainable land use and management under the new restriction of a maximum tolerable P-input. The new scenario option has its own land rent, which is either equal or lower than the land rent in the base scenario, which was considered to deliver the site-specific maximum land rent in the region. The first case means that no change in land use is necessary and there will occur no reduction of land rent on any sites. The second case means that a change of land use is possible and a land rent reduction will occur. The opportunity costs are the difference of original and sustainable P-input.

TABLE 9.1. Precautionary values and permissible additional heavy metal loads according to German soil legislation (BBodSchV, 1999) for Ni, Cu, Zn, Cd, and Pb.

	Ni		Cu	Zn		Cd		Pb	
pH	**≥6**	**<6**		**≥6**	**<6**	**≥6**	**<6**	**≥5**	**<5**
clay [mg kg^{-1}]	70	50	60	200	150	1.5	1.0	100	70
loam/silt [mg kg^{-1}]	50	15	40	150	60	1.0	0.4	70	40
sand [mg kg^{-1}]	15		20	60		0.4		40	
permissible additional loads [g ha^{-1} a^{-1}]	100		360	1,200		6		400	

9.3.4 Scenario description

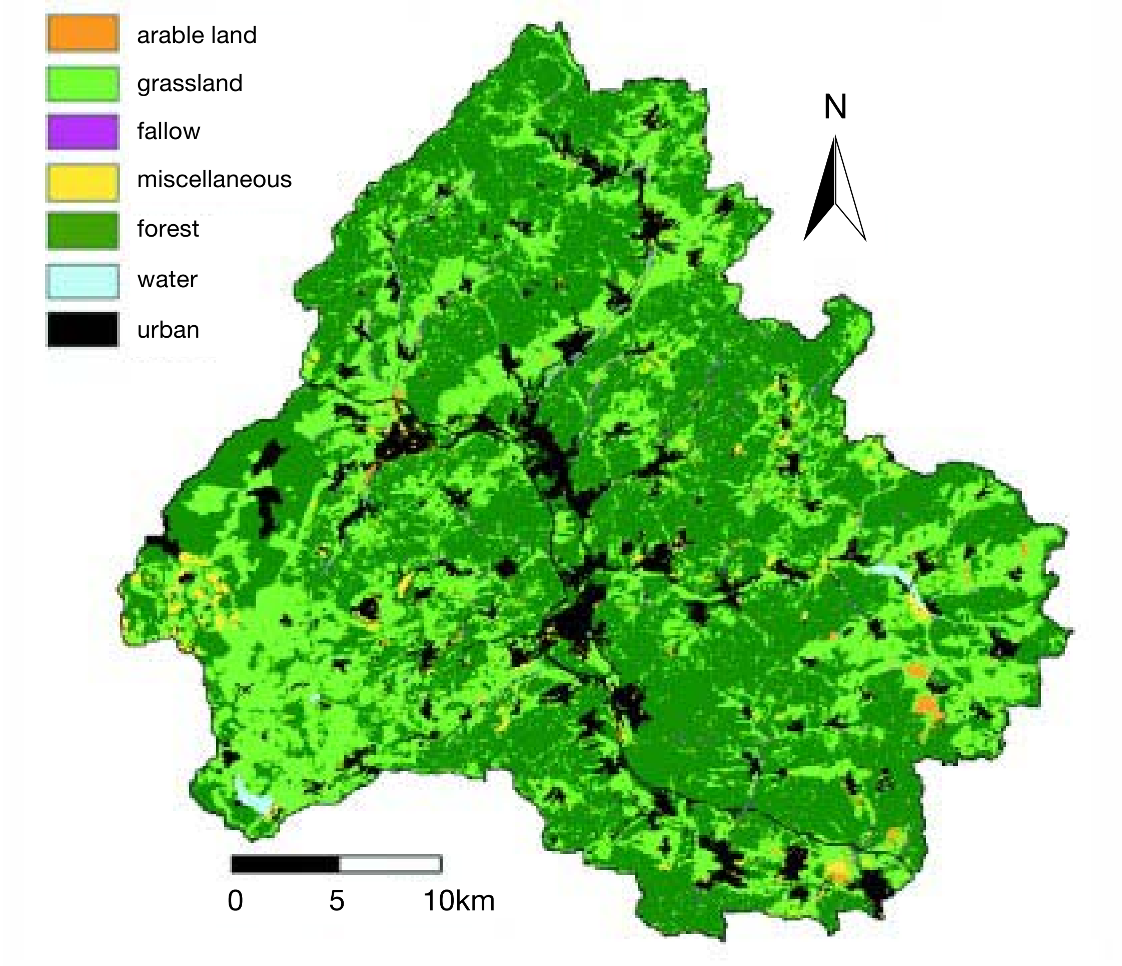
The study was done using the basic conditions of the 2003 reform of the Common European Agricultural Policy (CAP), described by Weinmann *et al*. (2006). It was assumed that area payments for grass- and arable land are equal, as it will be the case by the year 2013. The area of interest was the low mountainous Dill river catchment (693 km^2, Hesse, Germany) (Figure 9.1) as it is the region where all ITE^2M-models have been developed. Only cattle manure and mineral NPK-fertiliser were possible fertiliser types in the presented methodological study, because pig husbandry and sewage sludge or organic waste application was not taken into account by ProLand for the CAP-scenario. Cattle manure was assumed to be only applied to sites which produce fodder for cattle husbandry. As sustainability criteria the concept of the German soil protection legislation was tested (scenario A) with the above mentioned precautionary values and permissible additional loads (Table 9.1 page 63). To demonstrate the methodology and the effect of the permissible additional loads on the land rent, two more scenarios where computed. In scenario B the permissible loads were reduced by 50% and by 100% in scenario C.

9.4 Results

Cu (Figure 9.2a) and other heavy metal concentrations are mainly differentiated by geologic reason, even after 100 years which is due to no fertiliser application (forest) or relatively low P-application because of poor site conditions that result in a low P-demand by plants (Figure 9.3a).

Arable land covers only a very small part of the area (1.5% of agricultural area). The dominating crop rotation system is silage-maize/silage-maize/winter-wheat. With the exception of little fallow land intensively and extensively used grassland (91.8% of agricultural area) dominated the agricultural usable sites. All agricultural sites producing cattle fodder show accumulation of Cu and Zn (data not presented for Zn), originating from enriched Cu and Zn contents in livestock manure. Figure 9.2b demonstrates the modelled exceedance of Cu precautionary values over a period of 500 years. This long period was chosen due to the relatively extensive fertilising management, which causes a slow accumulation rate, to demonstrate site specific differences in heavy metal accumulation. The differentiation by time is due to site differentiated agricultural management practise. This holds true also for

FIGURE 9.1. By ProLand simulated land use for CAP-scenario in Dill river catchment results.



Ni, Zn, and Pb. An exception is Cd. Its sorption behaviour is relatively low compared to other heavy metals, the Cd input is relatively low due to low P-fertiliser application (Figure 9.3a) and Cd concentration is low in cattle manure, which is the dominating fertiliser in this scenario because grassland and silage-maize is used as cattle fodder (Figure 9.1). A wide area shows precautionary value exceedance for Cu within the first hundred years and most of these sites appear to show exceedance from the beginning due to geologic reason. Other heavy metals show comparable behaviour so that nearly each site shows an exceedance of precautionary values for at least one heavy metal. For Cu the permissible additional load is stated to 360 mg ha^{-1} a^{-1}. Because of low amounts of applied fertiliser (Figure 9.3a) the effective heavy metal loads are everywhere clearly below this value. For Cu the maximum annual load to a site is calculated as 173 mg ha^{-1} a^{-1} (Figure 9.2c). Thus, scenario A proves to be sustainable under the assumed model input parameters for the Dill river catchment in terms of heavy metals in agricultural topsoils in the next 100 years according to the German soil quality protection concept. The annual accumulated land rent is 15.8 mio. €.

Reducing permissible additional loads for all considered heavy metals by 50% leads to a distinct reduction of sustainable P-input on sites which get more than 19 kg P ha^{-1} a^{-1} in scenario A (Figure 9.3b). As there is no reduction to less than 7 kg P ha^{-1} a^{-1}, no additional forest area was simulated so that there is no reduction of agricultural used land. The area's total land rent is reduced by 73% to 4.3 mio. €, so that the opportunity costs of halved permissible additional loads can be calculated to 11.5 mio. € when P-fertiliser reduction is assumed to be the management restriction on regarded sites. In scenario C the effect of no permissible additional heavy metal loads is demonstrated. Here the sole sustainability criteria are the precautionary values. As there are some geologic classes in the Dill river catchment with relatively high contents of heavy metals,

FIGURE 9.2. ATOMIS-results for scenario A. A: Cu-concentration after 100 years. B: Time to exceedance of precautionary value of Cu. C: Annual Cu loads onto agricultural used soils.

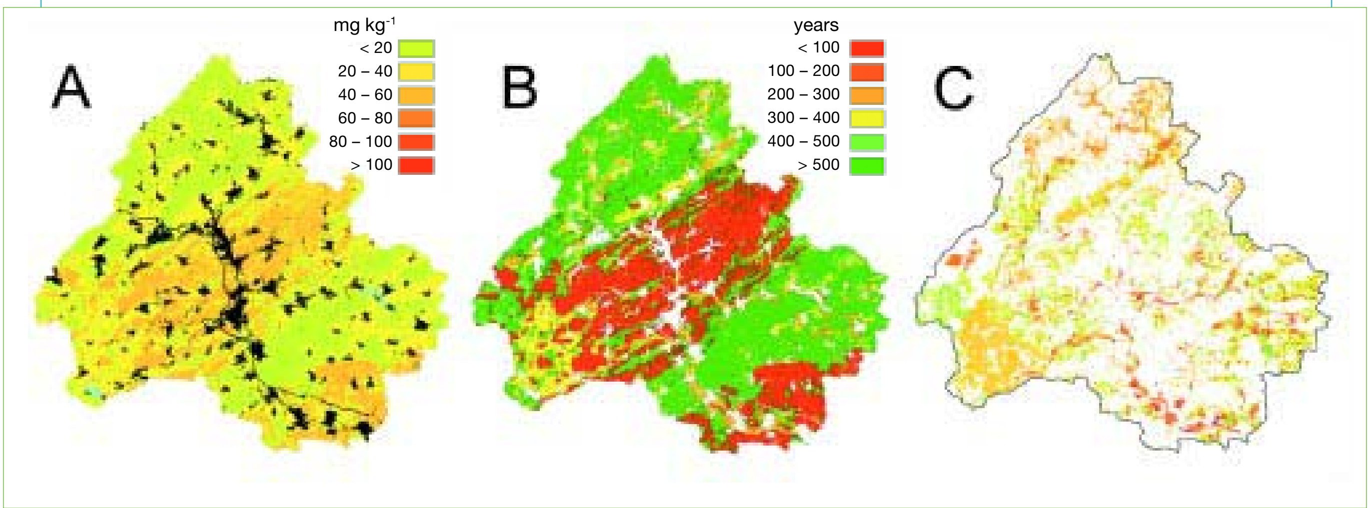
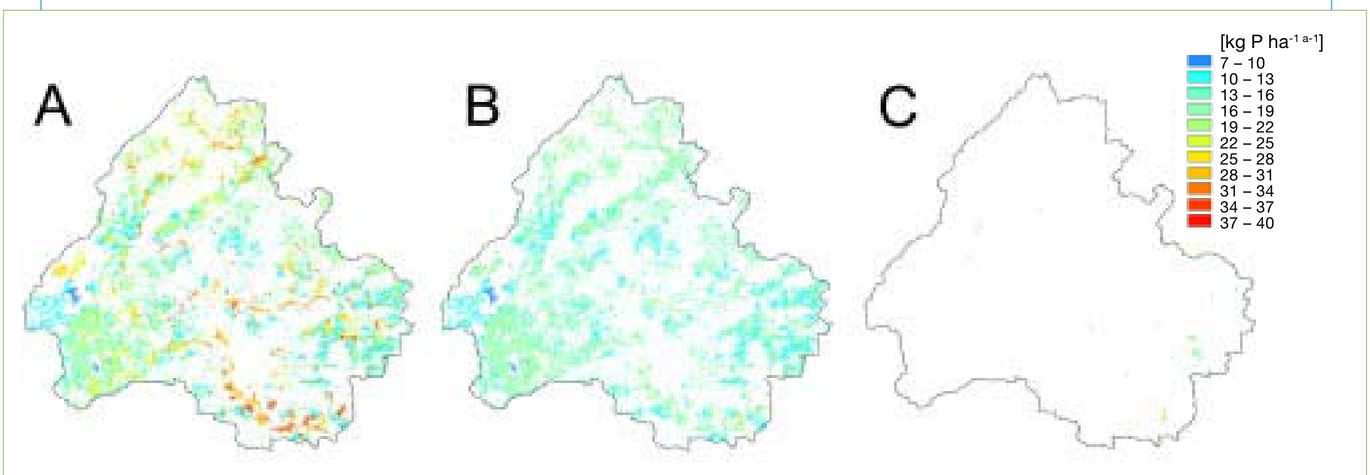


FIGURE 9.3. Sustainable P-input for scenarios A, B, and C.



e.g. Ni (median of 121 samples of basaltic topsoils under arable land: 207 mg kg^{-1}, LABO (2003)), and, as the dominating land use class is grassland, large agricultural used areas have a pH-value below the Ni-, Zn-, and Cd-threshold pH-value of 6, which decreases the valid precautionary value (Table 9.1 page 63), 98.7% of agricultural land in scenario A converts to fallow land or forest in scenario C. Figure 9.3c shows the allowed amount of P-fertiliser on the remaining agricultural land for this criterion of 'sustainability'. The opportunity costs are calculated to 12.5 mio. €, which is a reduction of total land rent of 79%. The remaining 3.3 mio. €, compared to the land rent in scenario A, consist of land rent of forestry, EU-subsidies for fallow land, and the land rent of the remaining agricultural land, which is mostly arable land. Arable land has usually higher pH-value and therefore rarer failure of precautionary values.

9.5 Discussion

Keller *et al*. (2002), who presented a comparable study, calculated the expected costs associated with the probability of failure of Swiss guide values for Zn after an accumulation period of 200 years to 22 mio. € for 36 km^2. This order of magnitude may indicate the agricultural intensity in the investigated Sundgau region (Switzerland). As Keller *et al*. (2002) had no exact information on land rent, they assumed for each site a decrease from 30 to 10 € per m^2 without further differentiation, if the critical value was exceeded. The here presented approach of coupling ProLand and ATOMIS shows that a more detailed estimation of opportunity costs is possible, even though we demonstrate the methodology of developing sustainable management due to heavy metals in topsoils only on the option of fertiliser reduction. In the current state it is useful for estimating the order of magnitude of opportunity costs, but it can only be a rough estimation as long as there are no other management options included. Possible other options are e.g. enduring and increased liming to keep a sites pH-value above the threshold pH-value of the problem elements so that a higher precautionary value is valid. Obviously, liming increases the heavy metal accumulation, so that at any time in the future of such a site when the application of lime can not be guaranteed any more by any reason, the soils will acidify and a higher content of heavy metals will become potentially bioavailable and leachable. As pig husbandry is not included in ProLand so far, which leads to underestimation especially of Cu and Zn in soils, the used types of fertiliser are limited for the recent state of ProLand development. To include pig husbandry will be the major challenge in the near future. A third critical point may be the way of distributing the fertiliser. One may argue that 'problematic' sites could be treated with unproblematic fertilisers, which have low heavy metal concentrations, and vice versa. This is of cause a thinkable way of assuring the right supply of fertiliser application and accomplishing sustainability criteria, but such individual behaviour can not be included in the presented model approach, that shall be transferable to other regions.

9.6 Conclusion

The site-specific calculation of land rent is an encouraging approach for estimating land use options, which depend on each site's natural characteristics. When site conditions are well known for differentiation of management options, their ecological effects on each site can be calculated. In case environmental quality criteria are violated, sustainability can be assessed and an adjustment of management options can happen. For the developed sustainable land use and management options the land rent and thus the opportunity costs can be estimated. Further possible management options like pig husbandry or a more sophisticated liming strategy have to be taken into account in the future.

Under the assumed basic conditions, the CAP-scenario proved to be sustainable on all sites in the Dill river catchment in matters of heavy metal contents of topsoils during the next 100 years. This is mainly the reason, because German soil protection legislation has introduced the instrument of permissible additional heavy metal loads on sites where precautionary values are exceeded by geogenic reason. As it could be demonstrated the value of these loads is a sensitive parameter in terms of economic and therefore potentially social sustainability.

Acknowledgement

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10. Spatially explicit approaches in integrated land use and phytodiversity modelling at multiple scales

Patrick Sheridan and Rainer Waldhardt
(Corresponding author: P. Sheridan, email: patrick.sheridan@agrar.uni-giessen.de)

Abstract

Landscapes provide multiple commodity and non-commodity outputs. The paper presents the modelling approach of the interdisciplinary and spatially explicit landscape evaluation tool ITE²M (Integrated Tool for Economic and Ecologic Modelling) using the land use model ProLand and the biodiversity model ProF as application examples. Linking land use and ecological models allows to assess socio-economic and ecological effects of changes in natural, technological, socio-economic, and political variables by identifying interactions and estimating potential trade-offs. Implications concerning the appropriate spatial scale and effects of policy changes on land use patterns, and plant species richness are discussed. Results suggest that effects are heterogeneously distributed in a study region in Hesse, Germany indicating the need for approaches capable of operating at the patch scale.

Key words
Land use modelling, biodiversity, multifunctionality, model network, GIS

10.1 Introduction

Landscapes are multifunctional, i.e. they provide multiple commodity and non-commodity outputs such as agricultural produce or species habitats (OECD, 2001). As outputs and their levels are interdependent, landscape evaluation frameworks need to address how technological, political, socio-economic, and ecological changes affect biotic and abiotic aspects.

Two methodological options may provide results from multiple disciplines: either one model integrates all relevant aspects or they are investigated by specialised models, creating an extensible model network. In the latter approach, output has to be shared between numerous models, creating data exchange issues. Also, stakeholders and decision makers may request results at varying levels of aggregation and spatial resolution, often based on administrative units, e.g. counties or nations. These units do not necessarily correspond to spatial units optimal for modelling purposes, leading to issues concerning raw model output processing, and perhaps, conflicting conclusions. The required spatial resolution and detail of input data and model results vary with the investigated landscape function. For example, larger spatial units may suffice for hydrological aspects (Chaplot, 2005) while biodiversity is affected by changes of both land use type and intensity at patch and regional scales (Duelli, 1997; Waldhardt *et al*., 2003).

The collaborative research centre SFB 299 at the Justus Liebig University, Gießen, develops the model network ITE²M, consisting of interconnected, GIS-based, economic, hydrological, and ecological models, to analyse and evaluate changes of land use and landscape functions at multiple scales. Its spatially explicit model output supports decision makers, stakeholders, and nature conservation authorities in their assessment of possible developments.

The paper presents the land use model ProLand, the phytodiversity model ProF, and selected results for a less favoured area in Hesse, Germany, as examples illustrating the overall ITE²M modelling approach and model interaction.

10.2 The ITE²M model network

ITE²M is an extensible network of transferable, GIS-based models supporting decision makers and stakeholders in their assessment of possible future land use scenarios (Möller *et al*., 2002). It first consisted of three stand-alone models that addressed agricultural and silvicultural land use (ProLand, Weinmann, 2002), biodiversity (ANIMO, Steiner and Köhler, 2003), and hydrology (SWAT-G, Eckhardt *et al*., 2002) and shared data through a raster-based GIS. Eventually, existing models were enhanced and new ones added to cover, e.g. heavy metals in soils (ATOMIS, Reiher *et al*., 2004), and floristic (ProF, Waldhardt *et al*., submitted) and faunistic (GEPARD, Gottschalk *et al*., submitted) species richness. The evaluation framework CHOICE (Borresch *et al*., 2005) utilises these multidisciplinary results to perform cost benefit analyses of different landscape configurations and assess potential trade-offs.

The detail of model input and output required varies with the investigated landscape function, i.e. between models. However, data are exchanged based on the smallest common spatial unit. Consequently, ITE²M abstracts from administrative or economic units and performs analysis for spatial units appropriate for the respective function or target audience, i.e. the spatial resolution is driven by output demands rather than input data supply.

The approaches ProLand and ProF are comparative-static, deterministic programming models, predicting endpoints of adaptation processes. Scenarios for varying political, socio-economic, and technological conditions provide the basis for the model runs. Output is generated starting at the patch scale and later aggregated to larger units, eliminating the problem of spatial disaggregation and allowing to analyse goal relationships at varying scales and levels of aggregation.

Evaluating multiple, interdependent landscape functions requires information exchange between models. Such multicriteria assessments allow to identify trade-offs and hot-spots but require spatially explicit information (Bockstael, 1996). ProF and ProLand exchange data based on land users' decision units through relational databases in a common GIS, thus retaining spatial information throughout the simulation process. This configuration enables both models to share detailed results and data from the models' underlying databases, e.g. crop rotation or farming intensity, among themselves and with other GIS-based models in the ITE²M network.

10.3 The land use model ProLand

ProLand simulates agricultural and silvicultural land use patterns as endpoints of adaptation processes (Weinmann, 2002; Kuhlmann *et al*., 2002; Weinmann *et al*., 2005). The model divides regions into decision units, which can be grid cells or vector elements of discretionary size such as individual fields, without relying on specific farm structures. Predictions are based on small-scale data of an area's natural, and socio-economic characteristics and price and quantity structures of agricultural and silvicultural land use systems (Schroers and Sheridan, 2004).

The model assumes ground rent maximising behaviour of land users. Ground rent is defined as revenues minus costs including opportunity costs for capital and labour in monetary units per area unit (Brinkmann, 1922). It represents the remuneration for land employed in agricultural or silvicultural production. Revenues are determined by given prices and endogenous yield estimates, calculated using linear-limitational yield functions. ProLand determines the ground rent maximising land use system for each individual decision unit and calculates economic key figures, and data on socio-economic and technological attributes, e.g. transfer payment volume or pesticide input.

Spatial information can be associated with available land use systems and policy instruments to simulate spatially variant interventions in land structure, market policy, and land use restrictions. This allows to estimate, for example opportunity costs of conservation programs in selected sub-regions. Thus, the model can be employed as an economic laboratory to analyse the effects of changes in political, technological, and socio-economic conditions (Weber *et al*., 2001; Möller *et al*., 2002). As all results are spatially explicit they can be easily combined with ecological as well as hydrological indicators provided by respective models (Sheridan *et al*., 2005).

10.4 The phytodiversity model ProF

The model ProF simulates patterns of occurrence probabilities of plant species as endpoints of adaptation processes (Waldhardt *et al*., 2004, Waldhardt *et al*., submitted). It operates at the level of an entire landscape or landscape tracts, e.g. rural districts, bio-geographical units, or land users' decision units as utilised by ProLand. The model is based on the compositional variability and heterogeneity of non-linear habitats in area units, the relative frequency of species in habitat types derived from field data, and probability calculations with respect to species occurrence. Two empirical studies confirmed the appropriateness of the approach (Waldhardt *et al*., 2004; Simmering *et al*., in press).

The habitat pattern of an area is derived from the area's physical characteristics (topography, soil moisture, geology) and land-use data at the patch scale (actual land use systems or ProLand results). The estimation of species frequencies is based on field inventories and/ or derived from expert knowledge. Occurrence probabilities are derived from species frequencies in either patches (vector approach) or grids (grid approach) of a certain habitat type. Probability calculations assume a binomial distribution of species occurrences within habitat types of a mosaic landscape.

ProF generates data on occurrence probabilities of each plant species that may be expected in the habitat types of an area, and the total number of individual species or species groups (e.g. number of weed species). Results can be shared and visualised as maps or tables. Analog to the model ProLand all results are spatially explicit and can be combined with indicators provided by other network models.

10.5 Application to the Lahn–Dill region

Both models are applied to the Lahn–Dill region, in Hesse, Germany. It is a heterogeneous, low mountain region with unfavourable production conditions caused by low yields and small agrarian structure, i.e. a typical less favoured area. The region covers about 650 km² with an average elevation of 380 m and 900 mm/ a average precipitation. Almost 70% of all plots have a usable field capacity below 100 mm. More than 55% of the area is forest, about 23% are grassland and less than 8% is used for arable farming.

Two scenarios illustrate model interaction and how multiple objectives may be assessed with ITE²M. The baseline scenario reflects Agenda 2000 policy. The CAP Reform scenario differs only in the transfer payment scheme. Payments are decoupled according to the German CAP implementation scheduled for 2013 (BMVEL, 2005). Simulations are performed *ceteris* paribus, i.e. all other political, socio-economic, technological, and natural variables are kept constant. Results deliberately omit a policy evaluation which can be found in Weinmann *et al*. (2005).

10.6 Scenario results

Scenario results presented are area shares and spatial distribution of the different land use categories, and associated plant species richness. Results concerning individual land use systems, economic key figures or additional landscape functions are available but omitted.

Figure 10.1 shows the endpoints of the simulated land use adaptation processes in the Lahn–Dill region for both scenarios. Forested area varies only marginally, mainly attributable to legislative protection. Grassland area in the CAP Reform scenario is about 5% larger, while arable farming area is about 5% smaller than under Agenda 2000 conditions.

Although these differences are moderate compared with the overall ratio of land use systems, reactions are more pronounced in some sub-regions. Illustration 10.2 is a magnification of the area marked by the rectangle in Figure 10.1.

The two simulated policies result in different land uses and thus a changed landscape in this sub-region. Arable farming systems account for around 59.4%, grassland systems for about 40.6% of cultivated land in the

FIGURE 10.1. Predicted land use patterns in the Dill catchment for Agenda 2000 and CAP Reform scenarios (Weinmann *et al*., 2006).

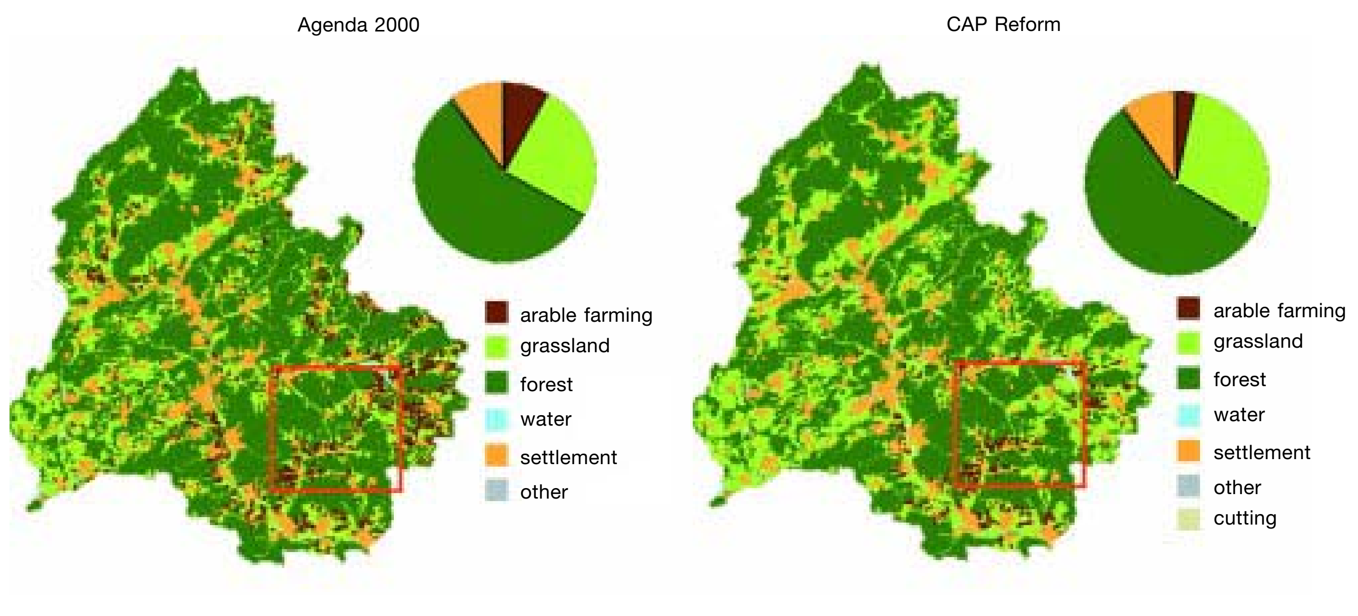


FIGURE 10.2. Predicted land use patterns in a sub-region for Agenda 2000 and CAP Reform scenarios (Weinmann *et al*., 2006).

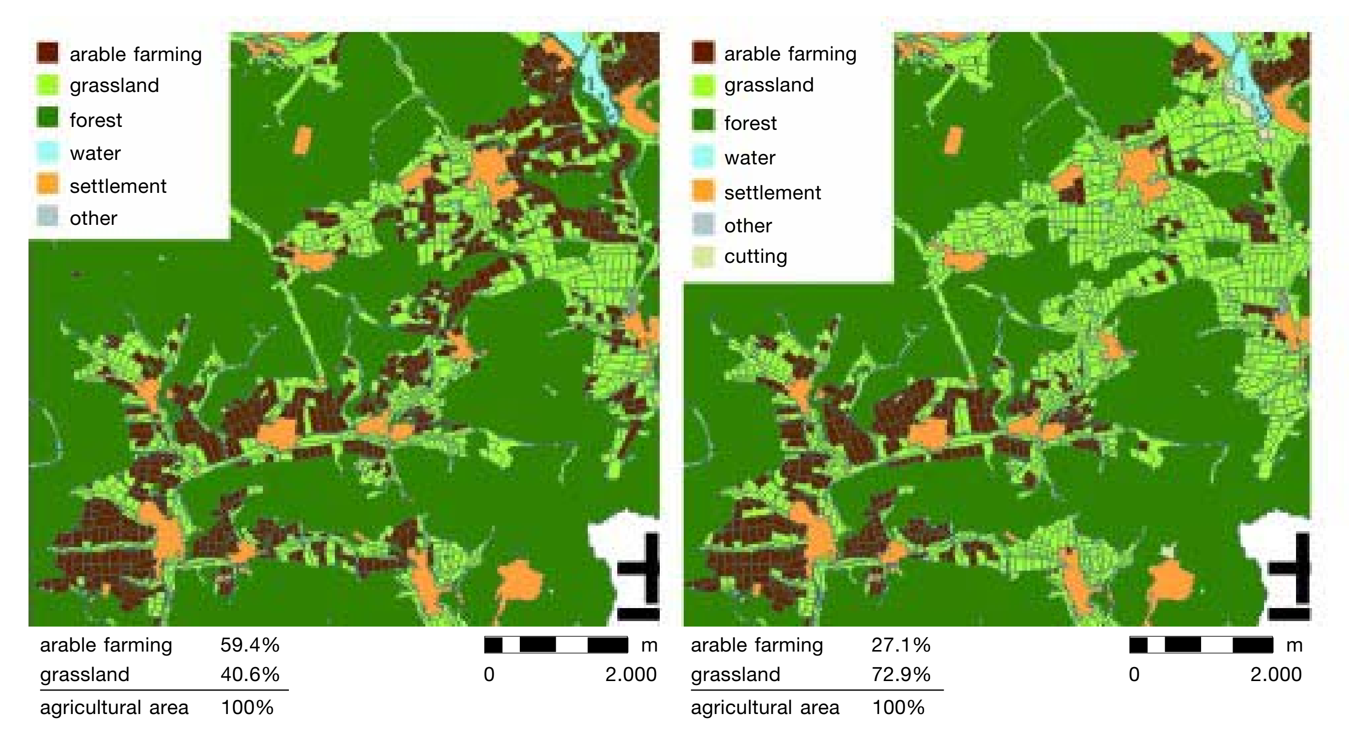
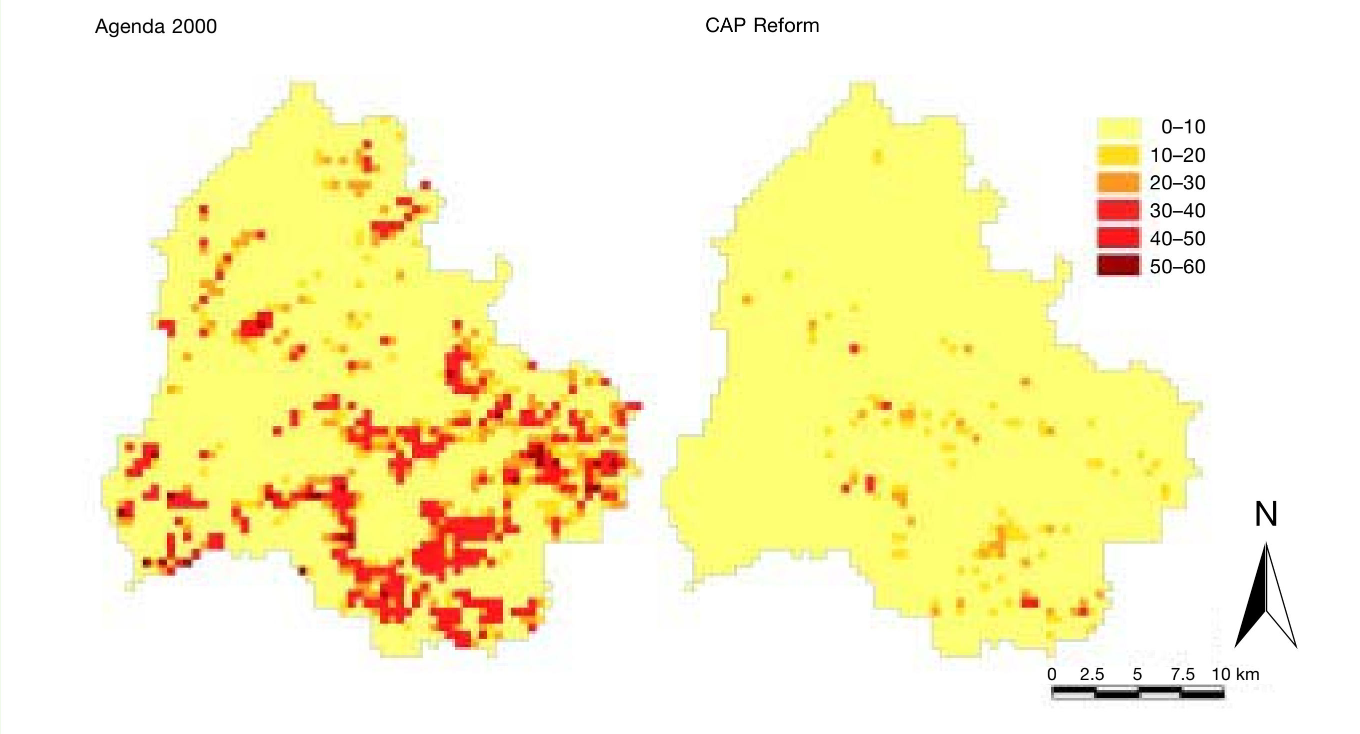


FIGURE 10.3. Predicted weed species richness in landscape tracts of the Dill catchment, grid size: 22.6 ha (Waldhardt *et al.*, submitted).



Agenda 2000 scenario. Note that arable farming systems are found throughout the sub-region. They retreat mainly to the south-western corner and are replaced by grassland systems in the CAP Reform scenario. Arable farming systems account for only 27.1% of the cultivated area, grassland systems for 72.9%.

ProF employs these land use results and the underlying crop rotation data to generate small-scale maps of weed species richness which may later be aggregated to the entire region (Figure 10.3).

The total number of species found varies with the scale considered and throughout the region. The number of species ranges from over 100 in the Dill catchment (650 km²) to about 60 in the rural district Erda (11 km²) (Waldhardt *et al.*, submitted).

Clearly, policy impacts on land use are spatially variant at small-scales which has implications for e.g. biodiversity models. This finding extends to technological and socio-economic variables as well (Sheridan, 2006). Contrasting the adaptation processes' end points of two or more scenarios allows to assess trade-offs between economic and ecological performance at multiple-scales as ground rent and other key figures can be linked to the land user's decision units as well (Sheridan *et al.*, 2005).

10.7 Discussion

As models simplify complex systems, they can provide insights into specific cause and effect relationships, thereby improving our understanding of the underlying phenomena. As such, comparative static approaches are adequate to model inherently dynamic processes. They can help determine the importance of individual factors and, if joined to spatial data, identify sensitive sub-regions.

The presented results are an illustration of how ITE²M models are employed to predict changes of multiple landscape functions; those not addressed here can be approached in a similar manner. Potential trade-offs and policy analyses were not presented in order to focus on the modelling approach. A plausible application would be supporting local authorities in their allocation decisions by estimating transfer payments necessary to induce land users to adopt an ecologically desirable land use system.

Although the results briefly presented are likely to contain considerable error they show that policy effects on land use and associated functions are spatially variant. Models not considering a landscapes' heterogeneity at a scale appropriate for the investigated problem may lead to wrong conclusions. 'Merging spatial units to decision units' (Hanf, 1994) appears appropriate for modelling multifunctional landscapes. Nevertheless, the described approach of calculating and aggregating patch scale results may prove unfeasible for larger units at national or continental scale. Obviously, data availability, computing requirements, and model assumptions are key issues in this context. ITE²M faces significant challenges in these areas when transferred to other regions and larger scales, as currently under investigation. However, approaches starting with larger units commonly encounter problems of spatial disaggregation, among others.

10.8 Conclusion

ITE²M is a decision support system operating at the level of landscapes or regions. Its rich detail and spatial resolution can support decision makers at sub-national level as they often require reliable estimates of economic and ecological costs and benefits when implementing supra-national policy measures. The approach may also help scientists to understand and further investigate the concept of 'multifunctionality' as cause and effect relationships between various landscape functions are explicitly modeled. As influential landscape characteristics and corresponding reactions are heterogeneously distributed over space, patch scale data appear necessary to accurately model functions such as biodiversity.

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11. Integration of multifunctional goals for spatial development

Antje König and Burghard C. Meyer
(Corresponding author: A. König, email: antjekoenig@foni.net)

Abstract

An assessment and decision-making framework for the integration of goals related to multifunctional land use for large areas has been developed. The integration of solutions from different decision-making tools and methods is made possible. From the results, landscape-ecological integrative goals (Leitbilder) for natural areas and land use units for mesoscalic (sub-regional in a scale of 5–20 km² per unit) purposes can be formulated. This procedure provides a complete overview concerning different land use functions and natural potentials as permitted by the ecological condition of the landscape. By means of clear methodological stages like interference analysis and the estimation of current and potential risks and hazards one can create an ecological matrix of conflicts for the whole area. Within these conflict areas potential solutions through developments of alternative land use scenarios are offered. Decision trees and a GIS-based spatial decision-making process (SDSS) Land Use Options (LNOPT) or a combination of both are available.

The method presented is highly flexible and allows the user to select the significant data, functions or nature potentials and tools for problem solving within the respective reference area. The method can be generally used for spatial planning related to land use problems.

Key words
Multifunctional assessments, multicriteria optimisation, landscape function, natural potentials, spatial decision support, integrative goal

11.1 Introduction

The multifunctionality of a landscape often leads to the problem of different and conflicting goals of land uses and land use developments. These conflicts can be found in whole landscapes (e.g. soil erosion or diffuse pollution problems in intensive arable landscapes) or in local sites (e.g. inflow of nutrients and materials into small water bodies).

For solving the question, how to integrate competing multifunctional goals into spatial development the authors formulated a set of integrated multifunctional ecological targets for the mesoscale level. The main aim of the project 'Comparison of methods of the decision making of function-related goals of the landscape evolution in heterogeneous spatial units' carried out by the Saxon Academy of Sciences and the Centre for Environmental Research (UFZ) has been the development of basic methodological principles for the identification of integrative goals on the basis of several assessment methods for landscape functions. For different heterogeneous reference areas the study compared a range of approaches for decision making.

11.2 Identification of integrative goals

The identification of integrative goals for a landscape is described by this study from the point of view of nature protection and landscape planning. The integrative goal explains the desired conditions and developments to be attained by a specific reference area within a specific time period (Wiegleb *et al*., 1999). The integrative goal methodology is a planning method with the objective of providing one or more integrative goals for a certain planning area and/or planned scheme (Wiegleb, 1997). The aim and objective of integrative goals is to help to create a reliable picture of the future. These pictures transfer the targets for the entire planning process. Landscape functions related to targets of land use have to be described in an integrated concept and related to concrete decisions (Müssner *et al*., 2002).

In the broad discipline of landscape planning and landscape ecology, different methods of integrative goal formulation exist (e.g. Bosshard, 2000; Bastian and Steinhardt, 2002; Potschin and Haines-Young, 2003). Further recent studies covering multifunctional landscapes have been described by Mosimann *et al*. (2001) and Klug (2002).

Integrative spatial goals exist at the object (property), landscape (sub-regional) and regional scale. The choice of scale is dictated by the indicator target. The basic modules in this study are assessment methods for reference areas, basic data, and decision-making tools and methodologies for the creation of potential solutions for land use conflicts.

11.2.1 Landscape assessment

Various assessment methods for the analysis and the assessment of existing landscape functions or landscape potentials have been developed in science and practise. A multitude of methodological examples for the assessment of functions for the local scale level exist. Only few studies relate to mescoscale areas and to the integrative assessment of multiple land uses with the goal of the identification of the multifunctionality of the cultural landscape (see Niemann, 1977; Marks *et al*., 1992; Bastian and Schreiber, 1999; Meyer, 1997). These methods refer to a high diversity of conflict types, from individual functions to system approaches, to reveal agreed compromises for land use decisions. The interdependencies between different functions to the target land use are categorised as complimentary, opposing or indifferent (Meyer, 1997). Examples of multifunctional assessment studies have been published by Meyer (1997), Grabaum *et al*. (1999), Meyer and Grabaum (2003), Haase and Mannsfeld (2002) and König and Bastian (2005). International studies for the assessment of multifunctional landscapes are described by Brandt *et al*. (2000).

11.2.2 Spatial Decision Support Systems

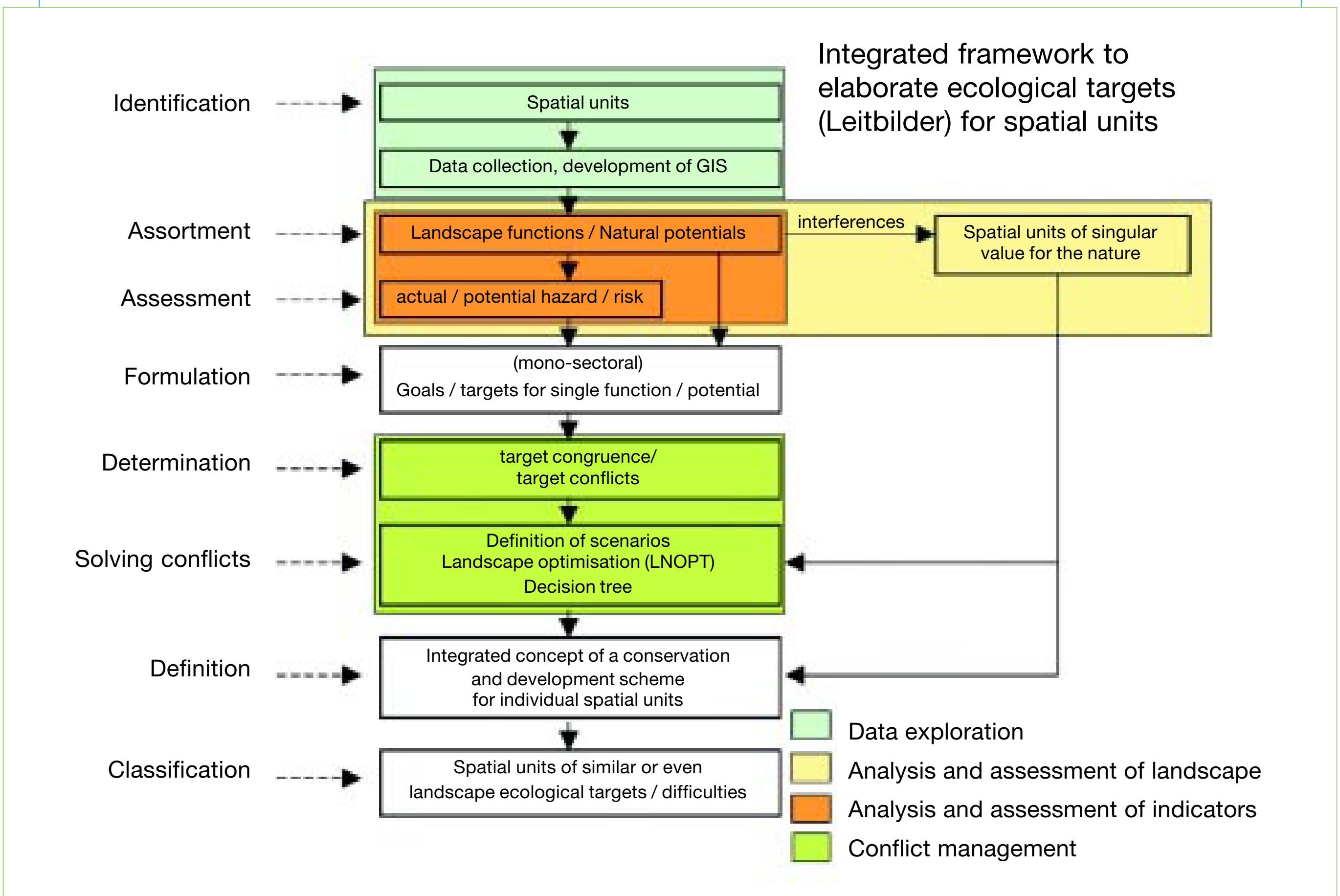
Computer aided spatial decision support systems (SDSS) are developed from management science and applied research perspectives (Czeranka and Ehlers, 1997). The aim is the support of decisions with pre-structured solutions (Densham, 1991). The complex spatial decision making process normally creates a high number of alternative solutions with a multitude of characteristics (Malczewski, 1999). SDSS have been developed on the basis of different mathematical algorithms, some of which can help to solve land use conflicts. Examples of studies prioritising mainly with agricultural land include those by Mandl (1994), Kächele and Zander (1998), Zhu *et al*. (2001), Meyer and Grabaum (2003) as well as Herzig and Duttmann (2003).

11.3 Integrative goals on a multifunctional basis

The following method introduces integrative goal development at the mesoscale. It concerns itself with the necessary standards and norms, benchmarks, minimum requirements, and limits for the carrying capacity of cultural or natural landscapes to enable sustainable land use. This function-related approach provides a multifactorial decision support system for the development of well-founded, understandable and acceptable land use aims, i.e. the capacity for actual integration of many parameters rather than basing decisions on one parameter in isolation. Landscape functions and natural area potentials embody a connection between ecological circumstances and social values, and they are suitable as an aid to the development of regional integrative goals (Bastian, 2002).

The method has been already applied on the basis of data for natural areas related to the 'Saxonian data recall system' in the Westlausitz in Saxony (Bastian *et al*., 1999) as well as in an agrarian environment in the south-east suburban area of Leipzig (catchment of the River Parthe) (König, 2003). Figure 11.1 shows the different

FIGURE 11.1. Algorithm to elaborate ecological targets to integrative goals (Leitbildentwicklung) for spatial units. (Bastian, 1999, changed).



levels and its methodical components for the integrative goal development explained in the following paragraphs.

11.3.1 Definition of spatial units

As a first working step, the basic units for the assessments and the decision making must be identified and chosen on the basis of the delineation of the river catchment. Mesoscale units related to natural units (micro-geochores) and landscape units determined by land use were the spatial basis of the project. Micro-geochores are defined by petromorphic parameters as soil substrata, relief, and hydromorphy. Landscape units are determined by land use. Two data modules were collected (Figure 11.2). The data modules for the assessment of micro-geochores include the Saxonian data recall system (Haase and Mannsfeld, 2002) and public data sets, for instance the hydrogeological map 1:50 000 and the mesoscalic soil map. The data module for the assessment landscape units include the selective biotope mapping based on colour-infrared (CIR) area photographs, 1:50.000 hydrogeological map, and mesoscalic soil mapping.

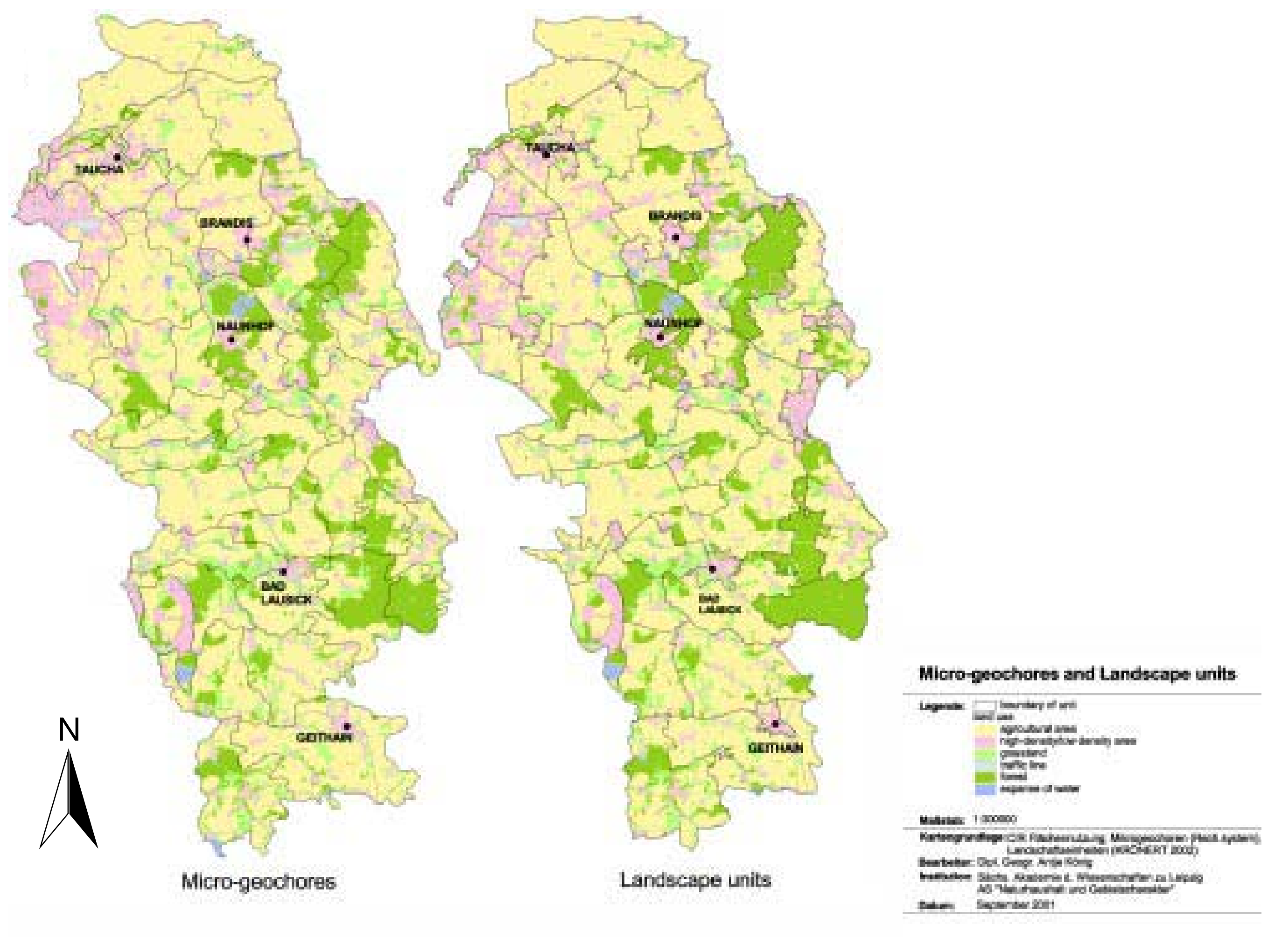
11.3.2 Determination of landscape functions and natural area potential and assessments

The multifunctional assessment of landscapes in the study contains hydrological functions as the water retention capacity, the groundwater recharge, and the groundwater protection, the potential biotic yield, the habitat function, the resistance to soil erosion, and function of recreation. Additionally, indicators have to be defined at a chosen scale related to the land use. These indicators are suitable for the integrative goal development on the basis of the current land use in this definition and solution phase. On the basis of chosen landscape functions, natural area potentials and land use indicators, GIS based data modules have been developed.

11.3.3 Interference Analysis

Using the Interference Analysis for the ascertainment and interpretation of the superposition of various land use types at the same area, different assessment results concerning the functions assessed have been overlaid (Bastian, 2002). Reference areas with an increasingly

FIGURE 11.2. Heterogeneous mesoscale units. Micro-geochores (left) and landscape units (right). (König 2005).



higher or lower importance as the average assessment of the landscape were determined (Figure 11.3) and knowledge about the interdependencies between different functions of land use integrated into the framework (Meyer, 1997). The Interference Analysis reveals the initial hints for potential conflicting areas.

The formulation of potential hazards and risks for landscape functions and their protection is the next step of the framework. In this treatment phase a matrix is used to provide an assessment for each reference unit. This includes actual and potentially endangering risks using the results from the functional assessments, and which also provide the potential assessment and additional indicators.

11.3.4 Formulation of landscape function objectives (monosectoral development)

Starting from superordinated environmental goals, e.g. general guidelines and higher ranking plans, this phase of the analysis is used to formulate purposeful targets for the single landscape function or natural potential for every reference unit (Figure 11.5 see page 78). These goals are gathered together in a matrix in preparation for the next step in analysis.

11.3.5 Conflict indicators and congruence of targets

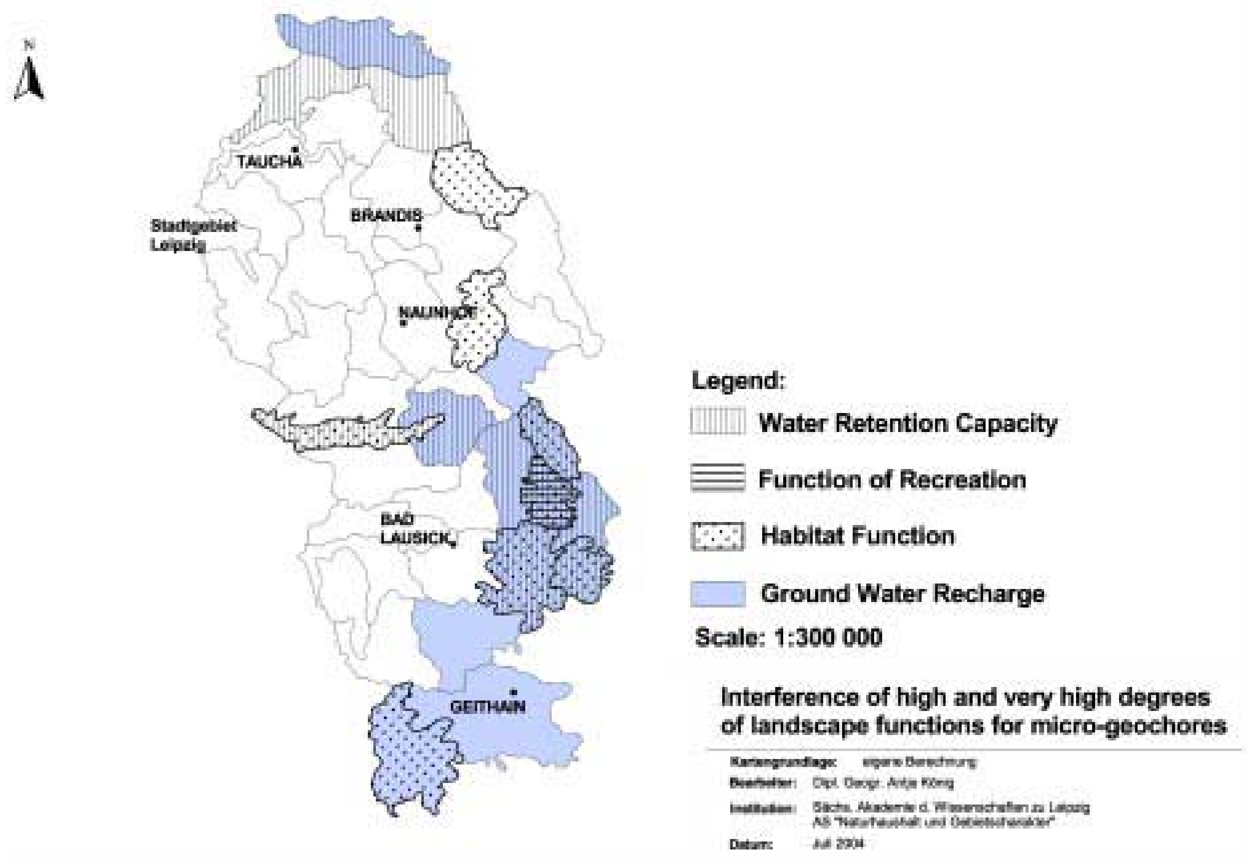
In the next stage single mono-sectoral targets (targets for each single function or potential) are compared with the help of an impact matrix (Bastian, 2002), positive interactions (congruence of targets), negative effects (target conflicts) and indifferences can be determined by using an ecological impact matrix (Figure 11.6 see page 78). The example for different functional targets for soil and water demonstrate positive interactions, conflicts and indifferences. These must all be considered through the development and calculation of an ideal compromise in multifunctional land usage – reaching the broadest agreement on landscape change for positive ecological and production outcomes.

11.3.6 Development of a conservation and development scheme

In the next stage, the functional-specific targets are all brought together to form complex general statements:

- A documentation sheet is assembled which outlines every relational spatial unit and valued indicators for the landscape functions and natural area potentials.

FIGURE 11.3. Interference of high and very high degrees of landscape functions for micro-geochores. (König 2005).



- Further additional information, conflict areas and their solutions are summarised.
- Spatial units of similar or even landscape ecological targets or problems are classified.

11.4 Discussion

The introduced method of integrative goal development is intended to be used for the determination of potential target conflicts. Two options are now discussed: firstly the integration of different goals using the decision trees method and secondly the determination of land use alternatives in form of spatial scenarios by using the multicriteria optimisation. The multicriteria optimisation is calculated with the program LNOPT (Land use options), as a component of the model framework for multifunctional landscape assessment and optimisation (MULBO; Meyer and Grabaum, 2003).

Decision trees were applied successfully as a relatively simple method for integration (Bastian and Röder, 1996; Mosimann, 2001; Bastian, 2002). On the basis of 'if-then' combinations a decision tree can link together land use targets for every reference unit without the problem of scaling. The decision trees can be used to produce a classification of the reference areas using the different groups or types of parameters. The transparency of the approach is an advantage for the application. Within the scope of the integrative goal development, decision trees are applied to help to classify spatial units with regard especially to conflict-laden areas at the regional level.

Figure 11.7 (see page 79) shows the steps of the landscape and assessment framework MULBO. In addition, the intended data preparation steps of MULBO have been applied into the integrative goal finding methodology as described above. LNOPT can also be used as a stand-alone module in the preparation of optimal land use scenarios.

FIGURE 11.4. Example of actual and potential hazards and risks for micro-geochores for soil functions (extract). (According to Bastian, 2002, changed).

Actual and potential hazards/risks for micro-geochores for soil (extract)

Micro-geochores	B1	B2	B3a	B3b	...
Senfberg-Frauenberg-Schwelle	r	xt	xt	A14/t	
Geithainer Löß-Hügelgebiet	r	xt	X	(A72), B7, Z/t	
Alttagebau Bockwitz Borna-Ost			xt	(A72)/t	
...					

B1: Soil sealing and exploitation of mineral resources
B2: Hazard of soil erosion
B3a: Contamination by agriculture
B3b: Contamination by traffic

X: applies to a considerable degree
x: applies
(x): applies reduced
/t: applies to parts of the unit
R: several mineral resource extraction areas
r: one mineral resource extraction area
Z: train
(A72): motorway in planning

FIGURE 11.5. Formulation of mono-sectoral goals for single functions/potentials. (König 2005).

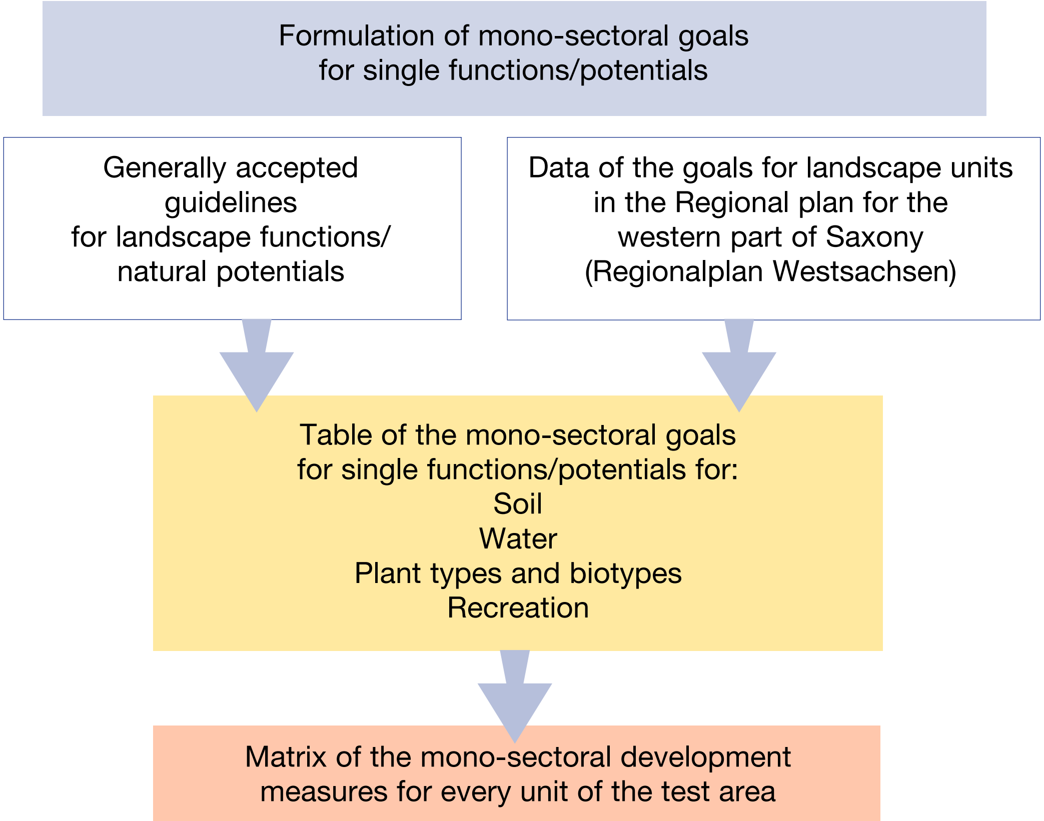


FIGURE 11.6. Ecological Impact Matrix (extract) – congruence and conflicts between development targets for landscape functions or natural potentials and protective goods. (According to Bastian, 1999, changed).

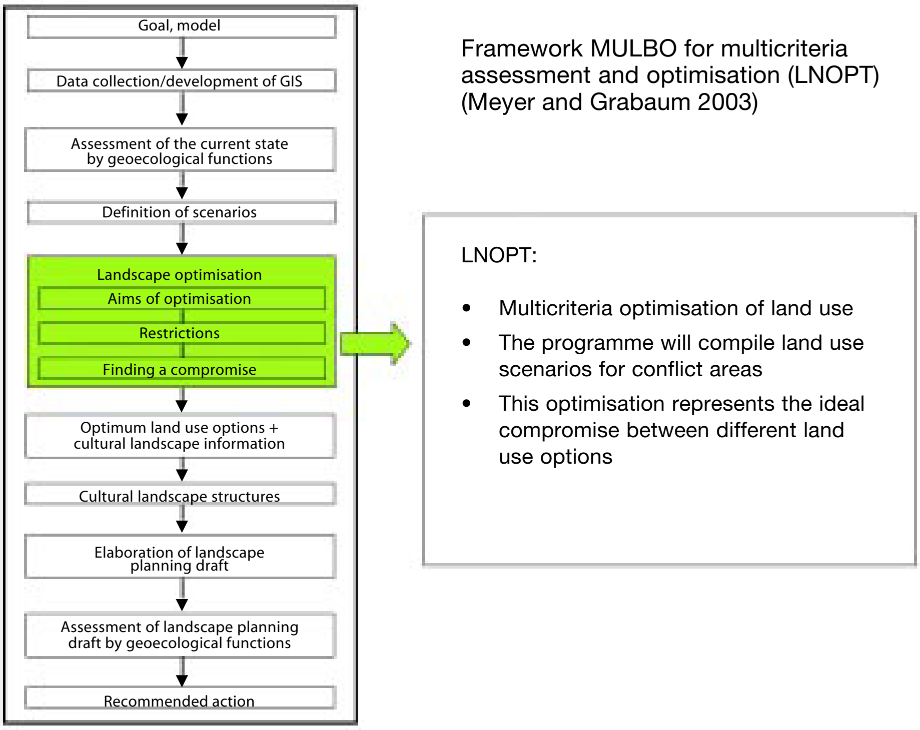
Ecological Impact Matrix (extract)

Aims of development	**Soil**			**Water**		**...**	
	S1	**S2**	**S3**	**W1**	**W2**	**W3**	**...**
S1		C	C	Pos. I.	C	C	
S2			Pos. I.	Ind.	Pos. I.	Pos. I.	
S3				Pos. I.	C	Pos. I.	
W1					Pos. I.	Pos. I.	
W2						Ind.	
....							

Pos. I.	**Positive Interaction**
C	Conflict
Ind.	Indifferent
Check	Check the individual case

Sig.	**Aims of development**
S1:	Retain of efficient soils for agriculture
S2:	Erosion protection measures for endangered areas
S3:	Conversion of the agrarian use on strongly loaded soils at motorways and federal highways
W1:	Degradation and avoidance of pollutant entries in little groundwater-protected areas
W2:	Extensive use of little groundwater-protected areas with high and very high groundwater formation
W3:	Extensive use or afforestation of groundwater-endangered areas without high groundwater formation

FIGURE 11.7. Procedure for working out viable action recommendations by Landscape optimisation with LNOPT (dark) as a part of the MULBO-Method. (Meyer and Grabaum, 2003, changed).



The optimisation program LNOPT (Grabaum, 1996) calculates the multicriteria optimisation for a chosen scale. Several functions are optimised at the same time. The result is a spatial compromise. The algorithm of linear programming chosen by LNOPT is based on the Game Theory. The possibility for defining weightings for the different landscape functions and future land uses are integrated. The result is a balance of the input functions for future land use and is therefore a suitable procedure for the protection and the development of the multifunctionality of landscapes. The resultant landscape patterns output from the optimisation orientate themselves by natural circumstances and social requirements. Large scale applications with LNOPT are described by Grabaum (1996), Meyer (1997), Bobert (1999), Grabaum *et al*. (1999) and Moser and Meyer (2002). An advantage of this scale-independent optimisation process compared with the decision tree process is the consideration of the whole region under investigation in its totality. Disadvantages include the higher complexity of the mathematical basis and the relatively larger number of parameters to be defined before an optimisation can be determined.
In the current process of the development of integrative goals, LNOPT can be applied as follows:

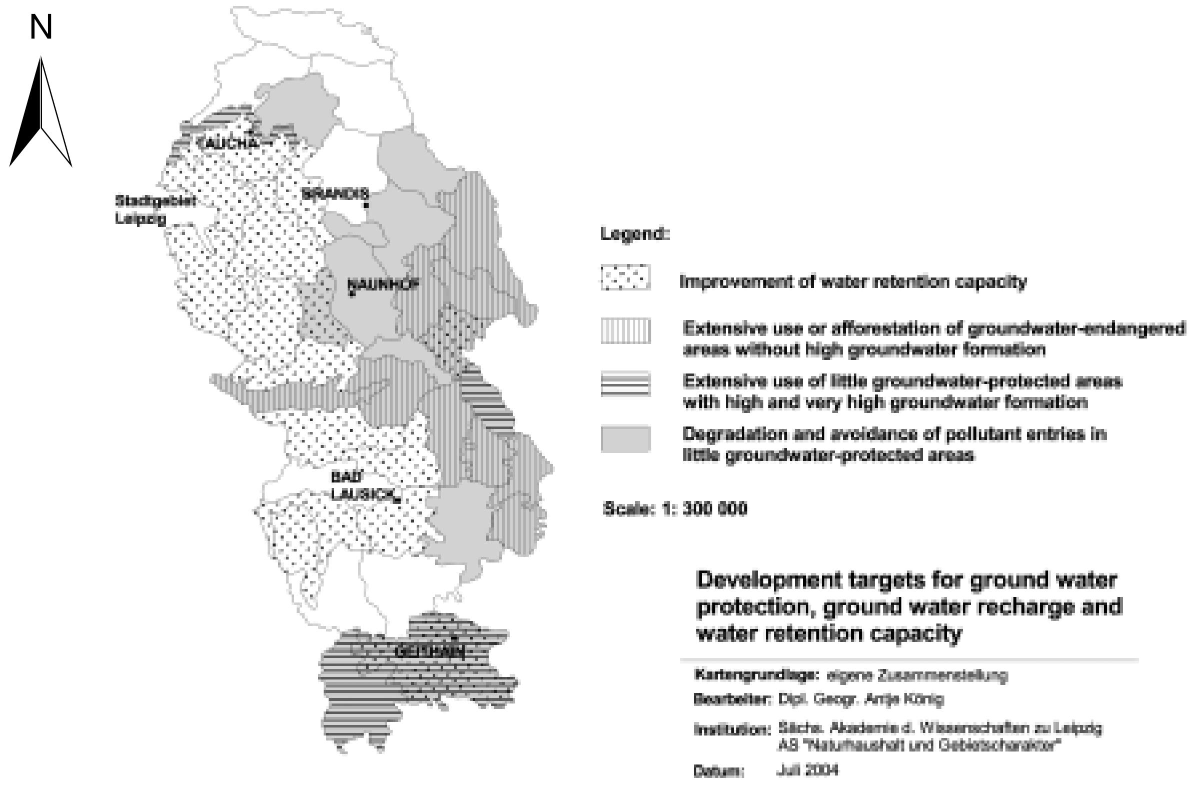
- In a two-stage procedure, as a combination of decision trees in the mesoscale and LNOPT in the microscale, decision trees are used for the classification of spatial units and for the detecting of conflict areas. LNOPT is used for solving land use conflicts with several alternative land use scenarios within these conflict areas.
- For the development of alternative land use scenarios for the whole area of investigation at regional level. This approach is well suited for all aspects of general land use changes such as afforestation, the increase of grassland, and the minimising of spatial conflicts which are related to the intensive land usage of the landscape. Neighbourhood relationships can be considered.

On the basis of these scenarios both approaches need inter- and transdisciplinary discussion. The participation of stakeholders is favoured for the definition of alternative land use scenarios and by the decision-making for the land use change. Identical spatial units having a similar aim can be summarised during a final treatment phase. Classification simplifies the feasibility of land use measures. Figure 11.8 (see over) shows an example related to development targets of water functions.

The results of the information gathered allow links to be operationalised between the methodologies and approaches of geosciences, especially developed by landscape ecology and landscape planning sciences and the interests of environmental policy as frequently requested. With an open integrative goal decision-based methodology the land use alternatives can be suggested on the basis of analysis and assessment methods, and proposed as land use changes in mesoscalic river catchment areas.

Importantly reference area assessment methods for landscape functions or natural area potential can also be

FIGURE 11.8. Development targets for ground water protection, ground water recharge and water retention capacity. (König 2005).



combined in the open framework of integrative goal development. The framework is ultimately and inclusive even though it originates from a relatively slender 'top-down' approach. The approach is not only useful for the assessment of river catchment areas with different possibilities for decision making, but also for landscape planning, town planning, regional planning, and further planning approaches the framework can be used. The framework gives a good overview and an integrative summary of the ecological state and the landscape problems of the whole area. It offers at the larger scale, broad solutions to be considered in both, biophysical and political land use conflicts.

Further research is needed with regard to advancing techniques related to the development of assessment methods for more complex (heterogeneous) land areas. In addition, further investigation is needed on quantitative and qualitative modelling of interferences between functions/potentials and land uses. Spatially-based integrative goal development in this framework accommodates economic, ecological and social functions. The framework described in this paper allows the preparation and presentation of scenarios for the sustainable change in multifunctional landscapes.

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12. Bridging multifunctionality of agriculture and multifunctional landscapes by applying the Leitbild approach

Hermann Klug and Peter Zeil
(Corresponding author: H. Klug, email: hermann.klug@sbg.ac.at)

Abstract

Multifunctionality is an intrinsic potential of each landscape and at the same time a concept of landscape planning. Embedded in a greater transdisciplinary framework this paper explores many of the aspects of multifunctionality and shows how the concept influences the easing of environmental pressures when applied to landscapes with respect to their vertical and horizontal multifunctionality. While vertical multifunctionality means the possibility of functional superimpositions, the horizontal multifunctionality is dedicate to spatial interconnections. Therefore, a matrix of functional superimposition and a matrix for determination of the necessity of buffer stripes has been developed to spatially explicit advice certain functions. These tools have been integrated in a hierarchical framework. This framework derives spatial explicit zones for land use priority taking into account social and economic values besides ecological ones.

Key words
Leitbild, functional superimposition, buffers, multifunctional landscapes, landscape development

12.1 Introduction

The post-war usage of landscapes focused on intensive agriculture, which caused significant impacts on the environment and laid the foundation to the present days' surplus food production. The eutrophication of surface waters – among many other effects – indicates in the course of the past decades that the economics of recent agricultural practices need to be changed. Hence, European and national directives, laws and agri-environmental subsidy programs were designed to overcome these problems with the aim to steer the development towards a more sustainable future. Farmers respond to these interventions by introducing changes in farm management leading to e.g. abandonment of agricultural plots, intensification or extensification impacting on diversification, processes, and functions in the landscape. Therefore, bringing landscape planning to the centre-stage does not merely mean to impose disconnected disciplinary actions addressing environmental problems one after another. Moreover, positively influencing landscape development involves policy instruments, funding schemes, business plans, and cultural perceptions of local people.

Generally, in Europe we find both shortages and surplus of agricultural produce. In central Europe, the extension of the urban fringe, housing construction in rural areas, expanding road networks, and progressing industrialisation tends to reduce agricultural land (marginalisation), while the granary of Ukraine with its profitable soils is still expanding its output. However, the recent accessions of new countries to the EU seem to initiate a shift in land use and production strategy towards intensively used agricultural regions in eastern countries and extensivation in the non-priority regions. Future planned accessions will intensify this trend, as present favourable climatic conditions combined with low production costs create a more profitable environment than in the western part of Europe. Due to the shifting land use, intensification, concentration, and specialisation are likely to take place in the high productive areas whereas in other regions extensification, diversification, fallow land and dispersion will prevail. The process clearly calls for systematic studies of landscape changes induced by policies which in both cases will influence and are influenced by the different conditions originating from landscapes and their indigenous potential.

Technological development in farming operations yields just another factor transforming agrarian landscapes: plots are arranged according to labour saving aspects causing often monotonous, homogeneous landscapes. While in economic terms, high productive areas are created, the vulnerability against environmental risks increases. The experience made in the past five decades in Western Europe should be transferred to the new accession countries with the aim to avoid the same problems encountered so far.

The main pressure stems from the overuse and overexploitation of natural and fossil resources. Besides the increase in agricultural production beyond the demand, the increasing spatial range for non-productive activities causes an additional pressure on landscapes. These pressures lead to a fundamental change in structure and morphology of the landscape and thereby possibly cause the loss of ecological functions necessary for the health of society. Especially land abandonment with resulting bush encroachment and afforestation in tourist areas is an unwanted phenomenon.

In response to the changing situation, landscape planning needs to integrate social, economic and political aspects with environmental measures to ensure a sound basis for regional planning aiming to ascertain the sustainable maintenance of ecosystem goods and services resulting from functions provided by the natural capital. To conceptualise the multifunctionality of agriculture and multifunctional landscapes under the above prerequisites, a Leitbild approach after Klug (2002) is extended towards a multicriteria analysis tool (Klug, 2005). This approach uses spatial explicit GIS techniques to develop scenarios framed by a commonly agreed vision for the future state of the landscape – the Leitbild. As most of the spatial planning approaches have a strong focus on ecological science aim at the optimisation of farmland priority zones, the concept proposed bridges socio-economic factors as well as political values and merges them into a semi-operational GIS procedure (Klug in press).

12.2 The future of landscape planning

Landscapes are by definition manifold in ecological character, multifunctional in cultural use and highly occupied cultural landscapes which will diversify in the next decades. Due to the fact that landscapes have to fulfil many functions, variations should not pass uncontrolled and ought to fulfil social objectives. On the one hand they create economic potential and living areas for all sections of the population; on the other hand they need to provide enough living area for a rich flora and fauna as well as serve among others for recreational activities.

Recent alterations came about from unresolved settlement pressure, fundamental structural changes in agriculture, new ways of recreation (complex of tourism and environment), and upgrading the infrastructure. However, steering development is not as easy, as political decisions are increasingly taken by laymen. Hence, it is very important to develop models, which are transparent and applicable, yielding distinct ideas for future landscape change.

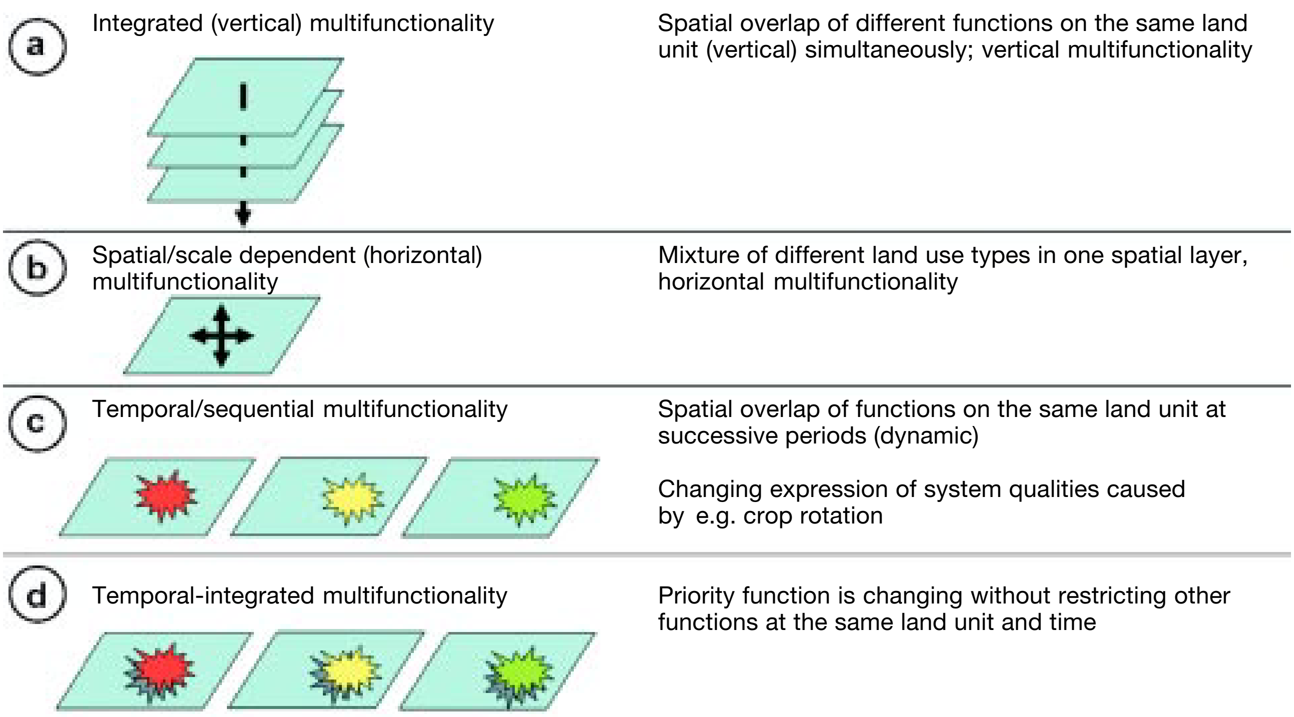
The major challenge for landscape planning today is to master the transition from sectoral thinking to more comprehensive holistic approaches as a transdisciplinary oriented part of landscape ecology representing the contribution to the development of 'scientifically based and viable Leitbilder which are accepted at least by the majority of people' (Bastian, 2004). The main problem arises when research is rooted in natural science's study of more or less objective phenomena and the integration of soft system thinking from social and cultural context (Olwig, 2004). From the review of relevant literature we summarise that above all, the natural science community is mostly working on more and more detailed, narrow aspects and concepts, whereas the holistic view in landscape planning does not necessarily require that high level of detail at least due to scale reasons (Elliot, 2002). Furthermore, no clear structure has been established beyond the philosophical discussion on combining environmental planning approaches with those from economics and society (Bastian, 2004). Nevertheless, it is the linkage between natural science, socio-economic and political categories – which need to react of each other in a synergistic way – that will facilitate the most valuable way of planning (Neef, 1969). Since Neef established this important idea, researchers have tried to overcome the so called 'transformation problem', without having succeeded so far. The main problems we are presently dealing with are:

- the understanding of the complexity of landscapes as such;
- the necessity of a strong background in natural-environmental, economic and socio-cultural disciplines;
- the decision making is usually complex or even hyper-complex with many stakeholders (Kay *et al*., 1999; Brans, 2002);
- the general political influences on the landscape system by regulations, laws and established funding schemes;
- the gap between those analysing a landscape and those who decide (Luiten, 1999);
- the distinct perception of each disciplinary knowledge as such; and
- the different priorities in using and interests in socio-cultural and economic values.

Sociology, economy and ecology pursue different interest and strategies. However, that these interests and strategies are interacting tends to indicate that several landscape functions are effective at the same time and in the same spatial unit. This again means that different material and amaterial processes take place simultaneously and interact in a synergistic, sometimes conflicting and non-neutral way. Correspondingly, all simultaneously interacting parameters are assumed as changing, as far as one parameter in this cause-effect-chain is changing outside of its normal range of variation (e.g. ecological amplitude). Hence, it could be that we partly destroy, by high intensive tillage, the foundation of the intended land use *per se*. This means in detail that an economic act based on maximum yield – especially in farming – destroys the foundation of the ecological functioning and therewith the whole operating landscape system (e.g. due to soil erosion). Is the soil fertility due to soil erosion once lost, it is – as a result of the minimal regeneration rate – irretrievable. The evidence implies that functional segregation towards monoculture has apparently contributed to these problems of ecological functioning, is discussed economically and socially in Knauer (1993) and Meyer (1997).

It is clear, that it is the right time to establish, what kind of sustainable land uses can be used in parallel or one after another on given areas and which land uses could border each other without hampering healthy ecological cycles. Therefore, the planning of landscapes is receiving increasing attention in landscape science. Society's awareness on future needs and demands require the paradigm of sustainable development which is connected to strategies to save time, money, and resources. The rational behind this planning method is that positive production of multiple use agricultural systems are maintained and that competing developments for producing most wanted goods and services supporting the major part of human society are resolved. Various human needs are to be met on the same limited terrain, forcing the entire landscape to be managed in a way that a variety of functions and demands from ecology, society, and economy can be met. This desire to plan, manage, and monitor landscapes is to enhance the functional integration through the 'simultaneous presentation of different functional viewpoints' (Brandt and Vejre, 2004).

FIGURE 12.1. Aspects of multifunctionality.



12.3 Methodology

12.3.1 The multifunctionality of single plots and the whole landscape

According to the definition of multifunctionality, a single piece of land can have multiple functions which are integrated, temporal or both (Figure 12.1). Therefore, one land unit can have multiple values at the same time.

Additionally, this single piece of land can have alternating values at different times. This occurs for instance, when applying a crop rotation system whereby certain crop products follow one after another. These alterations can take place periodically, frequently, in shorter or longer periods. This is what we define as temporal dynamics and what we can measure by change detection on satellite imagery.

The highest aggregation of multifunctionality is achieved when combining the integrated multifunctionality and the temporal multifunctionality. The result is a temporal-integrated multifunctionality, having multiple functions (values) at the same time on one and the same land unit, which are alternating in time due to shifts in their priority or changing items.

However, the whole ensemble of multifunctionality may work well from one person's perspective, while others may perceive the same land unit in a different way, with less or different functions prioritised. While, a farmer's primary objective is production with the objective to maximise yield, the tourism industry is more concerned about landscape ecology and scenery or the water industry regards the preservation of good drinking water quality as the highest priority. All these necessities and demands from society need to be taken into account. Therewith we need a framework that represents the perspectives of the majority of the people. This majority comprises normally the stakeholders elected as well as groups of actors that have been identified as having leading decision roles. These groups mainly consist of the general community, politicians, economists, socio-cultural associations, the land owners, and scientists from several disciplines.

Besides the multifunctionality concerning one patch, the landscape *per se* comprises a spatial multifunctionality through its mixture of different bordering patch types. The more heterogeneous a landscape is, the greater the variations of patch types in space. This is usually measured with landscape metrics, such as diversity index or number of distinct patches (McGarigal, 2002). While in general, a high degree of diversity is seen as a good ecological status, there are some restrictions of bordering land use patch types due to ecosystem health reasons. For example intensive tillage areas as well as intensively used grassland areas directly bordering surface waters inherit a danger of nutrients runoff.

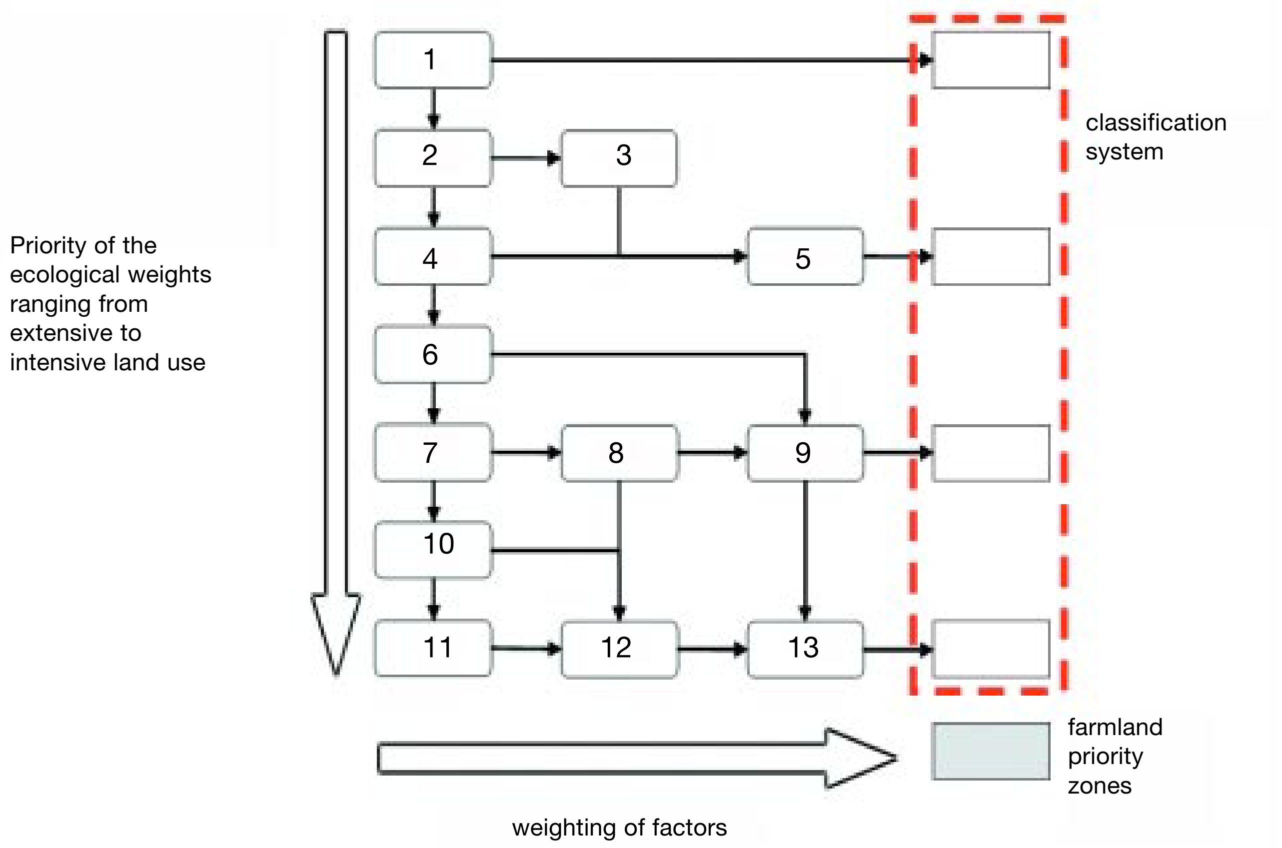
12.3.2 Introduction to the overall approach

As proposed above, multifunctional land use implies a mutual influence of the different kinds of land use, and therewith produces pressure on the environment. These pressures arise from the competing needs of tourism and recreation industry, nature and environmental conservation, waste management, military use, provision of drinking water, food and fibre production, and many others. Considering and keeping track of all relevant pressures and further on aspects such as declared protection zones for water conservation, water reserves, flood retention, nature conservation, landscape conservation, classified natural sites, ski lifts, ski slopes, safety zones of airfields, hazard zones of shooting and explosive facilities, building prohibition, hazard and fire zones of railways, protection zones of national roads, protection zones for underground and overhead power lines, green belts, priority agricultural areas, military exercise zones, and so on it becomes obvious that careful planning is needed when allocating activities (functions) to a spatially explicit land unit.

Additionally, landscape planning and agricultural (landscape) management is influenced in several ways, such as agricultural trades steered by the Common Agricultural Policy (CAP), market policy and market performance, general economics, legislative conditions from the EC (Water Framework Directive, Natura 2000 directive, Landscape Convention) and national authorities, NGO's, funding instruments, household issues, and ecological boundary conditions such as site and time specific natural conditions of different ecosystems resulting from terrain, hydrology, climate, air, and soil. All these influences have direct and indirect consequences on the land use structure, processes and the goods and services as outcomes. Hence, the qualities of the planning methodology must allow the landscape be studied from different perspectives, each emphasising certain processes and structures such as abiotic, biotic, and human-cultural components.

While landscapes are very complex in myriad social and biological ways, Klug (2002), Klug (2005) and Klug (in press) offers a new framework for understanding, analysing, interpreting, and monitoring landscapes as a series of tasks in a multicriteria analysis matched by logical inferences (Figure 12.2). The key idea of this framework is to adopt a land use strategy that focuses on a shift from functional segregation towards functional integration combining different theories and methodologies from social, political, economic and environmental perspectives. Ideally, methods such as the concept for the multifunctionality of landscapes, the strategic environmental planning, and others should be combined in such way that the strengths complement one another and the weaknesses are minimised. This

FIGURE 12.2. Schematic view on the hierarchical framework*.



*Due to the complexity of the hierarchical framework it is not possible to present it fully in the space available here, therefore, the framework is only represented schematically. Further details can be found in Klug (2002).

method-mix should be locally adaptable and facilitates successful implementation of future landscape planning. Therefore, the developed methodology should be transferable to other regions with more or less equal boundary conditions. It should serve as a tool to be used to plan and steer landscapes towards a sustainable condition. The success of implementation is strongly related to the technological skills, social will and the ability of stakeholders and actors affecting the landscape to tailor landscape functions and processes to fit each other. Hence, the approach should provide a tool facilitating communication between science, local people and stakeholders who are responsible for decisions.

The main idea behind the concept is that planning and the realisation of an aspired future state imply a management of each patch within certain ecological, economic and social limits. These boundary conditions are framed by decision makers based on ecological criteria focusing the potential of each patch. Having developed these potentials, certain land use functions can be allocated to this area according to the matrix of functional superimpositions and temporally modified. The modifications are to suit competing land resources and their claims from society. In general, this ensures the potential of each patch is not overburdened. Instead, this approach contributes to a better functioning in total and simultaneously minimises risks such as unclosed nutrient cycles. However, these efforts need strong social input and control with open-minded perspectives.

In general, the concept is based on a process-driven algorithm which investigates threshold values for certain attributes from a-prior derived geodatasets of functions and potentials according to De Groot *et al*. (2002) and with it dedicates a certain land use to a spatial unit (see Figure 12.2 page 85). These threshold values identify single properties and potentials of an area; for examples soil features as the soil texture and soil moisture or the usefulness of an area for ground water recharge expressed in five categories. Furthermore, datasets from ecology, economy and society can be integrated to reveal the primary functions to be best allocated to a certain area. These primary functions result from an assessment of a transdisciplinary compromise of interests from different stakeholders as developed in Klug (in press).

In detail the top-down structure of the hierarchical framework shown in Figure 12.2 is oriented from extensive to intensive land use to take care of environmental protection. Therefore, in each case the intensity allocated to an area is oriented to its load potential which is assigned by multiple properties questioned in the framework. This means, the more the hierarchical framework is processed, the higher the natural site potential and the possibility of putting loads to this area and the higher is the possibility to use this area intensively.

Having rejected a question at the left side the framework (e.g. number 7, Figure 12.2) proceeds from left to right (over number 8 to number 9 or 12, Figure 12.2). Here, further allocation of properties need to be assigned. The last stage, at the right side of the framework, a certain land use is allocated (e.g. grassland, or tillage). Each land use possibly being allocated frames the classification system. It is the same classification system we used to analyse the present landscape from ASTER satellite images. This allows a comparison of the present with the aspired future landscape state derived from the hierarchical framework to extract the problems to be solved.

In case of possible functional superimpositions as expressed in Chapter 12.3.1, the hierarchical framework joins the matrix of functional superimpositions (Figure 12.3) to assign land uses which are allowed to superimpose, are restricted to overlap, or not allowed to superimpose. Having allocated all land units within the landscape under consideration, the matrix of buffer functions determines necessary buffer strips to ensure that the competing land uses and ecological needs noted in Chapter 12 (Figure 12.4) have possible solutions developed.

12.3.3 The vertical and horizontal multifunctionality

The main function of the hierarchical framework is to maintain and further develop the process structure of the underlying ecosystem to get in return the best benefits demanded from society. Therefore, the hierarchical framework is the centre of the whole concept, being supported by the following modules surrounding it. In general, the model takes care of two perspectives:

a) vertical processes like functional superimpositions; and
b) horizontal harmonisation of different kinds of feasible spatial land use interconnections.

The matrix shown in Figure 12.3 explains the possibilities of area functions which are generally possible to superimpose, area functions that are precluding to overlap, and functions that are allowed to overlap with restrictions. These restrictions refer to manifold aspects which mainly can be classified by environmental protection restrictions.

This process structure therewith allows an easy allocation of different utilisation, regulation and protection function to one and the same land unit, whereby the functions are tailored to the concern of meso-scale landscape planning. They are suitable for mid-European conditions, but may be adapted to landscapes with special uses and functions.

Having applied the hierarchical framework and the matrix of functional superimposition, land use options that reduce site specific ecological risks and conflicts are revealed. However, this may not be true for neighbouring patches with horizontal process relations. The effects of off-site intrusion need to be minimised subsequently by buffer strips.

Buffers are best described as areas of land in permanent vegetation that help control pollutants and manage other environmental concerns such as nutrient discharge. Filter strips, riparian buffers, corridors, field borders, grassed

FIGURE 12.3. Matrix of functional superimpositions (modified after Mosimann *et al*., 2001 and Klug, 2002).

	Functions	1																	2							3				
		ice, firn, and snow areas	areas without vegetation	scrub, herb, and shrub vegetation are	rivers	slakes	settlement, roads, infrastructure	recreation area	tillage without management restrictions	tillage with management restrictions	Intensively used permanent grassland	Extensively used grassland	Intensively used pasture	Extensively used pasture	Intensively used orchards	Extensively used orchards	forest / plantation	Semi-natural forest (extensive logging)	exclusive protection areas	flora and fauna protection zones	bogs, fens, and mires	soil protection zones	areas of rivers in narrow sense	geotopes	witnesses of cultural landscape elements	retention areas	buffer area between protection and land-use zones	immission protection zones	climate-ecological compensation zones	ground water protection areas
3	ground water protection areas	-	+	+	+	+	-	+	o_1	+	o_1	+	o_1	+	o_1	+	+	+	+	+	+	+	+	+	+	o_1	+	+	+	
	climate-ecological compensation zones	+	+	+	+	+	-	+	o_{16}	+	+	+	+	+	o_3	+	o_3	o_3	-	+	+	+	+	+	+	+	+	-		
	immission protection zones	+	o_{19}	+	+	+	-	-	-	-	-	-	-	-	-	-	+	+	-	o_2	+	-	-	+	$+_4$	+	$+_4$			
	buffer area between protection and land-use zones	-	o_{19}	+	-	-	-	-	-	-	-	+	-	+	-	+	+	+	-	+	+	+	-	+	+	+				
	retention areas	-	-	+	-	-	-	+	-	-	$+_6$	$+_6$	$+_{14}$	$+_{14}$	-	$+_{13}$	o_7	o_7	o_7	+	+	+	+	+	+					
2	witnesses of cultural landscape elements	+	+	+	+	+	-	+	o_8	+	o_8	+	+	+	-	+	-	-	$-_9$	+	+	+	-	+						
	geotopes	+	-	-	-	-	-	+	o_{10}	o_{10}	o_{10}	+	+	+	o_{10}	+	+	+	+	+	+	+	+							
	areas of rivers in narrow sense	-	-	+	+	-	-	+	-	-	-	o_{15}	-	-	-	-	-	+	+	+	+	+								
	soil protection zones	-	-	+	-	-	-	-	-	+	o_5	+	o_5	+	o_5	+	o_5	+	+	+	+									
	bogs, fens, and mires	-	+	o_{21}	-	-	-	o_{22}	-	-	-	-	-	-	-	-	-	-	+	+										
	flora and fauna protection zones	-	-	+	-	-	-	o_{17}	-	+	-	+	-	$+_1$	-	+	-	+	-											
	exclusive protection areas	+	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-												
1	Semi-natural forest (extensive logging)	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-													
	forest / plantation	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-														
	Extensively used orchards	-	-	+	-	-	-	-	-	o_{11}	-	+	+	+	-															
	Intensively used orchards	-	-	-	-	-	-	-	-	-	-	-	-	-																
	Extensively used pasture	-	-	+	-	-	-	o_{18}	-	-	-	+	-																	
	Intensively used pasture	-	-	-	-	-	-	-	-	-	o_{12}	-																		
	Extensively used grassland	-	-	-	-	-	-	o_{18}	-	-	-																			
	Intensively used permanent grassland	-	-	-	-	-	-	-	-	-																				
	tillage with management restrictions	-	-	-	-	-	-	-	-																					
	tillage without management restrictions	-	-	-	-	-	-	-																						
	recreation area	+	-	+	+	+	+																							
	settlement, roads, infrastructure	-	-	-	-	-																								
	lakes	-	-	-	-																									
	rivers	-	-	-																										
	scrub, herb, and shrub vegetation area	-	-																											
	areas without vegetation	o_{20}																												
	ice, firn, and snow areas																													

List of restrictions respective condition numbers [n]:

1 As far as not to high slurry and/or pesticides and herbicides.
2 Dependent on the species and immission type.
3 Larger / closer wood distances may represent insuperable hindrances for cold air streams (fresh air production) towards the over-heated or polluted city.
4 As far as it is a thicket.
5 Utilisation is in dependence on soil sealing possible; in case of forest only location equitable stands possible.
6 The surrounding retention area can be used as intensive meadow (yield only as straw, not as fodder usable).
7 As far as the existent or aspired vegetation is resistant against pollutants or nutrient input.
8 Dependent on the amount and manner of substance input as well as the filter and buffer function of the soil.
9 Possibly protection measures for cultural witnesses necessary (e.g. heathland).
10 Limitations result from mechanical cultivation.
11 Small parcelled tillage possible.
12 As far as the vegetation is sufficient for pasture cattle.
13 As far as trees are not impaired by the retention function.
14 As far as locations are not too wet (soil sealing and sludging).
15 As far as used as retention area and dynamic is wanted.
16 As far as odour from slurry is not too high.
17 As far as habitats and species are not impaired in their way of life.
18 Superimposition from summer to winter by use of skiing or sledging possible.
19 As far as no wind erosion is occurring on the vegetationless locations.
20 Can superimpose when firn, snow or ice is temporary melting.
21 A certain degree of bushes can be tolerated.
22 Bogs, fens, and mires can be opened up for people on guided tours.

Key:

1 = Utilisation function
2 = Protection function
3 = Regulation and buffer function
\+ Buffer space always required
o Buffer space partly required
\- Buffer space not required

FIGURE 12.4. Matrix to determine the necessity for buffer strips modified after Klug (2000), Mosimann *et al*. (2001), Klug (2002).

		1																2						
	land use and protection zones	areas covered by ice and snow	areas without vegetation	foliage and shrub vegetation	rivers	lakes	settlement, roads, infrastructure	recreation area	tillage without management restrictions	tillage with management restrictions	Intensively used permanent grassland	Extensively used grassland	Intensively used pasture	Extensively used pasture	Intensively used orchards	Extensively used orchards	forest / plantation	Semi-natural forest (extensive logging)	exclusive protection areas	flora and fauna protection zones	bogs, fens, and mires	soil protection zones	areas of rivers in narrow sense	geotopes	witnesses of cultural landscape elements
2	witnesses of cultural landscape elements	-	-	-	-	-	+	o_{10}	+	+	+	-	+	-	+	-	-	-	-	-	-	-	-	-	
	geotopes	-	-	o_{13}	-	-	+	o_{10}	+	+	+	-	+	-	+	-	-	-	-	-	-	-	-		
	areas of rivers in narrow sense	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	o_{11}	-	-	-	-	-			
	soil protection zones	-	-	-	o_{14}	-	+	o_{15}	+	+	+	-	+	-	-	-	-	-	-	-	-				
	bogs, fens, and mires	-	-	-	-	-	+	-	+	+	+	-	+	-	+	-	-	-	-	-					
	flora and fauna protection zones	-	-	o_1	-	-	+	+	+	+	+	-	+	-	+	-	-	-	-						
	exclusive protection areas	-	-	o_1	-	-	+	+	+	+	+	-	+	-	+	-	o_7	-							
1	Semi-natural forest (extensive logging)	-	-	-	-	-	$o_{2,3}$	o_4	+	o_5	o_6	-	+	-	+	-	-								
	forest / plantation	-	-	-	o_{16}	o_{16}	-	-	-	-	-	-	-	-	-	-									
	Extensively used orchards	-	-	-	-	-	o_3	-	-	-	-	-	-	-	-										
	Intensively used orchards	-	-	o_1	+	+	o_3	-	o_{12}	-	o_{12}	-	-	-											
	Extensively used pasture	-	-	-	-	-	o_3	-	o_9	-	-	-	-												
	Intensively used pasture	-	-	-	+	+	o_3	-	o_9	-	-	-													
	Extensively used grassland	-	-	-	-	-	-	-	+	+	o_1														
	Intensively used permanent grassland	-	-	-	+	+	o_3	+	o_{12}	o_{12}															
	tillage with management restrictions	-	-	-	+	+	$o_{3,19}$	+	-																
	tillage without management restrictions	-	+	-	+	+	$o_{3,19}$	+																	
	recreation area	-	-	-	o_{18}	o_{18}	+																		
	settlement, roads, infrastructure	+	-	-	+	+																			
	lakes	-	o_{17}	-	-																				
	rivers	-	o_{17}	-																					
	foliage and shrub vegetation	-	-																						
	areas without vegetation	-																							
	areas covered by ice and snow																								

Buffer space under certain conditions required [n]:

1 Necessary when the danger of expansion of location-foreign species in neighbouring ecotopes is possible.
2 Necessary while high emissions at the settlement edge through traffic or industry.
3 Necessary when traffic is >10,000 vehicles per day.
4 Necessary in open recreational facilities as picnic sites or playgrounds.
5 Necessary by forests in drain area below tillage areas.
6 Necessary by forests in drain area below meadows or pastures
7 Structured forest edges are sufficient.
8 As far as protected species are endangered.
9 In case of meadows in drain area below tillage areas.
10 Necessary in case of emergency of anthropogenic destruction of the cultural witness.
11 Dependent on the structure of the stock and the utilisation form.
12 In case of emergency of substance lost (herbicides, fungicides, nutrients, sediments).
13 In case of risk of bush encroachment.
14 In case of risk of soil loss.
15 As far as no impairment of the soil is expected.
16 As far as no impairment of the surface water through forest use is expected.
17 Necessary while sediment loss.
18 In case of endangered or disturbed ecosystem.
19 In wind direction lying settlements hedgerows as dust catcher necessary.

Key:
1 = Utilisation function
2 = Protection function
+ Buffer space always required
o Buffer space partly required
\- Buffer space not required

waterways, field windbreaks, shelterbelts, and contour grass strips are all examples of buffer (McGarigal, 2002; USDA, 2005). Forman and Godron (1986) define buffers as 'narrow strips of land which differ from the matrix on either side' that 'may be isolated strips, but are usually attached to a patch of somewhat similar vegetation.'

The main reasons for buffer strips allocated to different kinds of adjacent patches relate to:

- improvement of soil, air, and water quality (removal of nutrients, pesticides, pathogens and sediments, reduce flooding);
- enhancement of wildlife habitat (biotopes, corridors, connecting elements);
- restoration of biodiversity;
- creation of scenic landscapes; and
- economic benefits (incentive payments, higher yields, protect buildings, roads, and livestock).

According to these theories, a matrix to determine the necessity to implement buffer strips has been designed with the same structure as the matrix of functional superimpositions; except the regulation functions (Figure 12.4). The regulation functions are dedicated to non-specific land use types and represented by the utilisation functions.

In case a buffer strip needs to be assigned between the borders of two patches, the buffer width is an issue often discussed. From a policy perspective in spatial development plans, national or regional laws, directives norms, or funding schemes buffers are often specified with a width between 5–10 m without considering any spatial ecological background information. In reality, the width strongly depends on the spatial surrounding of the two patches bordering each other, the type of each patch as well as the underlying problem to solve. As an example a grassland area bordering surface water may only need a narrower buffer strip than an intensively used tillage area. But both buffer strips need to be enhanced in case the slope towards the surface water increases. Therefore, a rule base needs to be formulated on the basis of morphological parameters derived from a digital elevation model (e.g. slope, exposition, slope length, curvature) or other geodatasets as for instance, information on wind direction and intensity in case of wind erosion problems. This rule base defines threshold values for buffer width which can be allocated semi-operationally using GIS techniques.

12.4 Discussion and conclusion

Due to the increasing challenge to develop more sophisticated types of land use regulations (e.g. the CAP-Reform) it becomes evident that former planning traditions as well as farmer's tasks on their land need to be gradually replaced. The realisation of this change in agricultural practices is strongly dependent on the insight of farmers and their understanding and recognition of land use in respect to differences in landscape conditions and an awareness of the contribution, good land management makes to society in general. Farmers have a multifunctional role to play as providers of both market goods and public services. Today, especially the non-market products are seen as by-products of market commodities and have not been valued in terms of money transfer. But these public goods (positive externalities) give the landscape values that we classify as open landscapes, biodiversity, leisure areas, etc.

We assume and recommend that transdisciplinary landscape planning will – with a high probability – become more widespread as many important trends concerning the interest for landscape planning at landscape scale have emerged in recent years. Being aware that this trend might support a more transparent and accepted landscape planning method, it should also be acknowledged that such approaches require high resource input from an organisational point of view.

However, we argue that transdisciplinary planning of different aspects of landscape functionality might add to the understanding of ongoing landscape changes (positive and negative trends) and widen the range of options for the formulation of policy measures as well as the activity radius of farmers which would lead to a more sustainable use of our landscapes. From those findings we can formulate guidelines for improving our present landscape towards an aspired situation in future. To give recommendations to reach the aspired future state, the following three points need to be fulfilled:

- people meet, respect each other, and are willing to collaborate;
- the agreement on a strategic conceptualisation and solution to find a commonly agreed aspired future state; and
- formulation of an action plan to reach the objectives agreed on before.

With a deeper insight in the cause effect relationships and the interconnectedness of processes we should be able to evaluate intervention options and – to a certain extent – make a prognosis about the expected changes. Therefore, the major advantage of a holistic planning method is to understand and improve our methods applied for a non-chaotic steering of our future landscape. The landscape's future will only be secured in its multifunctionality if we are more sensitive with nature and our interaction with it. This requires, not only doing everything to increase the efficiency of resource use for maximum yield; moreover it places us on the path to a sustainable lifestyle of human.

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13. Environmental and economic performance of agroforestry along a European gradient

João H.N. Palma, A. Riccardo Graves, P.J. Burgess, Yvonne Reisner and Felix Herzog
(Corresponding author: J.H.N. Palma, email: palma.joao@gmail.com)

Abstract

Silvoarable agroforestry (SAF) integrates use of trees and arable crops in the same field. In Europe, this potentially offers a range of environmental and economic benefits in comparison with conventional arable cropping. A modelling approach was used to compare the environmental and economic benefits of SAF with arable and forestry systems at a farm- and European-scale. At a farm-landscape scale, soil erosion, nitrogen leaching, carbon sequestration, landscape diversity, and infinite net present values were modelled for a stratified random sample of 19 landscape test sites (LTS) in the Mediterranean and Atlantic regions of Europe. At each LTS, different agroforestry scenarios were modelled and compared to status quo arable production. SAF had a positive impact on the four environmental indicators in comparison with the status quo, but economic benefits varied according to tree species and region. At a European scale, data on soil, climate, topography, land cover and tree growth were used to identify target regions for SAF, with the aim of finding areas where SAF could reduce the risk of soil erosion, contribute to groundwater protection, and increase landscape diversity. Target regions were found to make up about 40% of the total arable area of the European Union.

Key words
Agricultural land use, intercropping, environmental benefit, farm profitability

13.1 Introduction

Agroforestry has been defined as the practice of deliberately using woody perennials on the same land management unit as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence, so that there are significant ecological and economic interactions (Somarriba, 1992). In Europe, agroforestry systems have been used mainly in traditional agriculture to provide a variety of agricultural and tree products. The two principal forms of agroforestry are often described as silvoarable (tree-arable crop) and silvopastoral (tree-livestock) systems.

During the last three centuries, the agricultural landscape in Europe has seen a steady reduction of agroforestry (Dupraz and Newman, 1997), despite some systems increasing in area between the two world wars (e.g. Herzog, 1998). The reduction has been greatest since 1950, as the introduction of land consolidation programmes encouraged the removal of hedges and isolated trees from agricultural land (Eichhorn *et al*., 2005).

As the environmental cost of intensive agriculture have become apparent (e.g. Dealbere and Serradilla, 2004), there has been an increasing interest in the promotion of ecologically sound practices (Glebe, 2003). The EU project Silvoarable Agroforestry For Europe investigated the European context of modern silvoarable agroforestry between 2001 and 2005. It aimed to reduce uncertainties concerning the productivity and profitability of silvoarable systems, and to suggest European policy guidelines for agroforestry implementation (Dupraz *et al*., 2005).

Within this broad framework, an integrated assessment of the environmental and economic performance of SAF was undertaken with the objective of assisting decision-makers implement ecologically sound land management practices. The process of 'integration' posed two major problems. The first concerned the scale of evaluation. Whilst examining land-use systems at a small scale (e.g. through field experiments and subsequently, through models) can improve understanding of tree and crop interactions, the most profound effect on the environment often arises from larger scale processes (Grace *et al*., 1997). Therefore, up-scaling scientific knowledge gathered at a plot scale to the farm and landscape scale is needed to achieve an analysis that more closely resembles reality. The second difficulty concerns integrating environmental and economic analyses of land use. Although environmental and economic analyses for agroforestry have been made through previous research, they are usually assessed separately (e.g. Thomas, 1991; Dube *et al*., 2002; Udawatta *et al*., 2002; Burgess *et al*., 2004; Nair and Graetz, 2004). Only an integrated analysis, however, where both environmental and economic effects are evaluated under identical environmental and socio-economic conditions, allows to truly recognise eventual trade-offs between the potential environmental benefits of agroforestry and its possibly lower profitability.

In this research we co-ordinated the environmental and economic evaluations, which were carried out in identical test regions, representing at the same time small landscape test sites (LTS, 4 x 4 km) and hypothetical farms. We achieved the large scale assessment and the European dimension by randomly selecting the LTS along a gradient from Mediterranean (Spain) to Atlantic Europe (France, The Netherlands) and by combining this with a coarse evaluation of agroforestry target regions at the continental scale.

13.2 Material and methods

13.2.1 Farm-landscape scale

Landscape selection, data acquisition and scenarios
Nineteen LTS were randomly selected in the arable areas of Spain, France and The Netherlands (Figure 13.1.) based on an environmental classification of Europe (Metzger *et al*., 2005) and on the PELCOM land cover classification (Mücher *et al*., 2003).

For each LTS, existing geographical and statistical data were compiled, harmonised and complemented by field surveys. LTS were subdivided into a maximum of four land units (LU) using cluster analysis. The LU were considered to be homogenous with respect to soil properties and climatic conditions (Palma *et al*., 2006a) and were used to represent farm management units. The LU were ranked according to their potential productivity from 'best land' to 'worst land'.

The impact of SAF was explored by introducing SAF over 10% or 50% of the farm/landscape to simulate 'pessimistic' and 'optimistic' adoption by the farmer. Two tree densities (50 and 113 trees ha^{-1}) were compared and SAF could be implemented in the best or worst quality land of the LTS to simulate different management priorities. A total of five tree species were modelled: wild cherry (*Prunus avium* L.), black walnut (*Juglans* hybr.), poplar (*Populus* spp.), holm oak (*Quercus ilex L.* subsp. *ilex*) and stone pine (*Pinus pinea* L.). Up to two tree species were modelled for each LTS, according to an expert assessment of what would be most appropriate for each LU. Crop species were selected according to existing practice and included wheat, sunflower maize and oilseed. The Common Agricultural Policy (CAP) payments were modelled for arable and silvoarable systems assuming:
1. No CAP payments;
2. Pre-2005 CAP payments; and
3. Post-2005 CAP payments, assuming in the case of silvoarable systems that a Single Farm Payments would be made to the whole cropped area (whilst cropping occurred) and that 50% of tree costs would be covered for the initial four years of the tree rotation.

13.2.2 Agroforestry model development and application

YieldSAFE (van der Werf *et al*., 2006) was used to predict the long-term tree and crop yields for arable and silvoarable systems for each LTS, by using the relevant solar radiation, temperature, precipitation, and soil physical data developed for each location.

The framework developed by Palma *et al*. (2006b) was used to evaluate the environmental performance of SAF. Erosion was assessed by adapting the revised universal soil loss equation (Renard *et al*., 1997). Nitrogen leaching was estimated by combining the frequency of soil water exchange (Feldwisch *et al*., (1998) with a nitrogen balance computed according to equations developed by van Keulen (1982). Carbon sequestration was derived using the IPCC (1996) and Gifford (2000) relationships. A broad evaluation of the effects of SAF implementation on landscape biodiversity was based on the relationship between 'habitats' and 'non-habitat' farmland.

Time-series of annual production data developed using YieldSAFE and economic data for crop grants, tree grants, and revenue and costs for each LTS were combined in a farm-scale bio-economic spreadsheet model called FarmSAFE (Graves *et al*., 2006a). The economic performance of the arable and silvoarable systems was compared using the infinite net present value (iNPV) for a time-frame of 60 years (discount rate = 4%). As intercrop yields in silvoarable systems decrease over time due to tree growth, the crop rotation was optimised by replacing crop production by grassland when the five-year moving-average of the intercrop net margin was zero.

13.3 Continental scale

To locate target areas in Europe where there is a particular potential for SAF, we overlaid European datasets of:
1. arable landscapes;
2. regions of productive tree growth; and
3. regions where agroforestry can help to mitigate environmental problems (Figure 13.2 see page 94).

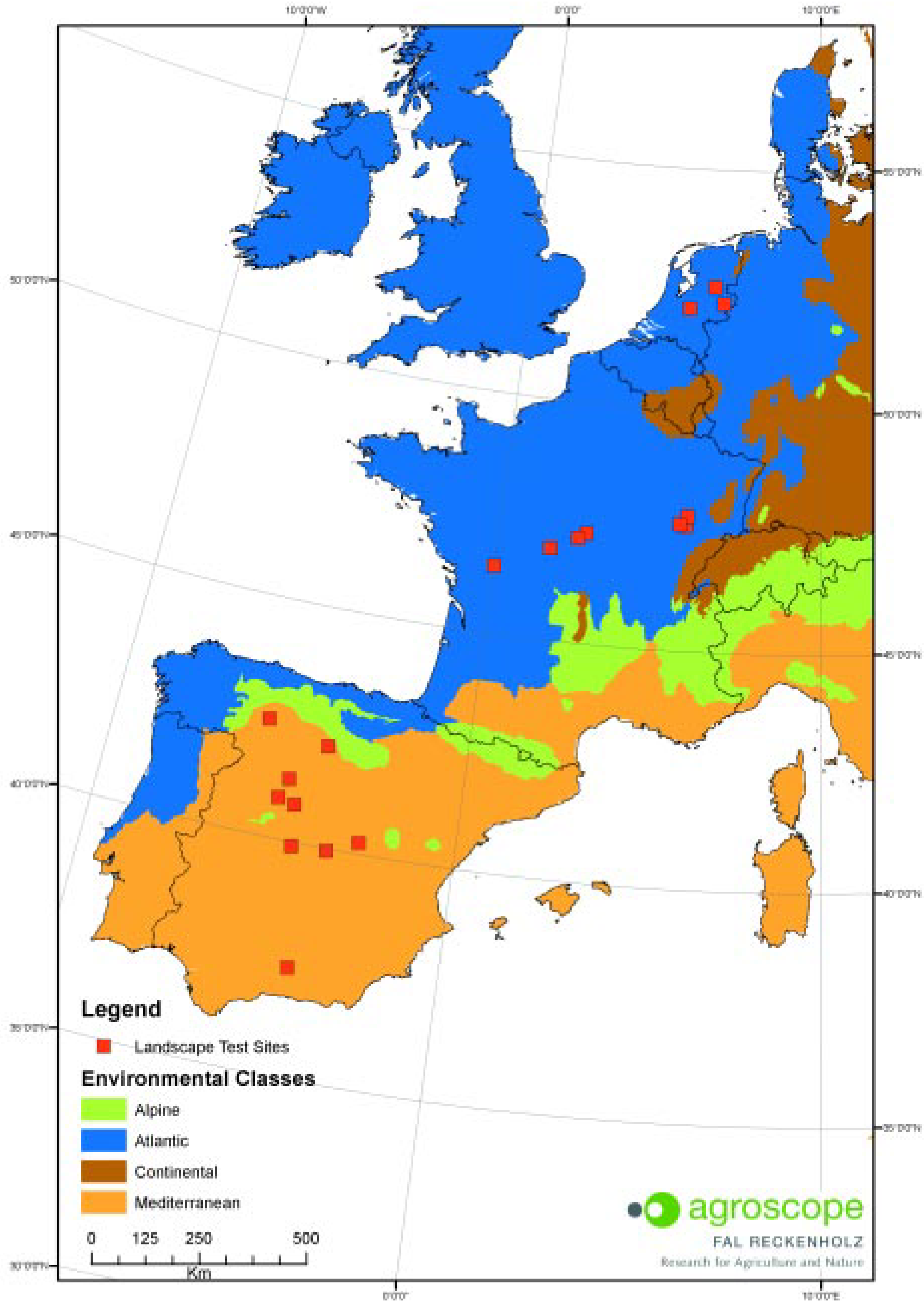
For a detailed description of this method, see Reisner *et al*. (2006).

13.4 Results and discussion

13.4.1 Effect of SAF systems at farm-landscape scale

The simulation showed that the environmental and economic effects of SAF were highly variable depending on the biophysical, management, and economic conditions in each LTS. However, the adoption of SAF systems generally led to reduced soil erosion and nitrogen leaching, and increased carbon sequestration and landscape biodiversity (Table 13.1 see page 94). The extent of these modifications depended on the severity of the problems and the SAF management options for each location. Environmental benefits were predicted to be highest when SAF was implemented on large areas (i.e. 50% of the farm) and on high quality land, where current agricultural practices were intensive and associated with high levels of soil erosion and nitrogen leaching. The environmental effects of different tree densities (50 or 113 trees ha^{-1}) were moderate because biomass production per tree was higher in the low density stands, therefore reducing the difference of the indicators on a per hectare basis. Even so, the reduction of nitrogen leaching was greater at high rather than low tree densities and per hectare carbon sequestration was still greater at high tree densities than at low densities. The effect on landscape diversity was greatest in

FIGURE 13.1. Selected landscape test sites in Spain, France and The Netherlands, based on the European environmental classification by (Metzger *et al*., 2005).



landscapes where agricultural monocropping was the predominant land use because few elements of ecological infrastructure existed in such areas (Table 13.1).

Economic predictions for the post-2005 CAP payments suggested that SAF with walnut and poplar in France could provide a profitable alternative to arable systems. In Spain, it appeared that holm oak and stone pine could be integrated into arable systems without substantially reducing arable production for many years (Figure 13.3). Since these trees are of ecological and landscape importance (Table 13.1), rather than productive importance, additional support in the form of an agri-environment payment could be justified.

As the environmental and economic results were assessed under the same biophysical and management conditions, they could be compared. Multicriteria decision tools (Brans and Vincke, 1985; Belton and Stewart, 2002) were applied to evaluate the land use scenarios under a neutral preference between environmental and economic criteria. A performance rank score was calculated based on an outranking approach (PROMETHEE) which summarises the pair wise comparison between all scenarios under all criteria (see Palma *et al*., 2006b).

The best scenarios were those in which SAF was implemented over 50% of the available area (Figure 13.4). The comparison with the 'no subsidy' scenario showed how well the arable status quo is supported by the grant regimes. This effect was also observed in some SAF systems when implemented on only 10% of the farm. In some cases, even the introduction of SAF on 50% of the farm was negatively affected by the subsidies. However in the post-2005 CAP there is a stronger support for introducing trees in the landscape. Nevertheless, irrespective of the subsidy scheme used,

FIGURE 13.2. A schematic representation of the use of thematic maps to derive target areas for agroforestry in Europe. Adapted from Reisner *et al*. (2006).

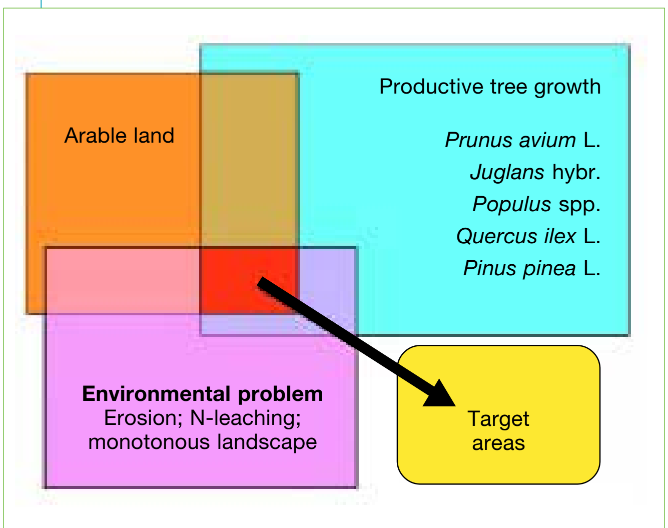


FIGURE 13.3. The difference in Infinite Net Present Value (discount rate = 4%; rotation = 60 years) between the arable status quo and silvoarable systems established at 50 (SAF50) or 113 trees ha^{-1} (SAF113), on 10% (10%SAF) or 50% (50%SAF) of the worst (W) and best quality land (B), assuming post-2005 CAP payments in which a Single Farm Payment is received for the total silvoarable area and 50% of tree costs are covered in the initial four years of the rotation. Developed from Graves *et al*. (2006b).

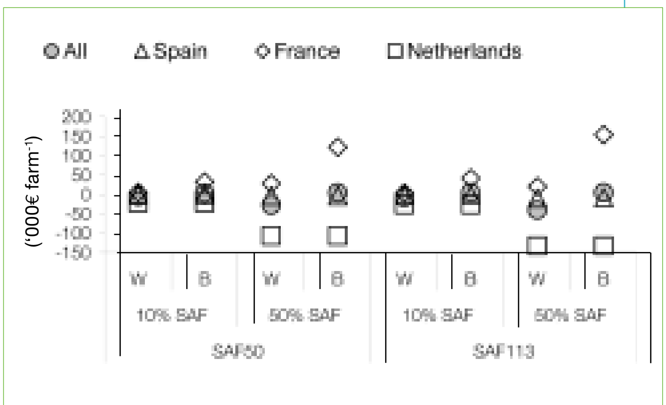


TABLE 13.1. Median of soil erosion, nitrogen leaching, carbon sequestration, and landscape diversity index (Ihab) for the arable status quo and for silvoarable systems established at 50 (SAF50) or 113 trees ha^{-1} (SAF113), on 10 (10%SAF) or 50% (50%SAF) of the worst (W) and best quality land (B). Average annual per hectare values for 19 landscape test sites over a 60-year tree rotation period. Developed from Palma *et al*. (2006a).

		Scenarios								
			SAF50				SAF113			
		A	10% SAF		50% SAF		10% SAF		50% SAF	
	unit	(status quo)	W	B	W	B	W	B	W	B
Soil erosion	t ha^{-1} a^{-1}	1.1	0.5	0.5	0.4	0.3	0.5	0.6	0.4	0.3
		(0–9.7)	(0–5.1)	(0–4.7)	(0–4.0)	(0–3.3)	(0–5.1)	(0–4.7)	(0–3.9)	(0–3.2)
Nitrogen leaching	kg ha^{-1} a^{-1}	37	37	37	36	36	36	36	33	33
		(0–155)	(0–151)	(0–151)	(0–140)	(0–136)	(0–146)	(0–146)	(0–118)	(0–111)
C sequestration	t ha^{-1}	0	3.4	5.1	18.9	21.8	4.9	6.9	28.7	32.1
		(0–0)	(0.2–69.4)	(0.5–69.4)	(3.3–138.8)	(2.5–138.8)	(0.4–83.7)	(1.1–83.7)	(7.1–167.5)	(5.3–178.9)
Landscape diversity	I_{hab}	16	24	24	58	58	24	24	58	58
		(1–81)	(11–82)	(11–82)	(51–90)	(51–90)	(11–82)	(11–82)	(51–90)	(51–90)

SAF performed better in comparison with the arable status quo in the integrated environmental and economic assessment (Figure 13.4).

In general, SAF provided the greatest environmental benefits whilst the arable systems provided the greatest economic benefits. The exception was France, where SAF provided both greater environmental and economic benefits than the arable status quo.

13.4.2 Target areas for SAF systems at the continental scale

The target area for SAF was found to cover 652,185 km^2 (Figure 13.5 see over). This implies that on approximately 40% of the arable land in Europe, it would be worthwhile considering to plant with at least one of the five tree species investigated here in combination with arable crops. Of these, 7% were found to be at risk from soil erosion (erosion rate > 5 t ha^{-1} a^{-1}), 34% were in nitrate vulnerable zones, and 59% had low diversity arable landscapes. For more details, see Reisner *et al*. (2006).

13.5 Conclusions and outlook

In order to provide a broad assessment of the effect of SAF, we had to balance modelling complexity, the number of indicators used and the geographic range of the study. The framework developed consists of a coherent approach to the integrated use of biophysical, economic, and environmental modelling tools at the appropriate spatial and thematic resolution. With this framework in place, the approach could be further improved by local validation of the input and output data. We believe that, beyond the application to agroforestry, the framework can be expanded to testing other alternative land-use systems such as new crops, agricultural energy fuel production, etc.

Silvoarable systems are complex, as there are many possible tree and crop arrangements, and implementation takes effect over a long period of time. Hence, general scenarios were investigated for the provision of general guidelines. However, many other scenarios are possible, investigating for example different tree species, densities and arrangement, crop sequences, phased implementation of SAF on the farm and changes in management strategy over time in accordance with tree growth. All these options can be explored with the modelling approach and tools presented here.

Many factors such as risk, land ownership, family situation, and farmer's age can affect the choice of the most appropriate SAF system. Our simulations indicate that SAF would often yield similar levels of profitability as conventional arable systems if there were no subsidies. However, under the pre- and post-2005 grant regimes, with the exceptions mentioned for France, the profitability of conventional arable systems was increased relative to SAF. As a consequence, under current payments, the uptake of SAF, if based on profitability alone, will be restricted to specific systems such as those examined in France, with high value walnut timber or fast growing poplar.

In Europe, SAF target regions covered approximately 40% of arable land. On a considerable amount of land, the introduction of SAF could thus contribute to mitigating some of the major environmental problems of agricultural land use-erosion, nitrogen leaching, poor landscape structure related to low biodiversity. SAF could also make a modest contribution to carbon sequestration. If other tree species were included, the target area for SAF would even increase. For example, coniferous species could be investigated for the boreal zone. Still, it must be stressed that the analysis also revealed the limitations of SAF. The natural and socio-

FIGURE 13.4. Performance results (□) of the different scenarios in the multicriteria decision analysis assuming equal weights for environmental and economic indicators, three different payment regimes, and for silvoarable systems established with 50 (SAF50) or 113 trees ha^{-1} (SAF113), on 10 (10%SAF) or 50% (50%SAF) of the worst and best quality land; post-2005 CAP scenario accounting for payments to the whole area and 50% of tree implementation costs in the first four years. For details see Palma *et al*. (2006b).

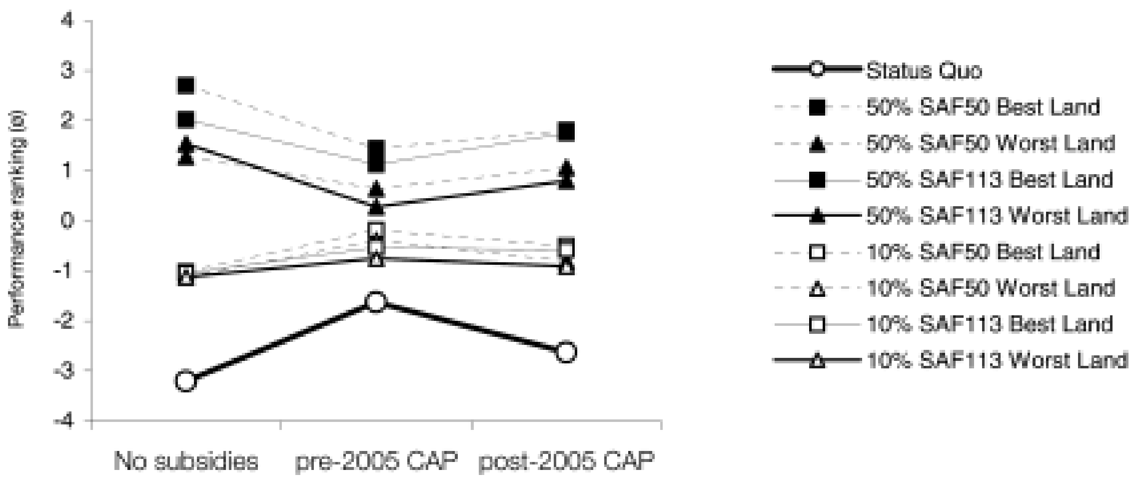
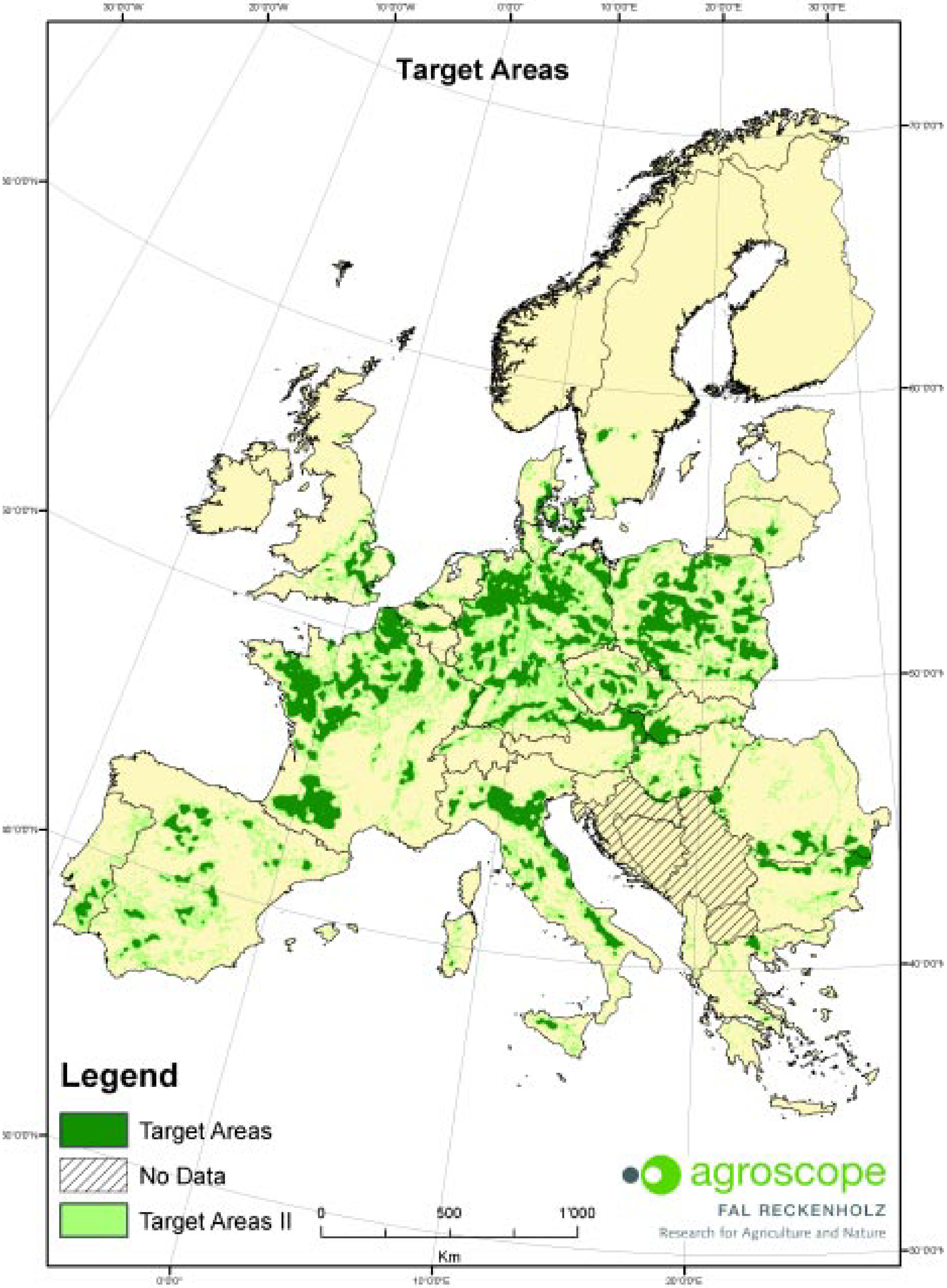


FIGURE 13.5. Target areas (I: aggregated, II: scattered) for silvoarable systems in Europe. Source: Reisner *et al.* (2006).



economic conditions need to be carefully evaluated before SAF is implemented.

The approach and tools developed were applied in an integrated environmental and economic study designed to allow for an assessment of trade-offs between different indicators. From the results, it appears that SAF justifies similar, if not greater, public support, than what is currently provided for conventional agricultural production.

With the recent CAP Reform strengthening the emphasis on environmental performance and sustainable use of natural resources (EC, 2005), SAF could play an important role since growing trees and crops in combination in SAF at the selected LTS was found to be more productive than growing them separately in arable and forestry systems (see Graves *et al*., 2006b). However, many challenges in modelling and promoting SAF will need to be met if agricultural landscapes in Europe are again to benefit from the presence of widely-spaced trees.

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14. An approach for sustainable and productive water catchments – the example of the Wethau-catchment (Saxony-Anhalt, Thueringia)

Christian Hildmann
(Corresponding author: Ch. Hildmann, email: Christian.Hildmann@geo.uni-halle.de)

Abstract

The landscape provides many fundamental functions to society, like the renewable resources. However, the anthropogenic impact caused the landscape to be again more dynamic and puts its functionality at risk. Based on the water budget, some suggestions for the Wethau catchment are derived. Newly introduced woody plants and wetlands should both improve the ecological functions and produce notable yields.

Key words
sustainable development, land use planning, water budget model, evapotranspiration, water and matter cycles

14.1 Introduction

Today, the densely populated and cultivated area of Central Europe is already multifunctionally used, since society demands several essential services: clean drinking water, balanced water budget, a tolerable climate, and good soil fertility for the production of healthy food. For the further development of the landscape two aspects, apparently moving in opposite directions, are to be considered compellingly:

1. The landscape is to be managed sustainable, i.e. its physical composition is to be preserved. However, up to now particularly the agriculturally dominated landscape is characterised by serious material losses. Apart from erosion, the dissolved salts transported with the running waters are to be mentioned. The amount of total salt losses is usually more than 1 t ha^{-1} (Hildmann, 1999) and not compensated by agricultural fertilisation. Due to the close interactions between water budget, soil, transformation of energy, and vegetation the ability of the landscape to function, and thus the physical basis of the society, are called into question by this creeping process.
2. The finite fossil sources of energy will have to be replaced nearly completely within the next 40 years by renewable sources, increased by the worldwide rising demand. Most of the management depends on this fossil energy, e.g. for the cultivation of a field about 100 litres of diesel are often needed per year and hectare. Beyond that, the oil processed by the chemical industry (e.g. for plastics) is to be replaced to a large extent with refined biomass. The landscape will be used again more intensively, a competition between the cultivation of renewable raw materials and food production is probable instead of set-aside land and agrarian surplus.

To complicate the task, landscape is not static but always a dynamic process. Sometimes this is forgotten, e.g. when talking about nature conservation or about reconstruction of old river meanders. Nature itself has a more self-organising process than any structure. The development starting after the last ice age has been demonstrating the power of this self-organising process. Vegetation started to cover the landscape again, matter losses from land to water have been reduced, and the regional climate changed due to increased evapotranspiration.

Today human (mis)management makes the landscape again more dynamic and jeopardises its functionality which is essentially needed by society.

The term multifunctionality reflects the demands of society for functions of the landscape. The overall aim should be a more adapted land use planning or, taking the demand for landscape products like clean surface water or renewable energy into account, an integrative resource planning. The dilemma consists of the limited load-bearing capacity of the environment and the virtually unlimited demands of society. Because landscape is the physical base of society, it is not negotiable as long as sustainability should be achieved. Therefore, three conceivable functions should be sorted hierarchically:

1. the ability of the ecosystem to function is to be protected and/or repaired: the maintenance of the material equipment of the landscape, their capability to dissipate the solar energy and their capability for self-organisation;
2. the vitally important uses for the society are to be ensured: balanced water budget, clean drinking water, maintenance/rebuilding of soil fertility, tolerable climate, healthy food;
3. further desirable requirements can be realised according to the remaining degrees of freedom: recreation, maintenance/improvement of the natural scenery, further demands of society.

This contribution will present some selected results from the research about the Wethau catchment and gives an idea of how a sustainable Wethau catchment could look like.

14.2 Wethau catchment and methods

To study more in detail how a sustainable managed landscape can look like, the example of the Wethau catchment area is introduced. A water catchment is chosen because of the unity of water and matter flow (most of the matter and water flow is directed to the outlet of the catchment).

The river Wethau flows below the city of Naumburg into the Saale River, the catchment area covers 238.7 km^2. Particularly on the plateaus dominate large fields (arable land: 62.1%); only in the southern headwaters follow forests (forest: 7.1%). Along the river Wethau and its feeder streams is a still richer landscape inventory with meadows (grassland: 16.6%), copses, orchards (copses etc.: 10.4%) and so on. Settlements include about 3.2%.

Especially in the south of the catchment very fertile soils are found, e.g. chernozems, eutric podzoluvisols, or eutric cambisols. Northwards they turn into less fertile soils like rendzic leptosols or spodic luvisols.

The upper catchment in the south is located in Thueringia, while the northern part belongs to Saxony-Anhalt. Population density is low with about 87 people/km^2. Industrialisation had already started in the 18th century in the Wethau-catchment with brown coal extracted from pits. Apart from some sand and gravel pits, today nothing remains in operation and agriculture dominates the landscape.

For a first investigation of the catchment, available data of runoff, water quality, soil data, population, and others were collected from the authorities and analysed. Since a key function is attached to the water budget, a spatially high resolution model was developed. As input parameters serve among others an elevation model, soil data, the current land use from satellite images, and daily data of climate. The model was written from scratch with FreePascal, of course with recourse of the formulas of other models, especially Wasim-ETH (Schulla, 1997) and SWAT (Neitsch *et al*., 2002). As a result, parameters can be estimated, e.g. real evapotranspiration, surface discharge, or groundwater recharge. By this, it is possible to evaluate the prospective effectiveness of measures and to locate them better, e.g. hints can be derived where riparian buffer strips are useful and where their width is to be adapted. Also scenarios like the expansion of forests can be calculated.

14.3 Results of catchment analysis

Corrected rainfall and run-off data show the importance of the water cycle. Precipitation from the year 1996 to the year 2000 is about 644 mm/a (4.183 m^3/s at the water level indicator at Mertendorf, about 204.9 km^2), with an increasing precipitation amount from north to south. Run-off at Mertendorf is 0.6532 m^3/s or 100.5 mm/a (mean 1996 to 2000). Apart from groundwater flow, which was not measured, and storage change, which can be neglected over five years, there is 6.4 times more precipitation than run-off. That means, statistically only a small amount of water is needed to drive the water cycle due to the importance of the evapotranspiration process. Taking into account that a part of 56% (or more) of the run-off is fed from ground water (base flow according to Neumann, 2005) with a larger residence time, evapotranspiration becomes one of the key factors of the landscape budget.

Based on measurements of water quality, an estimation of the soluted matter loss transported by the river Wethau was carried out. About 1,550 kg ha^{-1} total salts are leached from the catchment (about 283 kg Ca ha^{-1}, 57 kg Mg ha^{-1}, 13 kg N ha^{-1}). The stock of base cations and nutrients of the loess soils are high, e.g. about 425 t Ca ha^{-1} (related to the more fertile soils in Saxony-Anhalt).

High matter losses indicate disturbed ecosystem processes and can be interpreted as entropy of the landscape system. This missing functionality is based on incomplete dissipation of solar energy by water and biological cycles. Higher soil temperatures for example increase mineralisation of organic matter as far as water is available. Therefore, high surface temperatures of the landscape at day indicate incomplete dissipation of solar energy and missing functionality. Data from Landsat 7 (band 6) were used to evaluate surface temperature in the Wethau-catchment (following temperatures: mean temperature, 4 September 1999). As expected, surface temperature of open land, like arable fields (25.1°C) or grassland (23.4°C), are clearly warmer than forests or copses (20.4°C).

These differences can be proved by comparing fields and forests but as well as by comparing pine and beech forests. Evaporation and transpiration from the sites are main factors for these differences. Therefore, water budget and water cycle represent a key factor.

The presence or absence of vegetation in the landscape is not only an aesthetic question. This is emphasised by the significance of evapotranspiration, cooling vegetation during daytime.

Evapotranspiration was calculated with the derived water budget model for one year. The results show clear differences between the land cover types but also between different sites. The calculated mean evapotranspiration values for 1999 in mm/a are: gravel pits 371, arable land 442, grassland 456, settlement 481, deciduous forest 554, coniferous forest 628 and wetlands 716.

During most rain events, no surface (or near surface) flow is observed in the model run due to the high water storage capacity of the upper soils. However, when clearly more rain is falling during one or cumulatively during more days, the model predicts surface flow occurring at a lot of sites (Figure 14.1). The model shows flow routing, too. Even the water budget model did not calculate erosion, surface flow on arable land will trigger erosion in most cases.

14.4 Discussion

The presented results already show the dynamics of landscape processes at the Wethau-catchment. The high amount of soluted matter losses is not unique which can be shown with the detailed study of the river Stör (Ripl *et al*., 1997) or with a comparison of about 120 German catchments (Hildmann, 1999). In most recent publications, soluted matter losses are discussed only for special sites like karst or salt deposits. Even Aurada (1981), who compares the chemical erosion of catchments worldwide, gives priority to geology and direct anthropogenic discharge from salt exploitation. But in fact, the leaching process starts at the topsoil because the energy to lower the pH-value of the water and to solute salts seeps from the surface into the soil and underground. Increasing pH-values from upper to lower soil up to the neutral pH-range are frequently observed. More than acid rain, the mineralisation of organic matter releases acids (like nitric or sulphuric acid). For the uptake of base cations the plant roots release protons as well (cation exchange). Readily soluble base cations buffer the acids and are washed out together with other nutrients. Missing base cations can contribute to the acidification of the soils.

The process itself is absolutely natural, but the balance between releasing nutrients and base cations on the one hand, and the uptake by the vegetation on the other hand is out of order.

Catchments in Norway that are nearly without human influence or a recent virgin forest in Austria demonstrated significantly lower matter losses.

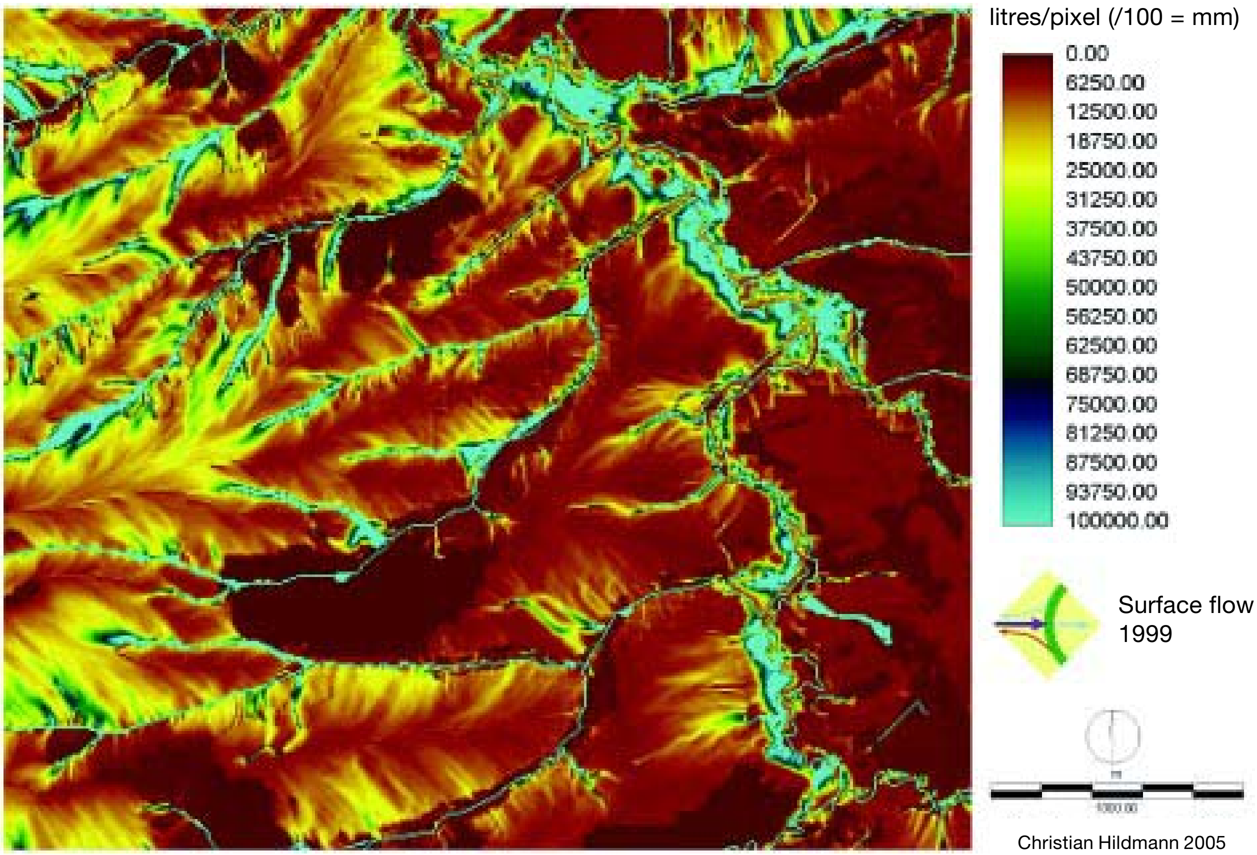
Besides increased soil temperature amplitudes, soil water fluctuations are often increased by drainage or management. Changing phases between wet and dry conditions increase the mineralisation process of fungi and bacteria (Ripl *et al*., 1997). And last, but not least, both agricultural and forested land is managed by high net productivity taking away base cations without closing the cycle again.

Leaching the base cations will also change the soil properties. One example: If the base cations are washed out, the substances harder to solute remain, like sand, not usable by the vegetation, or heavy metals – not recommended for plant or human uptake.

However, the high losses are practically irreversible and are not compensated by the use of fertilisers (Hildmann and Janssen, 2001). There are some recommendations of the agricultural research units, but the fertiliser statistics shows that the farmers do not care about it. Base cations can be released by weathering of the stones, but this process is too slow for compensation. In the mid to long-term soil fertility might be decreased.

Comparing soluted matter losses to the actual storage, the loss process seems to be harmless. But first the stock of base cations is not distributed equally. For example, glacial shaped sandy soils, like in the north of Saxony-Anhalt or in Brandenburg, have only a fraction of

FIGURE 14.1. Surface flow, calculated for 1999 (accumulated). A detail of the Wethau catchment is shown.



base cations compared to the northern Wethau catchment. Especially on the top of mountains or hills or at very steep slopes, the stock of base cations is decreased, if not depleted. Forest decay is often linked with a reduced availability of base cations and lowered pH-values buffered only by aluminium or even iron. Second, the loss process could not be extrapolated linearly. Reduced availability of base cations at the upper soil will increase the plant root activity for cation exchange. Affected areas may spread out non-linearly because of their increasing borderline. Third, the calcium losses correspond more or less to the total amount of calcium in 120-year-old beech forest (above ground). It should be our responsibility, also to conserve the privileged equipment areas like the Wethau catchment.

14.5 Conclusion: a view to a sustainable catchment

Keeping the loss process in mind, we can make the term of hard sustainability a little bit more precise. A sustainable management needs to conserve at least the physical condition of the sites and the landscape as a basis for vegetation and man. An increase in the floristic and faunistic diversity will contribute positively since they make the processes of self-organisation possible.

For further optimisation, the prevailing conditions would have to be set on a long-term basis in a way, that self-organisation processes are triggered both, on the landscape and on the social level.

The determining processes of both, the water budget and the transformation of energy are area-dependent processes. That means, suggestions to solve the problems must consider the total area. In addition, productive land use is needed to supply the people with food and renewable resources. Two types of land cover are especially useful. Both, woody vegetation and wetlands can be types of productive land use and further the landscape budget is positively influenced: the retention of water, nutrients and material, the improvement of the local climate and so on, is to be mentioned.

In detail, it is suggested to plant woody vegetation to a larger extent which is also adapted to the site conditions. There are some sites which are too steep for a sustainable agriculture (slope inclination > 10°). Afforestation with tree species adapted to local conditions is recommended. As an alternative, these sites could be reshaped into terraces (Holzer, 2004). Further sites are endangered by erosion and leaching, but they have less steeper slopes (5–10°). It is proposed to reduce slope length with rows of trees or hedgerows oriented to the contour lines. This trees and shrubs should be used for agroforestry to preserve a considerable yield (Herzog, 1998). The advantages are, for example product diversification, retention of water, increased transpiration, and control of soil erosion. If the rows of trees are oriented to the contour lines, it is necessary to cultivate the fields with contour farming. Up to now, contour farming in Germany is insignificant, but at Wethau-catchment with its large field sizes it would be highly recommended.

The produced wood from agroforestry can be either used for timber industry or can contribute to the energy supply. Further, the production of energy wood and the advantages of wetlands can be coupled with wet short rotation plantations. They can contribute to retain water and base cations from surface flow or from small surface waters. Beyond that application, they can be used for purification of wastewater from the villages (Perttu and Kowalik, 1997). Wastewater from households is a good fertiliser for short rotation plantations with willow or poplar.

Often, the Wethau brook is carved for more than one meter in the landscape, indicating that former wetlands are drained and removed. Their functionality is missing now, and why not re-establish wetlands again? Riparian buffer strips or reed polders cannot only contribute to species diversity, they can also be used to produce biomass as a resource for energy or further processing.

Surface flow induced by heavy rain should be retained as much as possible in the upper parts of the catchment before the water reaches the outfalls. A coppice or even a riparian buffer strip is not able to retain the water due to the high amount of water during these events. Therefore small hollow reservoirs are proposed, located near to the origin of surface flow. Suitable sites could be derived from the water budget model and, with respect to the water flow, should be located beside cart tracks and roads. The hollow reservoirs can be used as pasture, meadow or can be planted with tree species, if they tolerate occasional flooding.

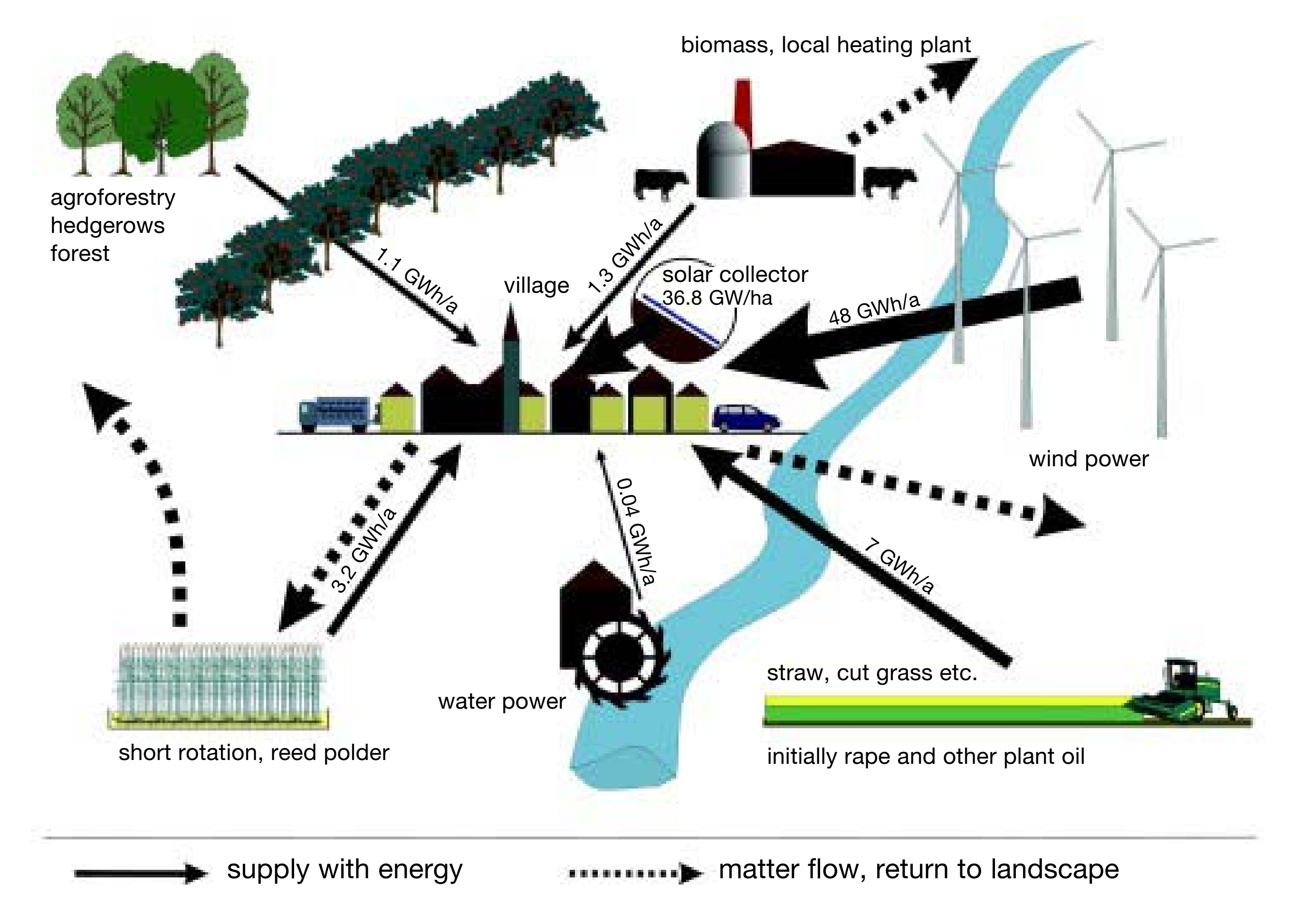
Further modules are raised fields, aquaculture coupled with agriculture, watered meadows, the use of wastewater from households, and a lot more. Basic ideas are to increase landscape functions and to couple processes instead of linear thinking.

Sustainable land use and energy supply is possible. We did some detailed research for one subcatchment of the Wethau, the Steinbach-Catchment. In short, there is a potential for renewable energy of two and a half of the actual need in the catchment (Figure 14.2). This example shows, how much rural areas can contribute to the energy supply or urban areas. The calculations are based on a sustainable use of this catchment, not of an overexploration, for example of the soils.

Today, landscape is often structured by the boundaries of the properties. Measures to improve, for example nature conservation are often oriented towards these boundaries. Unfortunately, all natural processes like water flow do not consider property boundaries.

To locate management modules like constructed wetlands, grassed waterways, or protective forests most effective, the water flow in the landscape is a very important factor. The water flow results from the

FIGURE 14.2. **The potential for energy supply of the Steinbach catchment (27.4 km², a tributary to Wethau) based on renewable resources (Hildmann and Liese, 2005).**



interaction of topography, vegetation, soil, etc. Because of this, the spatially high resolution water budget model can help for the placement and local adaptation of modules.

First of all, suggested land use changes indicate where restrictions of the actual land use are sensible. For this purpose, map derived data like surface flow, slope, hilltops, and areas suitable for wetlands are used.

These suggestions may be modified for areas with restrictions, if another sustainable module can take on their functionality, for example, very steep fields can be managed sustainable, if they are converted into terraces.

Finally, it is not necessary to plan the land use in addition to these restrictions too much in detail. Self-organisation can take effect also at the level of the farmers. The question for example, if they should produce regenerative energy or food can be left to the market demand. Ideally, there is also a market for clean surface water. Then every farmer and forester can act as water landlord and earn directly money with sustainability. However, the demonstrated planning tools should be used to improve the quality of landscape planning and plans introduced by the EU Water framework directive.

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15. Exploring new landscapes: what are the main factors affecting greenhouse expansion process in the Mediterranean coast?

Alberto Matarán Ruiz, Francisco Aguilera Benavente and Luis Miguel Valenzuela Montes
(Corresponding author: A. Matarán Ruiz, email: mataran@ugr.es)

Abstract

The aim of this article is to present a predictive model of greenhouse's growth based on logistic regression on the coast of Granada (Spain). This model of growth has been put into practice in three landscape units from 1990 to 2003. It investigates the identification of the main elements that affect this territorial process. This investigation pretends to be the base to transfer a new guideline to reduce the environmental impact related to the greenhouses in this zone.

Key words
Greenhouses, changes in the land use, diffusion factors, logistic regression, Mediterranean

15.1 Introduction

The Coast of Granada is located in the South East of Spain. In this area, as well as in the rest of the Mediterranean coast, the use of land for agricultural purposes and the consequent anthropisation have historically been very important (Fernández Ales *et al*., 1992). However, the changing process in land use that has occurred during the last 50 years is well known (Matarán and Valenzuela, 2004). Nevertheless, the greenhouse growing process is, undoubtedly, a new type of territorial transformation. It is mainly the result of the very successful initiatives carried out by the local producers. Greenhouses are very profitable thanks to the climate conditions that make a year-round (non-seasonal) production possible (e.g. this is the most important area that produces cherry tomatoes in the world). This new agro-industrial land use causes dramatic landscape changes, consumes high quantities of resources, and produces several waste fluxes (Matarán, 2005).

As well as in many previous research studies related to urban expansion (Antrop, 2000; Stefanov and Christensen, 2001), in this article we present an ex-post predictive analysis of greenhouses on the coast of Granada, on the basis of the spatial and temporal description of greenhouse dynamics between 1990 and 2003. We have developed an applied predictive model based on logistic regression in order to understand why, where and how the greenhouse phenomenon is increasing in the Mediterranean. Our main objective is to describe the most important factors taking part in this complex process. The results we present in this article might be the basis for a more up-to-date model aimed to overcome an unsustainable situation through new planning and management criteria.

15.2 Area of study

The coast of Granada is a 71 km-long coastline with a particular landscape: several deltas, full of hills, and huge slopes. The distance from the sea level to 1,000 metres would be just 10 km in a straight line and the highest mountain of the Iberian Peninsula (Mulhacen Peak, 3,482 m.) is only 30 km away from the sea.

This situation reduces the influence of the northern winds, which results in a subtropical microclimate unique in Europe and suitable for both, subtropical farming and greenhouses. The average temperature is 17'6 ºC (12'4 ºC in January and 24'3 ºC in August) and nights below 0°C are unusual. In addition to these good conditions for agriculture, there are an average of 3,000 sun hours per year, 138 cloudless days and 60 rainy days (Frontana González, 1984).

Our study area is constrained to a section of the coast of Granada that is occupied by greenhouses. As it is shown in Figure 15.1 (see over), three small landscape units have also been observed in order to improve the accuracy of the model.

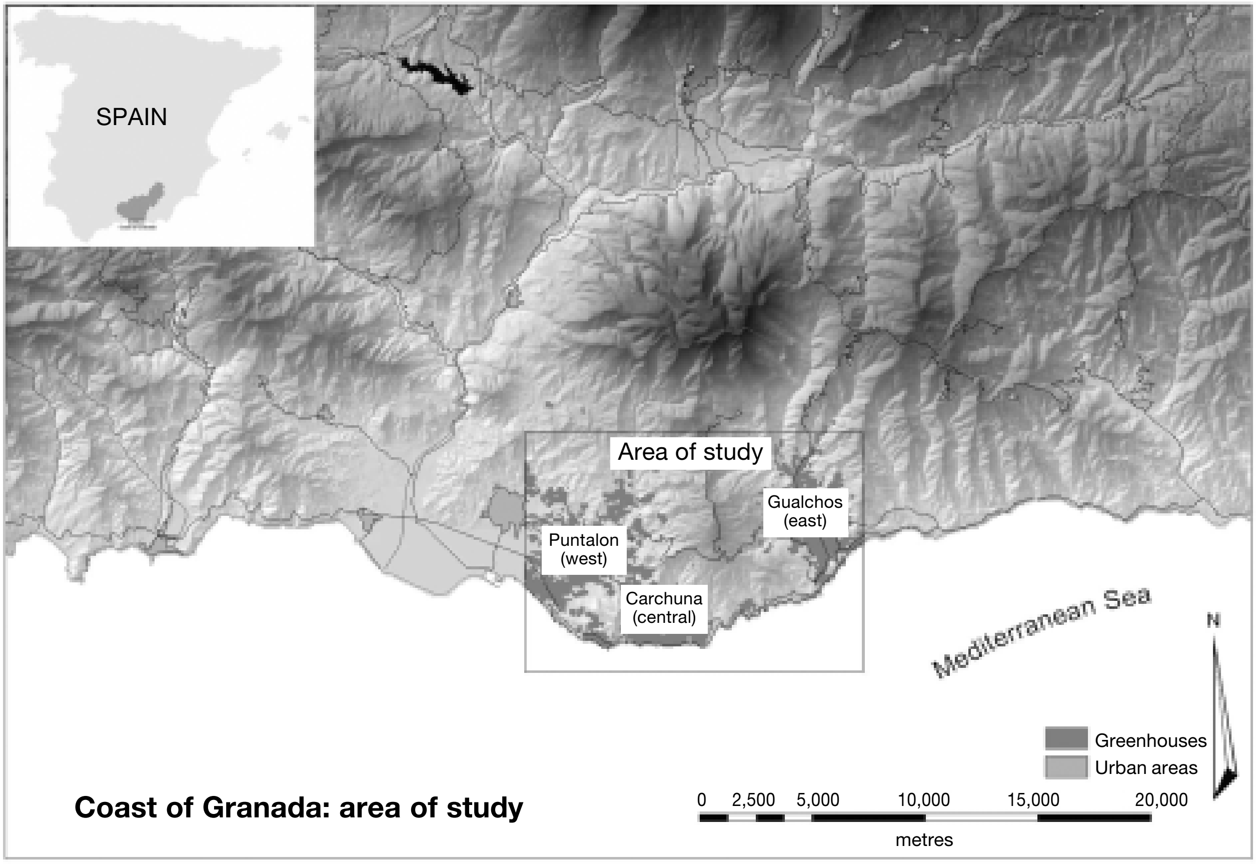
15.3 Territorial interpretation of the evolution of agricultural landscape and land use

In order to understand the current process, a historical analysis of agricultural landscape transformations on the coast of Granada is necessary. The three main steps in the agricultural development of this area are explained in the following paragraphs:

First step: increase and decrease of sugar cane
The sugar cane was introduced in the tenth century, and it meant the most important territorial transformation of the coast of Granada (Malpica, 1993). At the middle of the 17th century there was an important increase in sugar cane cultivation surface. However, it was followed by a great decrease at the end of the century caused by the introduction of sugar from America and Asia. At that time cotton started to substitute the sugar cane. After the creation of the first mechanic factory to treat the sugar cane, in 1845, sugar growing began to increase. It remained the main crop until the arrival and expansion of subtropical trees and greenhouses in the 1980s. Nowadays, it is in a non-return disappearing process (ESECA, 1998).

Second step: development of subtropical agriculture
At the same time as greenhouses increase in number,

FIGURE 15.1. The coast of Granada: study area and landscape units.



local farmers carried out one of the many attempts to introduce foreign crops: subtropical trees. Avocado and cherimoya are successfully planted in the Guadalfeo Delta and in the western part of the coast (ESECA, 1998). This is the only subtropical tree farming in Europe, including the East coast of Malaga that still remains at a commercial level. . The beautiful and all year long green landscape is unique in Europe and highly regarded by tourists (Calatrava Requena, 1994).

Third step: greenhouse development

On the coast of Granada, greenhouses appeared in the 1970s. after innovations took place on the west coast of Almeria. They were set up on strategic important points on the coast of Granada. The technology used for planting was based on traditional structures (*parrales*). Nowadays, there are many other structures (tube, curved, etc.) that achieve higher efficiencies (Hernández *et al*., 1998). Different kinds of plastics are used as cover material to create a passive control of the environmental conditions inside the greenhouse and all crops use dropping irrigation (Hernández *et al*., 1998).

Greenhouses are a type of agro-industrial activity, which is the main economic source on the coast of Granada. Its fast development has overcome the response capacity of public administrations and there are not many planning or management measures concerning this new activity that is producing great environmental impacts (Matarán, 2005). It demonstrates the importance of analysing the greenhouse expansion process and the main factors that take part in it in order to create new planning and management measures to overcome this situation.

15.4 Materials: producing the greenhouse cartography

In order to comply with the objectives of this research we have developed the greenhouse cartography for the years 1990 and 2003.

1990: It is based on the satellite image Landsat TM. We applied a non-supervised classification using the ISODATA (Chuvieco, 2002) algorithm. We have also compared our results with the land use cartography of the year 1991 (Consejería de Agricultura y Pesca, 1991). Considering the extraordinary expansion process that has occurred in the last decade of the 20th century, we have chosen 1990 as the initial year. It assures the accuracy of our cartography.

2003: It is mainly based on Landsat ETM+ of January 2003 satellite image. We have also compared the resulting map with the digital cartography of Andalusia at a scale of 1:10.000 (Consejería de Obras Públicas y Transportes, 2003), with the data of the Master Plan of

Motril (Ayuntamiento de Motril, 2003), and with several field inspections.

15.5 Methodological approach to the spatial diffusions of greenhouses

There is an important degree of uncertainty when we are analysing a complex process such as greenhouse expansion because it is influenced by many factors that belong to environmental and human complex systems. However, we have tried to describe the areas that have the highest transformation probability by means of the logistic regression. With this method we have established the value of the different variables that have been considered to influence this phenomenon in an extensive study made by Matarán (2005).

15.5.1 Explicative variables

We have included the following group of environmental and spatial factors considered to be the most influential ones in the greenhouse development. They have been mapped at a range of 0:255 according to their suitability for the setting up of new greenhouses, so those areas which have revealed the highest suitability show higher values.

Land uses: This factor represents the importance of previous landscape structure and growing pattern. From the 1970s until now, traditional irrigation in the planes and dry crop farms in the hills have been substituted by greenhouses (Figure 15.2). Nevertheless, subtropical farms have held out this dynamic thanks to their profits and moreover, thanks to their landscape value for residents and tourists.

Distance to greenhouses: It represents the 'landscape inertia' and the diffusion process which characterises this phenomenon. In this way, the closest areas to greenhouses show a higher probability of being occupied by new installations.

Distance to central places: The 'central areas' are the centres for commercial purposes and provision of services for farmers. Places far away from these centres present, *a priori*, more problems to the setting up of new greenhouses.

Distance to roads: A greater accessibility facilitates the expansion of greenhouses as it reduces the costs for building new lanes for the setting up of greenhouses and it also facilitates the access to merchandising centres.

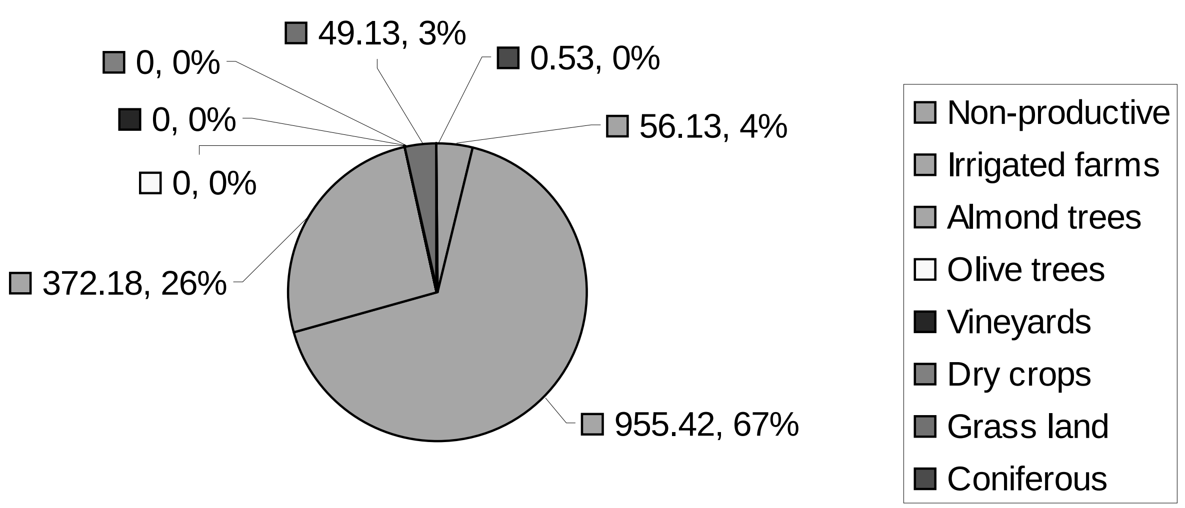
Distance to hydrographical net: A greater distance to the irrigation channels increases the costs of the irrigation. This means that areas far away from them are not very suitable for greenhouse use.

Topography: As height above sea level increases, suitability for greenhouse planting decreases due to the drop in temperature and the rise in irrigation costs. Slopes: the setting up of new greenhouses in high slopes implies greater costs whereas areas with low slopes decrease the costs.

Orientation: It is related to sunlight and temperatures. North orientated greenhouses have less suitability as there are lower temperatures, fewer sun hours, and less marine breeze.

Protected areas: In Natural and National Parks, it is forbidden to build greenhouses. This means that these

FIGURE 15.2. Contribution of land uses from 1977 occupied by greenhouses in 2000.



protected areas act as a barrier to stop the growth of greenhouses. However, as we state in the article, in local protected areas we have found less control.

As a complement to these factors, we have used an analysis mask. It means that we have excluded those areas with no potential for greenhouse growth: the roads, the coastline, and the urban and building areas, as well as the areas which were already occupied by greenhouses.

15.5.2 Logistic regression model

We have used the spatial logistic regression method in order to evaluate the correlation of explicative variables and to implement an ex-post simulation for greenhouse growing from 1990 to 2003. This method has been used to describe urban growing processes by Cheng and Masser (2003) and Aguilera (2005), so it could be useful for an agro-industrial activity with many urban-like characteristics, such as greenhouses (Matarán, 2005).

The IDRISI (Kilimanjaro version) is the software program we have used to implement this model as well as to analyse and evaluate the results.

The method evaluates the degree of correlation between an independent binary variable (greenhouse expansion) and a group of independent factors or variables (explicative variables).

The equation of the model is the following:

$$ln\frac{P}{1-P} = \alpha + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n \qquad (1)$$

P represents a probability of an event (a pixel transforming to greenhouse); between x1 and xn we have the different explicative variables; and α and β are the coefficients estimated by the logistic regression method.

As a result of the logistic regression, we have obtained an image with the change probability considering both the described variables and the statistic value ROC (Relative Operating Characteristic) that measures the degree of correlation between dependent and independent variables (Gil Pontius and Batchu, 2003). The ROC value is based on the efficiency in the assignation of pixels to the category greenhouse. Considering the explicative variables and using a double enter table (15.1), the ROC is comparing the real situation and the predicted situation for each pixel of the image. In our case, any variable could assign the same number of pixels with value 1 as in the real situation in order to avoid any errors in the growing dynamics.

On the basis of this table we could define the sensitivity (S), as the proportion of pixels identified as positive by our model (predicted greenhouse growth) and the pixels that have really changed.

$$S = \frac{a}{a + b} \qquad (2)$$

At the same time we could define the specificity (E), as the proportion of pixels identified as negative by our model, but where there has been a greenhouse growth.

$$E = \frac{d}{c + d} \qquad (3)$$

Finally, the efficacy index ROC has values from 0 to 1, taken into account that values less than 0.5 indicate a low degree of correlation, while values next to 1 indicate an acceptable adjustment between the independent and dependent variable.

15.6 Results

In view of all the described variables in the whole area, the results obtained in a first attempt to understand the process, are represented in Table 15.2. There are some variables, such as orientations, with a high sensitivity (a high% of goals in the dynamic areas), but this is due to a low degree of specificity (a high% of misses in the stable areas). It finally leads to a low ROC. According to this value, topography and distance to greenhouses are the most influent variables.

We have made a prediction of greenhouse growth from 1990 to 2003. We have selected the pixels that could change according to the following image of change probability (Figure 15.3 see page 110).

We have also used cross tabulation to compare the results of our prediction with the real growth. The kappa index shows a low degree of coincidence between the predicted situation and the reality.

TABLE 15.1. ROC value.

		Real Situation		
		Negative (0)	**Positive (1)**	**Total**
Prediction	Negative (0)	True Negative *a*	False Negative (Omisión) *c*	a + c
	Positive (1)	False Positive (Comisión) *b*	True Positive *d*	b + d
	Total	a + b	c + d	a + b + c + d

TABLE 15.2. Results for the whole study area.

VARIABLES	ROC	Specificity	Sensibility
Topography	0.8555	93.86 %	32.46 %
Distance to greenhouses	0.8355	93.81 %	34.18 %
Distance to centralities	0.8299	94.24 %	32.14 %
Slope	0.7982	91.98 %	38.82 %
Land Use	0.7257	55.97 %	70.95 %
Distance to roads	0.6291	77.39 %	29.39 %
Distance to hydrographical net	0.6106	92.40 %	20.47 %
Protected areas	0.5601	47.94 %	53.44 %
Orientation	0.5302	9.50 %	96.53 %
Total	**0.8999**	95.13 %	42.29 %

TABLE 15.3. Results for each of the landscape unit.

	ROC			Specificity			Sensibility		
VARIABLES	P	C	G	P	C	G	P	C	G
Topography	0.7121	0.7968	0.8541	83.89 %	90.88 %	92.64 %	33.94 %	29.01 %	34.43 %
Distance to greenhouses	0.6669	0.7381	0.7952	85.26 %	90.41 %	92.52 %	36.30 %	41.54 %	29.21 %
Slope	0.7162	0.7578	0.7398	84.03 %	90.15 %	92.84 %	39.10 %	32.75 %	24.40 %
Land Use	0.6703	0.6001	0.5981	81.44 %	74.61 %	27.84 %	47.45 %	42.76 %	91.81 %
Distance to roads	0.5014	0.5900	0.7096	64.60 %	72.48 %	86.04 %	31.82 %	28.82 %	25.30 %
Distance to hydrographic net	0.6040	0.6001	0.5909	83.92 %	89.07 %	92.53 %	30.25 %	18.68 %	23.21 %
Protected areas	0.5274	0.6569	0.5507	49.41 %	47.53 %	61.88 %	50.17 %	83.64 %	49.50 %
Orientation	0.5312	0.5133	0.5374	9.97 %	5.47 %	11.05 %	96.26 %	97.19 %	96.43 %
Total	**0.7884**	**0.8690**	**0.8775**	**87.42 %**	**93.30 %**	**94.65 %**	**42.99 %**	**45.19 %**	**39.17 %**

P: Puntalon. C: Carchuna. G: Gualchos.

Considering this first approach, we have developed the same analysis in each one of the three landscape units described in Figure 15.1. Our aim is to improve the degree of correlation and identify different processes in these units. In this new attempt, we have excluded the distance to centralities, as each unit has only one centrality and it will not explain a different concept than the distance to greenhouses. Table 15.3 represents the results obtained for the different units:

TABLE 15.4. Degree of coincidence between the predicted and the real situations.

Unit	Kappa index
Carchuna	0.4799
Puntalon	0.3682
Gualchos	0.3443

Once again we have developed a cross tabulation with the obtained results and the real situation. The following table shows the kappa index for each unit. The cross tabulation in the Carchuna unit is also represented (Figure 15.4 see over).

15.7 Discussion

In the following paragraphs we will compare the results in the whole area and in each of the observed units in order to understand the factors that affect the landscape dynamics. However, we should note the transparency of the results although some of the predictions and correlations are not strong enough.

For the first attempt concerning the whole study area, we have found that the main factors that influence the growing process are: the topography and the distance to greenhouses and to centralities. In the case of distances, it demonstrates the importance of the diffusion pattern in the greenhouse growth. This pattern also explains the lack of accuracy of our prediction for the whole area. Our model shows that the most important growth is in the western unit due to better weather conditions, but the real growth appears in the central and eastern units following a historic diffusion pattern.

We also found that the ROC for the whole area was higher than the ROC for any of the three units. This strange situation is caused by a less degree of specificity (proportionally, there are less pixels with value 0 in the units). Attending to the sensitivity, in the case of Carchuna and Gualchos we found a better result than in the case of the whole area.

According to the different variables in the second attempt (unit by unit), the topography and the distance to greenhouses are more influent in the Carchuna and Gualchos units because they are saturated areas without

FIGURE 15.3. Image of change probability in the study area.

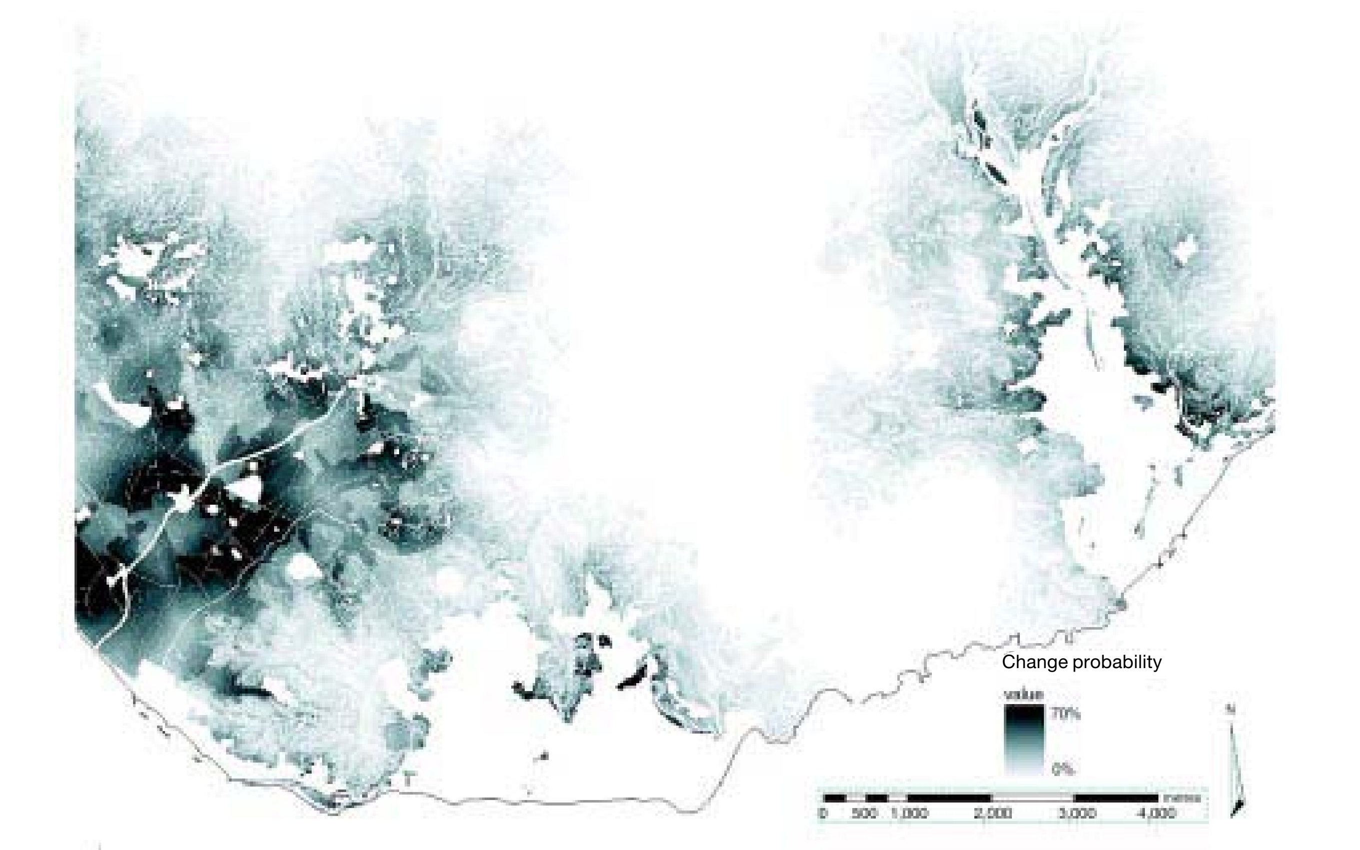
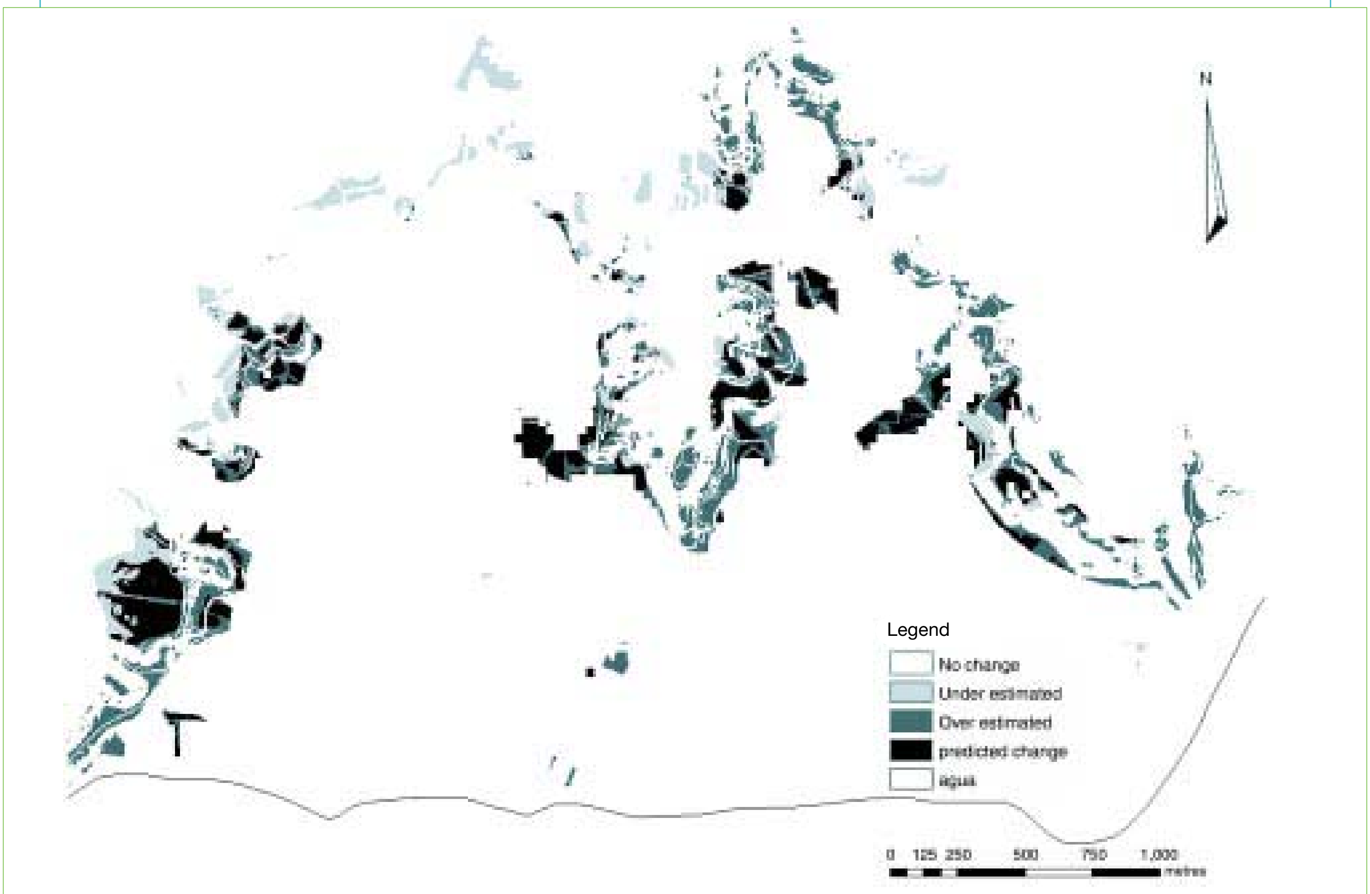


FIGURE 15.4. Cross tabulation in the Carchuna unit.



any other irrigated farm and with important physical constraints to increase the surface. There is also a higher correlation of all the factors in the Carchuna unit, because it was the most saturated area in 1990. In the case of Puntalon (a less occupied agricultural place) there are still other farms, so the main factor affecting the growth is the land use.

The value of Kappa index is not sufficient for the three units, introducing a high degree of uncertainty in our predictions mainly in the case of Puntalon (West). Although we have used several factors, it demonstrates that there are still some complex variables complicated to include in a map that could affect the process, principally in the case of non-saturated areas.

15.8 Conclusions

According to the obtained results and the following discussion, it is demonstrated that the prediction of the proposed model is more precise in advanced phases of greenhouse expansion when constraints (the physical ones and others) are important. It is also demonstrated a diffusion pattern leading to saturated and monofunctional landscapes that are far away from a sustainable goal. This requires to apply new planning and management criteria that consider the predictions, the influent factors previously described, and a more accurate model that has to be described on the basis of these results.

Considering this assertion, it is important to note that nowadays with the existing technologies it is not difficult to build a model with a high predictive capacity. It will be a product of an accurate spatial analysis, but also it will include a certain adaptation of tools and real data in order to achieve a better statistical correlation. Not always this complex job leads to a better understanding of the reality and to a better decision making process. Thus we have tried to simplify our model as much as possible.

It is also important to point out the difference between the real prediction of the land use change and the high spatial prediction after the implementation of a certain geo-statistical model. This is because the predictive modelling could produce different results depending on the selected technique (Verburg *et al*., 2004) and the following essential questions in landscape dynamics (Veldkamp and Lambin, 2001):

- The complexity of land use systems that include several scales and attributes.
- The scale of the analysis that determines the driving forces of land use change.
- The dilemma between the spatial and quantitative determination of land use changes.
- The feedback of biophysical processes in the land use models.

In addition to this, the case of greenhouses is more complex, because this spatial phenomenon is a new and accelerated process (with less than 30 years), and there is also an important lack of bibliographic references and research experience.

In future research it could be interesting to consider new greenhouse expansion factors such as landscape inertia (Matarán, 2005), land property, parcel shape, farmers preferences, urban expansion, etc. Further, future models could introduce a random parameter in order to simulate the effect of social behaviour, principally in less saturated areas. Non-linear models such as cellular automata could introduce both, this random parameter and the influence of any growth in the following processes (Aguilera, 2005). This is suitable when we are considering the medium term as in this article.

The new non-linear models will help the planning processes with a list of questions that need to be addressed in following research:

- How could we build a model of aspects with a vague nature such as landscape inertia?
- What are the main driving forces of greenhouse expansion and regression?
- What will the future consequences of a change on the greenhouse land demand be?
- Could an increase on the demand convert a whole territory in a suitable place for the development of this agriculture?
- How is the globalising dynamic of intensive agriculture changing local landscapes?
- How is the scale dominating the landscape resistances to greenhouse diffusion: local or global?
- What are the options for a multifunctional landscape according to the evolution of the land demand for greenhouses?
- What are the possible environmental limits to the greenhouse diffusion?

Finally, we should comment that, as previous landscape research have shown there will always be a certain degree of uncertainty that we have to accept, as we are trying to simulate a complex phenomenon (Antrop, 1998).

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16. Characteristics of intensively used agricultural areas and their impact on biodiversity and nature conservation activities within farming practice

Juliane Mante and Bärbel Gerowitt
(Corresponding author: J. Mante, email: juliane.mante@uni–rostock.de)

Abstract

Induced by changes in production methods, the situation at the markets and the conditions in agricultural policy an accelerated development to short crop rotations and large management units in intensively used agricultural regions is proceeding. The living conditions for many characteristic species of the agricultural landscape and the quality and quantity of their habitat deteriorate. In intensively used agricultural regions several restraints exist for the farmers to implement nature conservation measures. For example, due to the higher average yields of the field crops and the cultivation of very profitable crops like sugar beets, the opportunity costs implementing nature conservation measures increase. Subsidy levels often do not consider these regional distinctions. However, some developments in the political and administrative framework of agriculture, as the amendment of the Plant Protection Act in 2004 and the reform of the sugar market in 2006, will foster the implementation of production integrated nature conservation in intensive arable areas by lowering their opportunity costs. In Germany, five pilot projects which contribute to the project network *Lebensraum Börde* develop and implement nature conservation measures in particular adapted to the conditions of intensively used arable areas focusing on sown flowering strips. Characteristics, goals and stakeholders of these projects are introduced.

Key words
Intensively used arable areas, nature conservation projects, sown flowering strips, total costs, subsidy levels

16.1 Introduction

The term ‘agricultural used areas’ has a production aspect. Agriculture is farming land with technical hardware (tractors, machinery) and knowledge-based software (production techniques, know-how) – used together to produce commodities and non-commodity goods. Since farmed land consists of plots and properties, agriculture also has a spatial aspect. In these agricultural landscapes people are shareholder by owning and/ or using the land or stakeholder by having an interest in the land: e.g. as farmers, hunters, nature conservationists, or rural politicians. Thus, agriculture has also individual and social aspects.

For species of farmland wildlife, ‘agriculture’ has aspects of providing feed and habitat. Although, their requirements are of basic importance when implementing nature conservation measures within farming activities in intensively used arable regions, in this paper we want to address that all aspects of agriculture determine the success of these measures.

The paper focuses on characteristics of intensively used arable areas concerning soil quality, cultivation history, and appearance of the landscape given in the first chapter. The impact of the existing cultivation practice on the biotic resources in these areas and the arising potential for nature conservation are described in the following chapter. Farm economic costs are considered as one restraint for nature conservation measures in intensive arable regions. Thus, costs of sown flowering strips are calculated in the next chapter and the impact of various political options on these costs is emphasised. The final chapter focuses on examples for realising nature conservation options in five regional projects in Germany.

16.2 Intensively used arable areas

An intensively used agricultural region is normally dominated by one type of use – if soil conditions are favourable this is generally arable farming. In Germany, intensively used arable regions dominate in many regions – especially where airborne loess soils were deposited. These regions were first settled by arable farmers within the Neolithic era (Jankuhn, 1969). In German these regions are called ‘Börde’ – they stretch like a band from west to east in the middle of Germany.

In an intensively used arable landscape arable field connects to arable field, the only structural elements are lanes and their verges, which also carry the ditches necessary for permanent or often non-permanent water drainage. Only very seldom, hedges follow a lane or a ditch. Other biotope types like grasslands or forest spots are rare in these landscapes. It is stated that the small amount of structuring elements within intensively used arable regions is crucial from the viewpoint of nature conservation and environmental protection (SRU, 2000). However, intensively farmed ‘Börde’-landscapes were used and structured as completely open landscapes for centuries (Jaeger, 1963). In these landscapes a wide range of crops including all cereals, root crops, legumes and fodder legumes were planted. Field grass was also grown for up to four years to produce the feed for the livestock which was kept on every farm.

What has indeed changed is the manner of how arable farming is organised and managed – connected with dramatic spatial aspects within these arable landscapes.

Farms grew in the area and specialised – first completely on arable production. Due to this arable specialisation, the few grassland patches were changed into arable land and field grass and fodder legumes disappeared in the crop rotations. Few crops, like winter wheat were grown on an increasing amount of land while others, like sugar beets were more or less stable due to production quotas, but many crops lost more and more acreage.

The increase of farm sizes was only possible by renting land from farmers who gave up production. This continuous process has also led to high percentages of rented land in all parts of Germany. In the eastern federal states percentages of rented land vary between 73–93%, the amount of rented land in the western federal states is smaller (41–67%) (Statistical data of the various German federal states, 2003).

Parallel to the concentration on few arable crops, plot sizes of arable fields were augmented wherever possible in order to save costs for labour and machinery. While, this is a continuously ongoing process in the western German federal states, huge field sizes were performed in the eastern German federal states by establishing co-operative and state-owned farms between 1950 and 1970. Post communism transformation did not lead to smaller field sizes again.

Thus, because of several reasons crop diversity in space and time has dramatically decreased in intensively used arable regions.

Currently this process was stopped by introducing the cross-compliance regulation (EU 1782/2003) within the direct but decoupled EU payment system. There, the minimum number of arable crops is three for farms who want to further receive direct EU-subsidies for agricultural land. Thus, the process of further simplification of crop rotation is stopped but not turned back. Three coarse crop rotations are still much simpler than historical land use and farmers can further simplify to two or one crop by co-operating in land use.

The intensity of arable farming is commonly described by inputs like fertiliser, pesticides, labour, and energy. In general, inputs into intensive arable farming areas have always been high in order to further augment the high output in these areas. Due to their environmental effects and their relevance in farm economics, many efforts are spent to use input factors as sophisticated as possible. Abiotic risks, like erosion or nitrate leaching can be managed by applying more sophisticated methods at a regional scale within a framework of few farms, fields, and crops in arable landscapes. However, these adaptations in production methods for protecting abiotic resources will probably affect farmland wildlife only to a very small extend (Boutin and Jobin, 1998).

16.3 Nature conservation in intensively used arable regions

In summary, the previous description indicates that highly productive arable landscapes have never been very rich in structuring elements, but they have been much more diverse in the land use patterns than they are today. Of course species of farmland wildlife have adapted exactly to these conditions and accompany intensive arable land use. We will not provide details here, but state that for many flagship species of pure arable regions, like the red kite, hamsters, lark and corn bunting, partridges and hares, population losses are documented (Tillmann *et al*., 2005; Stubbe *et al*., 1996; Brickle *et al*., 2000).

Their living conditions suffer especially from the spatial aspect of lost crop diversity. That means over large areas food and habitat provision is disturbed by elementary arable measures, like soil cultivation, weed control, and combine harvest.

Nature conservation complains about this development and it is likely that public opinion regrets it – however, farmers will not return to small scaled diverse land use patterns in arable farming due to economic reasons. Although a slight increase in crop species is expected due to the decoupling procedure of the EU-agricultural policy, a small scaled patchwork of various crops and intensity levels is not likely to appear again on highly productive sites.

Hence, if farmland wildlife depends on diversity which cannot be achieved in the traditional way, a strategy can be to mimic crop diversity and intensity levels. Tools to mimic crop diversity are unsprayed or sown field margins. They can be sown with mixtures of flowering but not harvested crops, wild plants or a mixture of both. Field margins can also carry an unmanaged succession – however, farmers are often afraid of weeds dispersing from these fallow strips. Within fields, diversity can be increased by favouring certain weeds within the crops.

Farmers regard these tools in context with costs of setting up and long term aspects. The latter includes the question if the structures are removable again and whether they can rotate with crops. The fact that the majority of the productive land is nowadays rented hampers all tools with a long-term, often everlasting perspective. Thus, botanical diverse but managed elements at the field edges are appropriate tools within these landscapes. Although sown flowering strips are no classical tool in nature conservation, in these landscapes they do not compete with other measures, since here hardly any nature conservation measures are implemented.

16.4 Farm economic costs of nature conservation in intensively used arable regions

In these preferred agricultural regions several restraints exist for the farmers to implement nature conservation schemes to agro-botanically diversify the agricultural landscape. One of these obstacles is the high opportunity costs for the farmers. The main reason for the relatively high opportunity costs in intensively used regions is the comparatively high average yield of the alternatively grown field crops. The effect is shown in Figure 16.1.

Total costs per ha are calculated consisting of the costs of sown field margins – here annual sown strips – and the loss in gross margin of the displaced crop – here winter wheat. The pure costs for implementing sown flowering strips can be expected to be approximately identical for different farms and regions, whereas high crop yields due to a better soil quality and the management of large plots increase the loss in gross margin of the alternative crop in intensive arable regions. For the calculation of the different gross margins according to the crop yield the standard variable costs and benefits shown for the production of 8 t wheat per ha on large plots (KTBL, 2004) has been adapted to the higher or lower wheat yield. The costs for seed mixtures of crop plants were assumed with 35 €/ ha/a, of wild-/crop plants with 150 €/ ha/a and of wild plants with 600 €/ ha/a. These costs have been mainly adopted from the seed mixtures used in the below-mentioned projects of the project network *Lebensraum Börde* for sown flowering strips, which can be purchased at certain seed firms or the private agricultural trade. The underlying seed mixtures and their principle constituents are presented in Table 16.1. The pure crop plant mixtures mainly consist of annual species which have to be re-sown every year. The calculated costs include only the operations necessary for sowing, maintenance works were not envisaged.

Furthermore, the cultivation of very profitable crops as sugar beets in comparison to less profitable crops as e.g. winter wheat can increase the level of opportunity costs and the subsidy level as shown by the calculation in Figure 16.2. The lost gross margins of the displaced crops winter wheat and sugar beet have been taken over again by updated measured standard gross margins (KTBL, 2004). Independent from the subsidy level, farmers will choose the alternative site and crop with the lowest opportunity costs for implementing nature conservation measures. Thus, calculating subsidy payments as crop rotation gross margins including sugar beets will frequently raise the profit for the farmer.

FIGURE 16.1. Costs of annual sown field margins subject to the crop yield of alternative crop winter wheat (€/ha/yr).

		Costs field margins	Lost gross margin
Crop plants	70 dt/ ha	106	95
	80 dt/ ha	106	184
	90 dt/ ha	106	274
Wild-/crop plants	70 dt/ ha	221	95
	80 dt/ ha	221	184
	90 dt/ ha	221	274
Wild plants	70 dt/ ha	671	95
	80 dt/ ha	671	184
	90 dt/ ha	671	274

FIGURE 16.2. Costs of annual sown field margins subject to the displaced field crop (€/ha/yr).

	Winter wheat	Sugar beet
Crop plants	289.66	2211.66
Wild-/crop plants	404.66	2326.66
Wild plants	854.66	2776.66

Different levels of opportunity costs are seldom considered in the composition of the subsidy payments. The calculation of subsidies is mainly based on standard gross margins and does not regard regional distinctions. Therefore, existing subsidies for nature protection schemes often cannot cover the arising opportunity costs in intensively used areas, what inhibits the implementation of nature conservation measures in these areas. Since contributions to farm economics is an important decision criterion for farmers to implement nature conservation measures, the specifics of intensively used agricultural regions should be considered in the calculation of subsidies.

One possibility to achieve this goal is the grading of subsidies according to the potential yield of the soil. At federal level, the compensation allowance for farmers in

TABLE 16.1. Seed mixtures partly used in the project network *Lebensraum Börde* for sown flowering strips and fallows and their composition.

	Name of the mixture			
Characteristics	**OLAP**	**Lebensraum 1**	**Wolfenbüttler Mischung**	**Field flora**
Share of crop plants in %	100	70	100	0
Share of wild plants in %	0	30	0	100
Principal constituents (60–100%)	*Secale multicaule* *Fagopyrum escul* *Helianthus annus* *Avena spec.* *Lupinus angustif.* *Pisum sativum* *Trifolium incarnat.* *Panicum spec.*	*Onobrychis viciif.* *Medicago falcata* *Fagopyrum escul.* *Sanguisorba minor* *Helianthus annus* *Foeniculum vulg.* *Trifolium prat.* *Vicia sativa*	*Helianthus annus* *Phacelia thanacetifolia* *Raphanus sativus*	*Adonis aestivallis* *Agrostemma githago* *Centaurea cyanus* *Chrysanthemum seget.* *Linum usitatissimum* *Matricaria inodora* *Papaver rhoeas*

less-favoured areas and the subsidies for first afforestation and for perennial set-asides within the scope of German Joint Task for the Improvement of Agrarian Structures and Coast Protection (GAK) are graded according to the yield index. Apart from these examples at federal state level this approach has not become widely accepted within the set-up of agri-environmental measures since more administrative efforts are expected compared to the standard procedure.

However, the new development in the organisation of the EU sugar market in 2006 may expect a reduction of sugar beet production, so that the costs for nature conservation measures will presumably decline in intensively used agricultural areas.

Another promoting factor for implementing extensive field margins comes along in the amendment of the Plant Protection Act in 2004. In Germany, farmers are legally obligated to omit the application of pesticides, not only in the vicinity of aquatic but also of terrestrial boundary biotopes, provided that they are farming in an area that does not meet a specified minimum share of structural elements and that the adjacent boundary biotope is not situated on agricultural or horticultural used land or rather roads, alleys, and squares. The calculation of the required regional minimum share of structural elements is based on the intensity of crop rotation and pesticide use – hence, up to 20% structural elements can be required in some regions. The type of pesticide and the application technology used further determine the required distance to adjacent biotopes.

Sown flowering strips are nature conservation measures that exceed the cross-compliance commitments (EU 1782/2003) as well as the commitments of the German Plant Protection Act (PflSchG). Hence, they are supposed to be eligible in areas affected by the obligations of plant protection, also in the future context of the *Regulation on support for rural development by the European Agricultural Fund for Rural Development (EAFRD)* as from 2007. By participating in sown flowering strip schemes farmers can partly compensate their yield losses caused by the obligations according to the Plant Protection Act.

The calculations in Figure 16.3 illustrate the arising additional profit for farmers who gain subsidies for sown flowering strips on land affected by obligations of plant protection. Beside the exclusive consideration of the displaced crop with the lowest opportunity costs the calculation of crop rotation gross margins is another possibility for determining opportunity costs and thus subsidy levels of nature conservation measures, even though it will mostly raise the subsidy level. Using this mode of calculation the crop rotation sugar beet – winter wheat – winter wheat as one usual crop rotation in intensively used arable regions forms the basis of the different calculated costs in Figure 16.3.

For working out the opportunity costs on land under obligations the yield loss resulting from suboptimal application of herbicides and nitrogen fertiliser has been taken from a field experiment realised by the Federal Biological Research Centre (BBA) and is estimated for winter wheat with 23% (Bartels and Kampmann, 1994). Based on this field experiment and a literature review, the yield loss of sugar beets was estimated with 40%. Furthermore, the reduced costs for applying pesticides and partly for fertilising were considered for calculating the changing crop rotation gross margin.

Thus, subsidies for sown flowering strips calculated with standard crop rotation gross margins can increase the profit of the farmers in areas affected by obligations of plant protection by at least 25 to 42%. This circumstance can be an additional impulsion for farmers in intensively used arable areas, to enhance boundary biotopes by implementing sown flowering strips.

16.5 Examples on projects to implement nature conservation into farming activities in intensively used arable regions

How can successful projects be set up? Besides financial instruments, concepts for nature conservation projects require also political and administrative instruments to enable the development and implementation of nature conservation measures. One needs farmers as partners (who provide know-how and in many cases have the property rights), land owners, and other stakeholder (e.g. nature conservancy, hunting associations). Public interests should be served to enhance the acceptance of the projects, for instance by presenting flagship species and enhancing the aesthetic value of the landscape by structures and colours.
Five projects in the project network *Lebensraum Börde* aim at enhancing the biodiversity in intensively used

FIGURE 16.3. Changing costs of sown flowering strips in compliance with obligations in plant protection (based on the gross margin of the crop rotation sugar beet – winter wheat – winter wheat).

	Wild plants		Wild-/crop plants		Crop plants	
€/ ha/ a	**standard**	**obligation**	**standard**	**obligation**	**standard**	**obligation**
annual	1495.33	1114.82	1045.33	664.82	930.33	549.82
biannual	1160.00	779.49	935.00	554.49	930.33	549.82
triannual	1048.22	667.71	898.22	517.71	930.33	549.82

agricultural areas by dint of production integrated nature conservation measures focusing on sown flowering strips. Beside sown flowering strips and fallows other forms of extensification field margins and fallows, riparian buffer strips, hedgerows, fruit trees, the diversification of the crop rotation, and extensification measures on grassland are implemented, too. The projects are actually funded for four years.

The five projects are situated in intensively used arable areas in the federal states North Rhine-Westphalia (*Kölner Bucht*, *Soest*), Lower Saxony (*Wolfenbüttel*) and Saxony-Anhalt (*Querfurter Platte*, *Hakel*). Their main principle is to develop production integrated nature conservation measures adapted to the characteristics of intensively used arable areas mostly together with the farmers as their main target group. The farmers are more or less actively involved in the development of the measures, either by acceptance studies or interviews (*Wolfenbüttel*, *Soest*, *Kölner Bucht*) or by specifying the measures to be implemented (*Querfurter Platte*).

The projects mainly consist of actors from the range of nature conservation, agriculture, science, and administration whose strength and weighting differ between the projects. Furthermore, it has become evident in the ongoing work, that including hunters as stakeholders enhances the success of the projects because the nature conservation measures as sown flowering strips and fallows have an impact on game wildlife. This fact has enabled a strong dedication of hunters to foster the implementation of the project targets.

The projects are accompanied by scientific support in several fields such as acceptance studies, monitoring of goal species, and analyses of relevant success factors by investigating actor groups and network constellations. High emphasis and expertise is placed on the monitoring of goal species within the project work. It could be established that almost all measures had the expected promotional influence on the chosen goal species, although the short project duration often does not enable the presentation of proven knowledge.

Flagship species can facilitate the public relation and enhance the societal acceptance of the projects. In case of the project network *Lebensraum Börde* the hamster, partridge, hare, breeding birds like sky lark, birds of prey like the red kite and butterflies are representing on the one hand important goal species but also effective flagship species for public relation.

Following instruments are used by the projects for financing the offered nature conservation measures: agri-environmental measures (as pilot schemes), landscape plans, the Impact Regulation under Nature Protection Law and German Federal Building Code, land consolidation schemes, and the compulsory set aside. Also lottery funds could be raised as it was done in the projects *Querfurter Platte* and *Hakel*.

The Federal Foundation for Environment (DBU) provides the main amount of funds necessary for the administration and implementation of the projects.

Nature conservation measures are implemented in different amounts. Some projects focus on maximising the amount of implemented measures, others have concentrated on ensuring the permanent stock of existing measures. Thus, the project *Wolfenbüttel* has implemented nature conservation measures on approximately 415 ha farmland with the focal point on sown flowering strips and fallows. In the project *Soester Börde* approximately 70 ha production integrated conservation measures could be established, focusing on several forms of extensified field strips. During the project term the project in the *Kölner Bucht* has implemented approximately 40 ha mainly sown flowering strips and fallows. A similar amount of diverse nature conservation measures – approximately 30 ha – were durably implemented by the project at the *Querfurter Platte*. More than 4,000 ha of diverse extensification measures that also include conversion of crop rotations, hedgerows and tree rows could be set up by the project in the European Bird Sanctuary *Hakel*. Beside the implementation of nature conservation measures there have been several other important project results. To mention only some of them: there have been endeavours of the projects *Wolfenbüttel* and *Soest* to foster the take-up of sown flowering strips into the agri-environmental programs of the respective federal states, that has been so far successful in Lower Saxony. Another outcome of the project *Kölner Bucht* is the establishment of the Foundation for Rhenish Cultivated Landscape which will give support to farmers and other interested land users to plan and implement nature conservation measures also beyond the end of the project. Further during the project term the project at the *Querfurter Platte* has advanced the Method of Multicriteria Landscape Assessment and Optimisation (MULBO), a planning method that tries to compromise between different land use interests (Grabaum and Meyer, 1998).

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17. Improving the institutional delivery of agri-environmental schemes via local action groups

Jan Freese and Horst-Henning Steinmann
(Corresponding author: J. Freese, email: jan.freese@agr.uni-goettingen.de)

Abstract

Agri-environmental schemes (AES) are the main instrument to improve environmental and nature conservation issues in the agricultural landscape. On the basis of an analysis of ecological effectiveness, economic efficiency and acceptance among farmers, we propose to support the environmental improvement by installing or supporting regional organisations for the management of the agri-environment. This is confirmed by results from the regional 'Bördeprojekt' in the Wolfenbüttel District, Lower Saxony, Germany. With a regional and co-operative approach, this project developed AES for intensively used agricultural regions namely a flowering field margin strips programme. After reviewing some important factors of success, we point at the possibilities of a local organisation e.g. to bring the topic on the local agenda, to compile a locally adapted AES or to provide a nature conservation advisory service for farmers.

Key words
Agri-environmental schemes, local management, factors of success, intensively used agricultural landscape, flowering field margin strips

17.1 Introduction

Since 1992, the EU develops and supports measures for rural development and environmental protection within the common agricultural policy (CAP). Several times, the regulations have been improved with respect to economic efficiency and ecological efficacy but the EU always refused to finance manpower to implement the programmes. So, all work has to be done by the national administrations without additional payment. In the 2003 reform, the EU opened the regulation for financing so called local action groups. These local management concepts, successfully tested with the LEADER initiatives, will become a fundamental element within the new programme period of the rural development programme (Council Regulation (EC) No. 1698/2005 of 20 September 2005 on support for rural development by the European Agricultural Fund for Rural Development, EAFRD).

The economic efficiency and ecological efficacy of agri-environmental schemes[2] (AES) has often been discussed and questioned (see e.g. Kleijn *et al.*, 2001; EU-Court of Auditors, 2000; Kleijn and Sutherland, 2003). It has also been stated that the ecological and economic effectiveness of different AES varies widely (Wilhelm, 2001; Marggraf, 2003; for a discussion on different interpretations of efficiency see e.g. SRU, 2002, Tz. 224–229). The EU tried to make the programmes for rural development (and within them the AES) more effective and efficient by implementing stricter control and evaluation instruments (Agri-GD, 2004; Wilhelm, 1999; Carey *et al.*, 2003). With the promotion of local management within the LEADER concept and the integration of the LEADER concept into the rural development regulations (Agri-GD, 2005), the EU opens another path to improve effectiveness and efficiency of AES.

Hence, this paper aims to determine whether local management concepts provide increased potential to improve environmental and conservation goals in the agricultural landscape by a simultaneously improvement of acceptance, economic efficiency and ecological efficacy of agri-environmental schemes. We use a socio-economic approach to analyse the driving factors and main requirements to the AES and give a short insight into the way AES are implemented today. After reviewing different types of organisations for this local management, we point at the chances of local strategies. With the experience from the socio-economic sphere of the *Bördeprojekt Wolfenbüttel* we demonstrate the positive impact of local management. Furthermore, we present factors of success for local AES-management strategies derived from the *Bördeprojekt Wolfenbüttel* and other environmental and nature conservation projects documented in the literature. Finally, we conclude with an outlook on options to implement a local management of the agri-environment and the idea of a nature conservation advisory service for farmers.

17.2 Balancing AES: ecology, economics and farmers' acceptance

With every new programme period the EU initiates the programming and implementation of AES[3] in all German Länder (Land [sg.] - Länder [pl.]: in Germany also called Bundesländer, sometimes translated as federal states). Following the EU-regulations AES have to meet three needs:

1. AES are mostly directed towards farmers. Farmers participate voluntarily, so the programmes must be acceptable to them. This means that schemes must

2 We use the term agri-environmental schemes as umbrella for all kind of measures often divided into agri-environmental and contractual conservation measures.

3 AES are a part of the EU rural development programmes, Programme period 1992–1999 Council Regulation (EC) 2078/1992; period 2000–2006: Council Regulation (EC) 1257/99; period 2007–2012: Council Regulation (EC) No 1698/2005 of 20 September 2005.

fit into their every day farming activities and must compensate costs and losses derived from programme participation.
2. AES aim to improve environmental and conservation issues, so the programmes must generate positive ecological effects. The measures must be ecologically effective.
3. AES are funded by money from EU, federal government and Länder sources, so the programmes have to be administrated effectively and the money must be used efficiently.

The EU sets only the framework for the AES (so called contextual guidance, see e.g. Willke, 1999, 39), and leaves the member states wide scope for the implementation. Here, we present two contrasting examples from German Länder how they have used this scope in the former period and characterise the resulting programmes (see also Wilson and Wilson, 2001, 201–204).

a) The Proland-Programme of Lower Saxony can be seen as an example for the implementation of a limited set of agri-environmental measures uniform for the Land. In the former years, the farmers were able to choose between four and 10 measures[4] within the AES. The aim of the administration was to keep the programme small and concise. The scheme has had no variations, top-ups, or restrictions concerning the spatial extensions and was not menu-driven.
b) Alternatively, a Land can provide a menu-driven programme with a large set of measures with multiple variability and top-ups. Within the Kulturlandschafts-programme of North Rhine-Westphalia or the MEKA in Baden-Wuerttemberg, for example the farmers can choose between at least 20 measures and variations. The countries or regions were allowed to define local aims and choose adequate measures, select variations, and set spatial restrictions to compile a local AES.

Generally, the Länder are responsible for the correct implementation of the EU-framework. In case of misuse or inadequate implementation, the administrations carry a (high) financial risk.

The two strategies described above differ in their aims. In System A the efforts and costs of the administration for implementation, administration, and control are small and the programme is kept clearly arranged for the farmers. System B focuses more precisely on the ecological efficacy and practical requirements. It can be fitted into diverse local situations and covers many special conservation efforts. The drawback of System B is that the administration both at the Länder and at the local level requires more effort with the implementation, administration and control. Also, it is not easy for farmers to keep an overview about all possible combinations of the scheme.

But even the simpler Lower Saxony AES (System A) has been criticised for a lack of clarity. The mid-term review of the programme shows that there is a lack of personal advice for the farmers (ML, 2003; Kap. 6, 23–24). The review positively highlights only one measure: the protection programme for rare arable weeds. It achieves the highest acceptance and most positive evaluation from the farmers. The farmers complimented the direct and personal advice given by the hosting employee of the administration.

Hence, the challenge to implement all three requirements – acceptance, ecological accuracy and economic efficiency – has not been successfully achieved. Thus, a lack of effectiveness and efficiency as well as a poor acceptance by the farmers is observed (Arzt *et al*., 2002; Deblitz, 1999; Jungcurt *et al*., 2004).

The economic efficiency aims at preventing windfall gains from paying overpriced measures[5] and at keeping the transaction costs of implementation, administration and control low. Economists normally try to apply this by installing a market. According to this, their proposal is to use calls for tenders and auction designs, and not to work with spatial or other limitation. If enough farmers participate at the call for tender and present different offers, the administration can choose those offers which are lowest in price. So, they hand out only relatively low grants and can contract a maximum area for reaching the protection target (examples for realising auctions see e.g. Cason and Gangadharan, 2004).

The ecological effectiveness demands to contract the most valuable and promising areas for conservation targets. This makes it necessary to have detailed information about the areas. To have or to develop locally adapted conservation targets is often connected with an inspection of fields. In most cases, this leads to a very limited and spatially fixed set of interesting areas from a conservation point of view. It is neither easy nor sure to get the appropriate areas under contract and this makes the measures expensive.

But no matter how the ecological and economic requirements are implemented, without farmers willing to contract, the best AES are worthless. So, the AES must be focused on acceptability[6]. Until now the aspect of acceptability is rarely put into account within the discussion on effectiveness of AES. Even though, Coleman *et al*. (1992, cited in Carey *et al*., 2003) argued that 'policy measures which encourage positive attitudes to conservation will in long term be more effective than those do not.' As a reason, they point out how the

4 This included subsidies for organic farming. Not counted were specialised sub-programmes of the Proland-Programme facilitating special conservation issues.
5 There are several authors pointing to the tendency of AES in Germany to overcompensate farmers apart from the allowed 20% incentive surplus (e.g. Ahrens *et al*., 2000).
6 For a definition of acceptability see e.g. Prager, 2002, 6–29; Lehmann *et al*., 2005, 27–30 present an actual literature review about the discussion on acceptability of AES.

positive shift in the attitudes increases willingness to implement additionally voluntarily and unpaid measures. AES not designed to change the farmers' attitude will mostly be seen as temporary bribes, as Morris and Potter (1995) stated.

Regarding acceptance as a complex individual multistep process (see also below and Prager, 2002; 12) it needs at least the same attention as the economic and ecological aspects of AES. For participation to occur, the farmer must have a positive attitude towards AES. Then, he must have access to the programme information. Also, he needs advice in this phase of checking the actual programme. The programme must fit into everyday farming activities. If all this is positively checked, the farmer still must apply for participation. Finally, if he has contracted, he will need support with the implementation and has to face the programme control. At every single step, one negative check will hinder him from participation. And even if he has contracted, every bad experience – a lack of support or negative experiences with the application and control process – will disincline him to participate the next time. To meet all these demands, we propose to install regional management organisations for the agri-environment. A framework for the ecological and economic demands can be set at the Länder level, but the balancing between them can only be done locally. Therefore special local knowledge of both the ecological situation and conservation potentialities and the possibilities and requirements of the farmers is needed. Despite all possibilities of classical programme optimisation, substantial improvement can only be achieved by a regional representation and adaptation of AES with direct contact to the farmers.

In the following section, we highlight concepts for such regional organisations to foster the agri-environment and then suggest ways for the successful work of such institutions.

17.3 Local management organisations for the agri-environment

17.3.1 Different organisation forms

Local organisations for the management of the agri-environment and the local implementation, adaptation and promotion of AES help to close the gap between the clients, stakeholders and the administration. Nature conservationists, farmers and the local population should be integrated into the process, which is until now mostly only driven by the Länder administrations with consultations of the top organisations of public interest (see e.g. Freese and Rüffer, 2005).

The variety of organisations[7] implementing the efforts of local management is enormous (Blum *et al*., 2000) and they can generally be referred to as regional intermediate organisations or local action groups. Examples are:

- Landcare associations (DVL, 2005; Speer, 2000).
- Project born advisory boards, composed of local experts and stakeholders, like the 'advisory board for the agri-environment' in the district of Northeim (Bertke *et al*., 2005; Hespelt, 2005, 35–98).
- The integrated area management in the water protection area 'Fuhrberger Feld' (Haaren *et al*., 2005), a co-operation between farmers, scientists and water supply companies.
- The Agrarumweltforum Grano (Arzt *et al*., 2002), a round table concept in Brandenburg.
- Nature conservation and biological stations, driven by private conservation organisations but supported and assigned by Länder (e.g. for North Rhine Westphalia see Neiss, 2001).
- The initiatives of Leader (Leader, 2005) and Region Aktiv (BMVEL, 2005; Brocks and Weiß, 2004; Knickel *et al*., 2004) implemented the ideas of local management even if they not always deal with the agri-environment.

17.3.2 Experiences in a local project: the 'Bördeprojekt Wolfenbüttel'

In the Börde region of the Wolfenbüttel District arable land is very productive[8]. Land is valuable and farms are modern and thriving. This is a situation where nature conservation programmes are not very competitive against production incomes and farmers tend to use their full acreage for intensive production, so except the casual participation in a conservation tillage measure, farmers in the Börde region of Wolfenbüttel did not participate at all in AES. However, also in highly productive regions it is necessary to fulfil nature conservation standards, e.g. to develop a net of extensive margins to ensure a positive nature conservation impact.

Starting in 2003, the Bördeprojekt aims at analysing the social, political, and economic driving factors in the field of agri-environmental protection and developing AES adjusted to this intensively used region and to motivate the farmers to participate. Before 2003, the Lower Saxonian AES was mainly directed towards grassland and marginal sites. On the one hand, facing the modulation of direct EU-payments farmers and agricultural authorities became increasingly interested in measures for agricultural productive regions. On the other hand, the Börde regions lack semi-natural and natural habitats due to the long-lasting intensive agricultural usage. This was the starting point for the project funded by the Deutsche Bundesstiftung Umwelt (DBU) and supported by the Ministry of Agriculture, Lower Saxony. Main aspects of the accompanying scientific research were institutional, political and economic aspects. Despite the above-mentioned critics on the ecological effectiveness a positive environmental and

7 See e.g. Streeck, 1999, they are also called 'encompassing' (Olson, 1982) or 'corporatistic' (Schmitter, 1979) organisations.

8 Börde in Germany is referring to intensively used agricultural landscapes. Soils are mainly derived from loess. The Börde regions offer excellent conditions for arable farming. The Börde region of Wolfenbüttel (in the eastern part of Lower Saxony, Germany) is mainly used as agricultural land, which covers 69% (500 km^2) of the Wolfenbüttel District. There are approximately 350 farms lying within the district.

ecological impact of extensification measures in the Börde region was assumed and not investigated.

The project was locally installed at the existing Landcare Association. The first step of the project was to establish an advisory board consisting of the local stakeholders, such as farmers, the farmers' union, conservationists, district administrations, agricultural chamber and the local agrarian extension services, and additional experts from the Ministry of Agriculture and the ecological advisory body of Lower Saxony. This board gathered reasons that prevented farmers from participating in AES. These results were accompanied by a census. A questionnaire was sent to all full-time farmers (n=320) in the Wolfenbüttel District with at least 15 ha farmland. From the returned 79 questionnaires it became apparent that in addition to purely economic reasons, operational and structural reasons led farmers to refuse agri-environmental schemes. The five-year contracting period of AES is one of the major obstacles. In a time where European agricultural policy changes significantly farmers in the Wolfenbüttel District try to avoid long term contractual binding to AES. Another obstacle is the large number of schemes and programmes with different rules and regulations. Even if there were adequate measures the variety of schemes, lacking sources of advice and lacking motivation, hinder farmers to participate[9].

The project started with the assumption that improper schemes and measures are not the bottleneck, but a lack of farmers' information and motivation. The Bördeprojekt installed a local management at the Landcare Association Wolfenbüttel. In co-operation with the Centre for Agriculture and the Environment (ZLU) farmers, local authorities, and nature conservation associations were invited to define local goals and adequate measures. Information on agri-environmental schemes was gathered and farmers were encouraged to participate. The project also assisted during the process of application and implementation of the measures.

As central measure, the establishment of flowering field margin strips (3–25 m width, no use of fertiliser and plant protection agents and no mowing allowed until the end of the vegetation period) across the Wolfenbüttel District was initiated[10]. Different sources of funding like impact-regulation, a river margin programme, a special Lower Saxonian agri-environmental scheme for the Wolfenbüttel District and project-funding were used. The experiences were recorded and discussed with the partners and actors from agriculture, conservation, and administration. This influenced the development of a Lower Saxony-wide implementation of an additional agri-environmental scheme in 2004. Now, farmers can be paid for extending flowering field margin strips. It is not allowed to use the strips for production purpose, to apply fertiliser or plant protection agents, but the farmers have to sow flowering plants.

17.3.3 Project results

The process of developing and testing measures in a local context together with the invested manpower and the involvement of the relevant local partners increased the interest and acceptance among farmers, nature conservationalists and authorities.

As a result, in 2005 more than 170 ha or approximately 140 km of flowering field margin strips were sown in the district of Wolfenbüttel. This is a remarkable success and shows that it is possible to achieve nature conservation goals in highly productive areas, if a local organisation drives the development of the agri-environment.

Additionally a straightforward co-operation of local actors was established. At the beginning the farmers and their organisations strictly opposed the central funding mechanism of the AES. This so called 'modulation' transfers money from the first pillar of the European common agricultural policy (market support e.g. subsidies for farmers) to the second pillar (rural development). The farmers get the money from the second pillar only by contracting to additional activities like AES. But after a while the farmers supported the measures, promoted the participation and finally called for prolongation of the measure.

17.4 Discussing factors of success for AES

17.4.1 Usage of existing networks

Networks of farmers and their organisations as well as the structures of nature conservation differ between regions. Intermediate organisations for the improvement of the (agri-) environment are not widely established. Building up new structures between the members of nature conservation unions and farmers can easily take years. Forming a new structure between stakeholders in the field of agri-environmental improvement requires an impartial and well-balanced process. To avoid barriers between groups, it is favoured to set up a project or organisation that consists of all relevant local stakeholders.

As a frequently successful example we present the also in the *Bördeprojekt Wolfenbüttel* used concept of the German Landcare Associations (DVL, 2005; Speer, 2000). Here the local stakeholders such as members of the administration, the farmers, and the members of the conservation unions constitute an association together. The three parties are equally represented in the steering committee. The Landcare Association (LA) is open to both further individual and constitutional members.

In the Wolfenbüttel Landcare Association farmers, the district administration and members of conservation unions had already worked together for seven years on

9 Detailed analysis see: Freese and Steinmann (2005, 15–28).

10 Other used and aimed at measures are the establishment of set-asides, grass strips, meadow and hedges within the Börde region. But according to the experts' opinion and the survey, the flowering field margin strips were the most promising and favoured measure.

several small nature protection projects. The Bördeprojekt benefited from the existing co-operative climate and was able to use the structures and contacts of the groups within the LA.

17.4.2 A dualistic partnership with a strong 'public to private' element

The specific advantage of LA is that there is an organisational frame for the stakeholders to communicate and work together at a limited topic. Hence, the members work goal-oriented, and the dualistic partnership raises their chances of success. Dualistic partnership[11] means that the partnership has not only a 'private to private' element between private stakeholders like farmers, conservationalists, landowners and hunters, but also a strong 'private to public' element. This 'private to public' element is represented by the regular participation of members of the administration or politicians. The close connection to the decision-making sphere of administration and politics motivated the private stakeholders to participate and to invest time in the Bördeprojekt. Motivated by the chance to get results directly to the implementing administration, all stakeholders had an additional interest in participating and finding presentable solutions. The chance of participation in the formation of AES stimulated the stakeholders for a conceptual and constructive co-operation.

17.4.3 Dedicated management

Especially in the field of environmental and nature conservation, direct motivation of people – in our case, the farmers – is the key to success (see e.g. Brendle, 1999). Although surveys show a general awareness for the importance of nature conservation (BMU, 2002; BMU, 2004), practical experience shows that people neither see their own responsibility nor their possibilities and calls for action to improve the environmental quality[12]. A variety of attitudes and phenomena prevents people from contributing to nature conservation issues in their everyday life: e.g. the so-called 'Not-In-My-Backyard phenomena', the 'what-for-heaven's-sake-can-I-do-within-these-worldwide-problems' attitude (see e.g. Ott, 2002) and the individual cognition, that the environment in the local context is in good shape, but that massive problems are found in worldwide and distant ecosystems (BMU, 2002, 36).

To conquer this barrier, local management is required. A known and trusted organisation like the LA in the Bördeprojekt is the background for a local action group or a promoting team for the agri-environment. Without people dedicated to the topic and the common aims, an organisation is inanimate and lifeless. On the one hand, the manager has to keep the organisation alive. This means he has to motivate the stakeholders to contribute to the organisation, to discuss and develop common aims and projects. On the other hand, the manager is the driving force for the implementation of the organisation's aims. He must appoint the local calls for action, possible resolutions and the contribution everybody can bring. Together with the following factor of success – the process competence – this must be done without a moralising undertone and in an adequate and friendly way. Practical demonstrations and an intensive dialogue are a very good way to do so. The manager must listen to the farmers and their concerns. Only if they are taken seriously, the manager has a chance to motivate them. To get in contact with the farmers requires good connection and a trusting appearance. In the dialogue it is important to find good reasons for the farmers to get involved (find win-win situations). But this is just the first step. Afterwards the manager has to continue to gather information and to disseminate it to the farmers. He must support farmers with the application and practical questions.

In the Bördeprojekt this task was carried out by the secretary of the LA Wolfenbüttel in co-operation with the project partners from the ZLU, the farmers union and the Agricultural Chamber. The growing number of farmers contacting these persons with general questions concerned with environmental and conservation issues, is a good indicator for the success of the work.

17.4.4 Process competence

As mentioned above, the people behind the organisation have to fulfil a complex task. They have to bring together the stakeholders and motivate them to participate in the process of finding common aims and strategies and to implement them. Often it is important to balance between the stakeholders, to find areas where co-operation is possible and to exclude fields touching taboo topics.

They also have to organise and to steer the processes and to co-ordinate the activities of the stakeholders. Finally, it is their task to get farmers involved in environmental protection and nature conservation. This again is a multiple-step process (see e.g. Prager, 2002; 12):

1. get farmers interested in AES;
2. motivate them to collect information about measures and funding regulation and check their possibilities to implement AES on their farm;
3. motivate them to participate and test the programme; and
4. motivate them to maintain the measures.

For every step an adapted action is needed. Additionally, every farmer must be addressed individually. The manager cannot follow a straight roadmap. Instead, he has to adapt it to the people and the appearing problems.

11 The dualistic organisation principle is one element of new governance strategies often summarised under the topic of 'good governance'. With integrating well-governed (private) networks into a larger public environment they aim to make the policy leaner while simultaneously securing supra-individualistic rationality (Elsner, 2000, 435 ff, Bogason, 2000, 76 f).

12 The problem is discussed under the term 'deficits of acceptance for nature conservation' (see e.g. SRU, 2002, Tz. 77–93; Schuster, 2003).

This illustrates what is meant by the term 'process competence'. Building up trust and co-operation is always a long, fragile and multistep process. Loss of confidence and withdrawal of willingness to co-operate can be caused by one wrong word or one rash action. The process competence within the Bördeprojekt was provided by the experience the project staff. Especially the experiences of the secretary of the LA as secretary of the regional farmers union and the partner from the agricultural chamber concerned with environmental questions allowed the project to adapt the strategy to the local particularities.

17.4.5 Flexibility matters

To support these organisational and personal factors of success, flexibility is a crucial factor (Brendle, 1999; Hampicke, 2001). The managing organisation must not only possess flexibility in its strategies, but the AES and the measures must also offer flexibility, in order to adapt to individual and special situations and demands. The variability of funding including free disposable project-funding and the possibilities to use structures or consult the specialists e.g. within the agricultural chamber, the farmers union and the administration to answer questions or solve problems were central elements of the flexibility within the Bördeprojekt.

17.5 Conclusions

Taking into account the presented findings from the ecological, economic and acceptance demands it becomes evident that the efficiency and efficacy of the AES can be improved best by installing and supporting an organisation for the local management of the agri-environment instead of improving the regulations only in the common way at Länder level[13]. This is confirmed by the local experiences in the Wolfenbüttel District and was also reported by other studies (e.g. LEADER, 1997; Geißendörfer *et al*., 1998; Geißendörfer and Seibert, 2004). The organisations, pillared on the participation of the relevant stakeholders, should be enabled to design local AES or to adapt measures to local specialities and requirements and the local discussion processes.

For cross-compliance rules[14] as well as general environmental aspects, the need of individual advisory services for farmers is accepted within the midterm-review reform a funding possibility is implemented into the EU regulations. For the more specific implementation of nature conservation aspects, the farmers lack a service of individual advice and a financial stimulus to inform themselves about voluntary nature conservation measures on their farm. In Germany an initiative has recently begun to build up a network for nature conservation advisory services for farms[15] (Keufer and van Elsen, 2002). The future task is to fit existing local structures concerned with agri-environmental topics to the European efforts of a co-operative rural development to form a local management for the agri-environment.

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14 Cross-compliance mean the bondage of the EU direct payments for farmers to their adherence to regulations concerned with environmental and nature protection, quality management, consumer protection and animal welfare (Council Regulation (EC) 1782/2003).

15 See also http://www.naturschutzberatung.info

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18. The digital user manual for the multicriteria assessment and optimisation method (MULBO)

Ralf Grabaum, Thomas Meyer, Julia Gerung, Torsten Wolf, Klaus E. Friedrich, Torsten Kildal, Vera Schreiner and Burghard C. Meyer
(Corresponding author: R. Grabaum, email: grabaum@olanis.de)

Abstract

The MULBO method (Multicriteria Landscape assessment and optimisation method, Meyer and Grabaum, 2003) can be considered as a Spatial Decision Support System. The usage of this method could improve planning processes significantly. For this reason, there is a need to make this method usable for the planning practice. Therefore, a digital interactive user manual has been developed as a part of the project IUMBO (Integrative Realisation of the Method of Multicriteria Assessment and Optimisation in the Querfurt Region) which was funded by the 'Deutsche Bundesstiftung Umwelt' (DBU).

The article describes the structure of this digital user manual and gives instructions how to use the method in the planning practice. The linkage of steps is described as well as the usage of GIS and optimisation software. Furthermore, some examples with a focus on different questions of planning are discussed.

The digital user manual of MULBO is currently only available in German, but translations into other languages are planned depending on the needs of interested users.

Key words
Landscape assessment, multicriteria optimisation, planning praxis, optimisation software, GIS

18.1 Introduction

The MULBO method (Multicriteria Landscape assessment and optimisation method, Meyer and Grabaum, 2003) which can be considered as a Spatial Decision Support System for Spatial Planning was developed in several scientific projects during the last years (Grabaum and Meyer, 1998; Grabaum *et al*., 1999; Bobert, 1999; Mühle, 2001). The main focus has been set on the GIS compatible integration of several landscape assessment methods (Marks *et al*., 1992; Hennings, 1994; Frede and Dabbert, 1999; Bastian and Schreiber, 1999) and on the development of the optimisation software LNOPT (Grabaum and Kildal, 2004). Several assessments dealing with planning questions were carried out during this period.

MULBO is a seven-stage method integrating different (in use and complexity) assessment methods, scenario technologies and the multicriteria optimisation. The scientific background to the development of MULBO was complex and it was necessary to apply time and resources to make the method practicable for daily use. That's why one goal of the IUMBO-Project (Integrative Realisation of the Method of multicriteria Assessment and Optimisation in the Querfurt Region), which was funded by the 'Deutsche Bundesstiftung Umwelt' (DBU), has been the development of an interactive user manual for MULBO which should be referred to the planning practice actors (authorities, planning offices, land owners, land users). This also includes general information about GIS-based assessments and the development and integration of biotic assessment methods (habitat assessments) into MULBO. One of the goals of MULBO has been the improvement of nature conservation planning.

The development of the user manual started in 2003 with the definition of a catalogue of requirements and has been finished at the end of 2005 with the release of the CD-ROM. To communicate the availability of the user manual, a system development workshop with potential users including a software training session will complete this part of the IUMBO project.

18.2 Structure of the digital user manual

The digital user manual contains six main menus which are described in more detail in the sub-menus. In the menu 'About this manual', the user receives starting information about the purpose, the target group, and the usage of the handbook.

The 'MULBO' menu gives an overview about the method, containing remarks about purpose, history and advantages of the method. Furthermore, the method is described in detail by means of screenshots and formulas describing the mathematical method of optimisation.

A detailed description of available assessment methods is located in a separate menu named 'Interactive Assessment Manual' due to the complexity of this method. Using three sub-menus the user can get information about abiotic, biotic and socio-economic assessment methods.

The 'Examples' menu deals with the description of three different case study areas where MULBO has been adapted. By using different levels of details the user can follow the workflow of the method.

A short description of the aims and partners as well as the realisation of the IUMBO project can be found in the 'IUMBO' menu .

A roundup of the manual is offered through the 'Resources' menu. It allows speedy access to all relevant information. This menu contains useful additional information like a description of the software including a demonstration version of the optimisation software LNOPT 2.0, a data wizard which is a collection of internet links to find available digital data, and galleries of maps and photos as well as a download area, a literature index, a glossary, and a source index.

The concept of the user manual is a two-way concept. Firstly, it is developed like a digital book with chapters where the user can go forward and backward page by page. Secondly, it uses the advantages of web applications with links and history functions. A simple navigation is possible using the sitemap (see Figure 18.1).

18.3 Description of the MULBO method

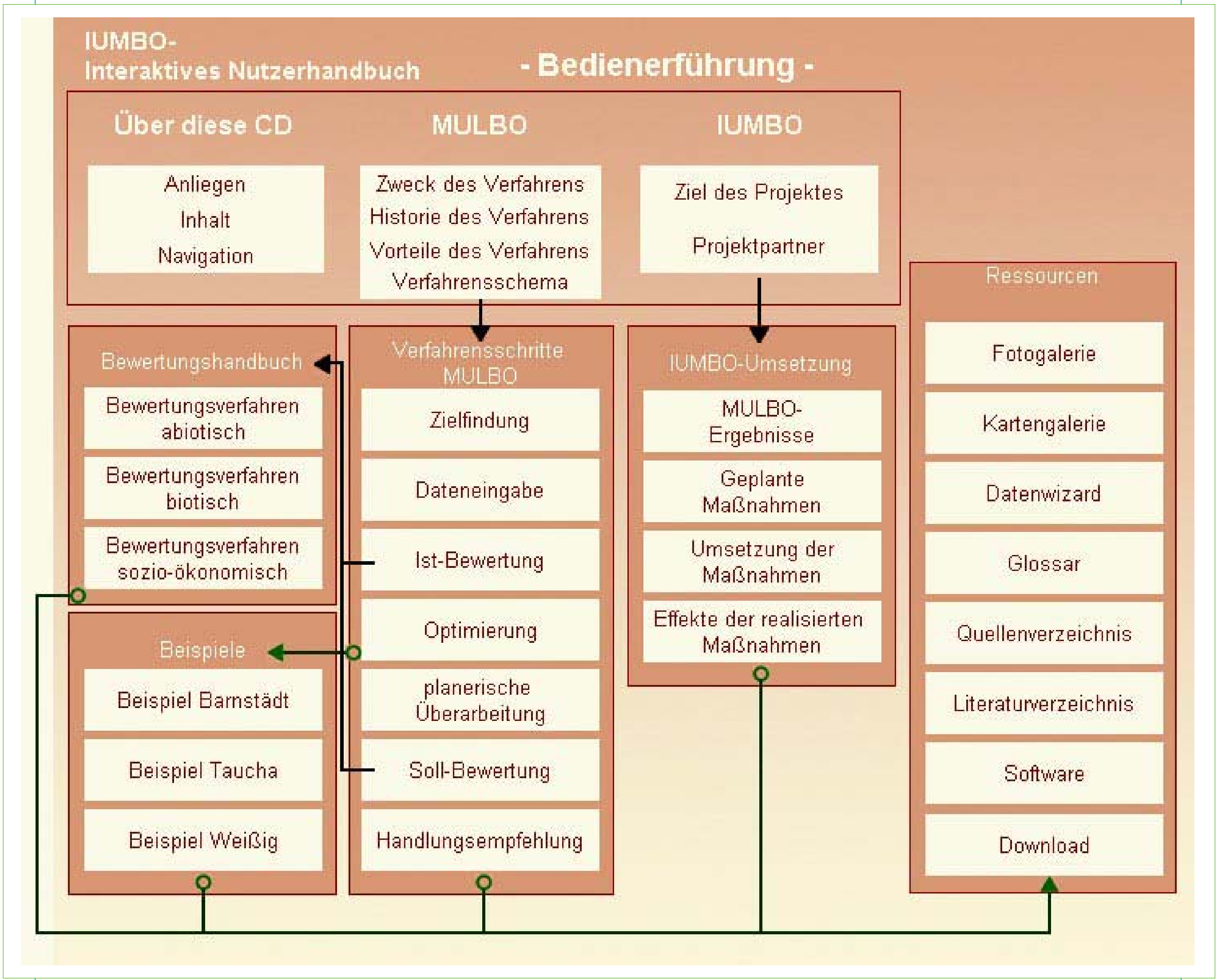
The description of the method is a major part of the user manual. After reading, the users should be able to adopt the method for their special planning purposes. MULBO is a seven-stage method including the following steps:

Goal definition:
The defining of goals is based on landscape analysis, local and regional planning targets and discussions with the stakeholders. The goals are described by landscape functions (based e.g. on the concept of nature functions by De Groot, 1992, 2006; De Groot *et al*., 2002,).

Choice of assessment methods, data input and construction of a data base:
The choice of assessment methods depends on the selection of relevant landscape functions. Once the assessment methods are chosen the need of data types can be pointed out and the database can be created using GIS.

First assessment:
The assessment of the actual state is needed to get information about the fulfilment of the chosen landscape functions. The most important assessment methods are described in the 'Interactive Assessment Manual' (menu assessment).

FIGURE 18.1. Sitemap of the digital user manual.



Multicriteria optimisation:
Based on defined scenarios and restrictions, optimal land use pattern are calculated to fulfil the chosen landscape functions in an optimal sense. Because the functions are conflicting the solution can be considered as an optimal compromise between the chosen functions.

Planning revision:
Additional information which are not applicable for optimisation (e.g. landscape aesthetics, visibility etc.) are post-processed in a draft of a future land use plan on the basis of the chosen compromise solution.

Second assessment:
The developed land use options can be assessed using the same methods as for the first assessment. Hence, a comparison of the fulfilment of functions in the actual state and the optimised solution is possible.

Delivery of land use options to the decision maker:
The results can be provided cartographically or statistically for the decision maker.

The concept of landscape analysis and landscape functions as a background for this method is well described in the menu. Furthermore, the landscape optimisation is described more detailed (including mathematical background). The assessment methods are not described in this chapter; they are put into the section 'Interactive Assessment Manual' described in the next section of this paper.

At any time, the user can choose the level of information. He/she can get an overview of the part of the method and more detailed information by following the links.

18.4 The Interactive Assessment Manual

This part of the digital user manual for MULBO is the most detailed. Here some of the most required assessment methods for 13 landscape functions (Gruehn and Kenneweg, 2002) are integrated. The menu has three sub-menus. The first describes abiotic functions, the second biotic (habitat) functions, and the third socio-economic functions.

In the section *abiotic functions* the following are explained: groundwater recharge, ground water protection, climate function, nitrate leaching, retention, soil erosion by water, soil erosion by wind, and filter capability.

In the section *biotic functions* the following examples are explained: habitat suitability for three species: corn bunting *Emberiza calandra*, hare *Lepus europaeus* and red kite *Milvus milvus*.

In the section *socio-economic functions* the following are explained: agricultural production function and recreation function.

At first, each function is defined using background literature. Also for each function a scheme is available (Figure 18.2 see over) showing the simplified way from basic data to the assessment results by presenting the assessment rules (formulas, tables, descriptions) and maps of each intermediate step and resulting maps (if available). Thus, the user gets an understandable overview about the complexity of the method. Figure 18.2 shows an example for the habitat assessment of the corn bunting. There are very complex methods like groundwater recharge assessment and methods with low complexity like agricultural production function.

If the user wants to receive more information, he/she gets detailed description of each method including all tables, description of data handling and relevant literature. So the user will be guided through the whole process of assessment and can adopt it for his/her own specific questions.

18.5 Field sites

Three examples are integrated in the user manual. The examples are different in content and in depth of description.

The main example is the example of the field site for the IUMBO-project, Barnstädt in Saxony-Anhalt (Mühle, 2001). Here, an intensively used agricultural landscape with high quality soil can be found. The main goals are the increase of biodiversity and the maintenance of agricultural production. Using this example, all steps of MULBO are fully described in detail. First of all, there is a landscape description including land use, soil, relief and climate. The subsequent goals are described using references from local and regional planning authorities. A list of data used is kept. From a set of assessments which were carried out the following are described: soil erosion by water, soil erosion by wind, ground water recharge, retention and production function. For the optimisation, three different scenarios are defined (15%-scenario, 30%-scenario and 7.5%-scenario) depending on the area of arable land (in percent) that has to be changed into new nature conservation landscape elements like extensively used grassland, woods, or hedges. With these scenarios the optimisation has been carried out using the software LNOPT 2.0 and calculating five different solutions by using different weightings. The results are listed in tables and plotted into maps. For further work, the equal weightings compromise (each considered function has the same priority) from the 7.5%-scenario was chosen. During the planning revision, linear structure elements were planned and some small areas were adapted. The result was assessed again using the same landscape functions. A comparison of the functional outcomes for the soil erosion by water function, the soil erosion by wind function, the retention function, and the production function shows the advantage of the method (see Figure 18.3, page 131, for the function soil erosion by water).

Two other examples are provided in the user manual. The example Taucha-Eilenburg in North-West Saxony is a more differentiated intensively used agricultural landscape with suburbanisation tendencies due to the close location of the city of Leipzig. The examples were used as a reference site for the IUMBO project. Assessments of regulation functions, recreation and production as well as habitat functions are presented and optimisations of regulation and habitat functions are included.

As another example the method was used in Dresden-Weissig (Bobert, 1999), a site with agricultural use, suburbanisation propensity and recreational potential. Here the suitability for housing was one of the criteria taken into account along with production and ecological functions.

All examples show the portability of the method to different regions and various land use planning issues.

18.6 Demonstration project: optimisation software

To learn more about landscape optimisation and how it works, a demo version of the software LNOPT 2.0 is implemented in the user manual. The software was developed by Grabaum and Kildal (2004). The implemented method (Dewess, 1985) is based on game theory, a branch of applied mathematics that uses models to study interactions (predicted and actual behaviour of individuals in games, as well as optimal strategies) with formalised incentive structures ('games'). The mathematical background was described in more detail by Grabaum (1996).

A test project is included containing GIS data from the IUMBO project. The user can define the functions and restrictions and can choose the weights for optimisation. An integrated map viewer shows the resulting land use options (Figure 18.4).

The software can be used for testing purposes. A full version of the software will be available in the near future.

18.7 Conclusion

The development of the digital user manual is complete. It is available on CD-ROM which can be ordered directly from the authors. It can also be downloaded from the internet (http://iumbo.olanis.de). If there is enough demand for languages other than German, translations will be undertaken.

There are different options for further developments of the method. Future steps and developments which should be available for practice will be integrated into the manual.

Making the digital user manual available for the public is likely to increase the number of land use projects in the field of spatial planning using the MULBO method. Such applications could be agricultural planning, landscape planning, or environmental impact assessments (EIA). As the example shows, the application of MULBO will lead to a greater optimisation of environmental and socio-economic functions, helping to make intensively used landscapes more sustainable.

FIGURE 18.2. Example of an assessment scheme including assessment rules (table) and resulting maps.

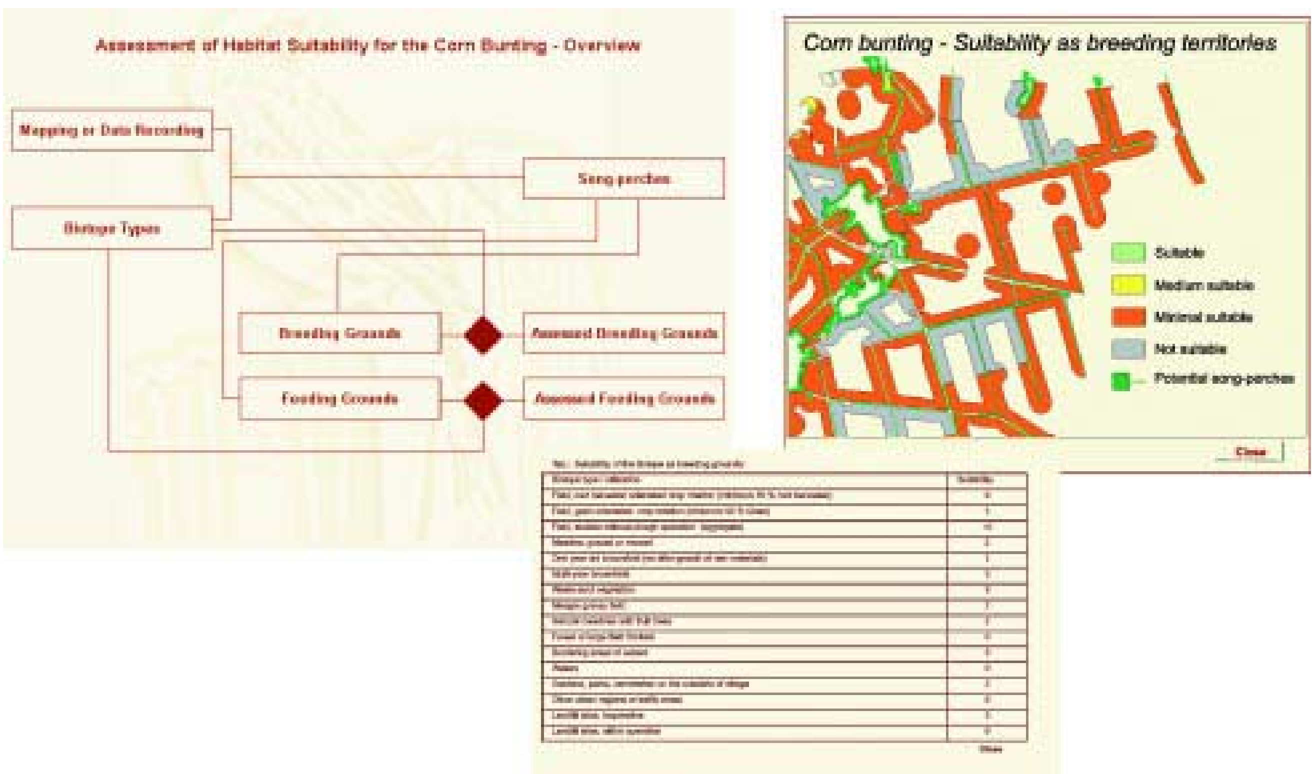


FIGURE 18.3. Comparison of the actual state and the MULBO option for the function soil erosion by water.

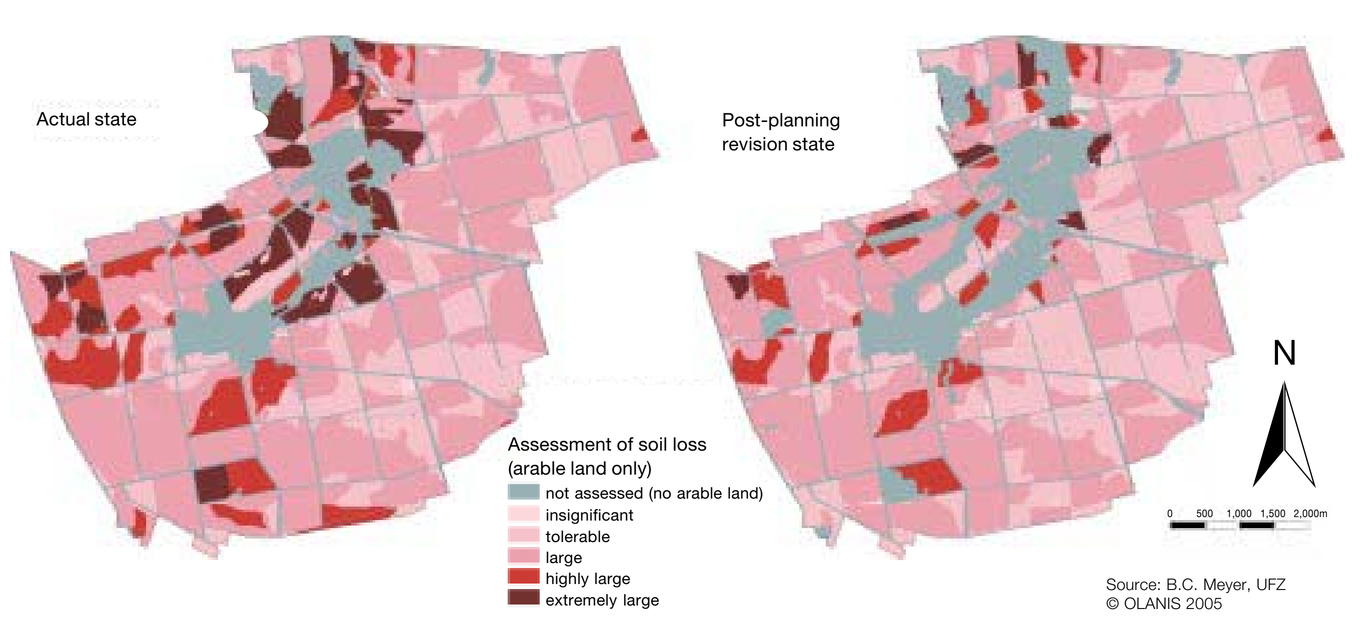
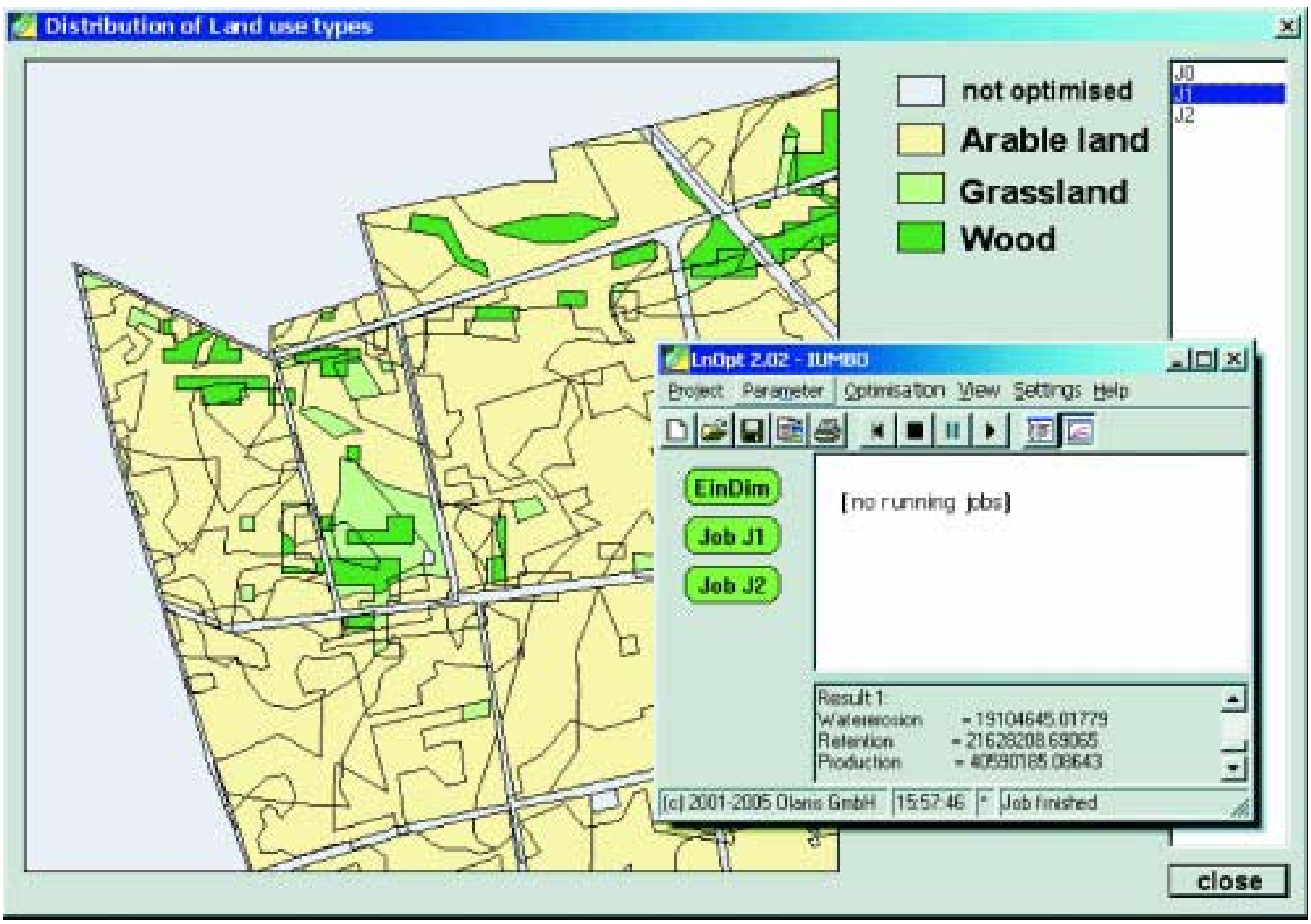


FIGURE 18.4. Output from the LNOPT 2.0 software calculating the demonstration project.



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19. Achieving integration of landscape values through multifunctional farm plans

Christine Schneider, Anna Peterson and Gary Fry
(Corresponding author: Ch. Schneider, email: christine.schneider@lpal.slu.se)

Abstract

Farmers require advice on how to best manage their land to enhance an increasing array of values. Integrating these values on farmland needs further research in the development of integrative theory as well as on how to operationalise the process in practice. This paper examines the potential for a design approach to achieve integrative farm plans. The plan process involved an iterative dialogue between farmers, professionals and researchers in developing a farm plan to enhance multifunctionality. Integration is viewed as the process of incorporating diverse values on farmland in order to achieve multifunctional aims. We made inventories of biodiversity, visual quality, recreation potential, and cultural heritage, on four farms in the county of Scania in southern Sweden. The results were integrated in a draft farm plan that was then communicated to the farmer with the aid of visualisations of spatially specific management proposals. The farmer could weight different values associated with specific landscape elements and take into account features important to himself and other stakeholders. The resultant plans enabled us to identify common conflicts and synergies. We also relate the plans to current agri-environmental grant aid in Sweden.

Key words
Aesthetics, agriculture, biodiversity, design, farmer participation

19.1 Introduction

The agricultural landscape within Europe has undergone profound changes. The intensification of agriculture on the one hand and the abandonment of marginal farmland on the other have led to the loss of many landscape structures and resulted in a homogenisation of the rural landscape (Jongman, 2002). These landscape changes have been driven by the aim to achieve a rational and profitable production of agricultural products. The rationalisation and intensification of farming practices have had a major impact on other landscape functions such as biodiversity, cultural heritage, recreation and landscape aesthetics.

Multifunctionality of farmland has become a central issue in landscape research (van Mansvelt 1997; Vos and Meekes, 1999; Brandt and Vejre, 2004). The different landscape functions and values have been identified and analysed (e.g. Hendriks *et al*., 1997; Clemetsen and van Laar, 2000; MacNaeidhe and Culleton, 2000; Kuiper, 2000; Dolman *et al*., 2001; Dramstad *et al*., 2001; Højring 2002). To resolve the complex issue of how to manage landscapes for different interests an interdisciplinary approach is needed (Antrop, 2000; Palang *et al*., 2005). However, it has been shown that interdisciplinary landscape research involves overcoming problems related to the lack of methods, theory, and common language (Fry, 2001; Haugaard Jakobsen *et al*., 2004; Tress *et al*., 2005).

We chose the farm level to study potentials and limitations in the integration of four different landscape values (biodiversity, cultural heritage, recreation, and aesthetics). The importance of involving farmers and understanding their decision-making are seen as essential in finding management solutions to support multifunctional farmland (Bosshard, 1997; Primdahl, 1999; Gravsholt Busck, 2002; Alumäe *et al*., 2003; Bohnet *et al*., 2003; Koontz, 2003; Søderkvist Kristensen, 2004).

19.2 Methods

19.2.1 Study area

Four farms situated in Scania (Skåne), the most southern province of Sweden, were chosen for this study. The size of the farms (without leased fields) varied between 40 and 125 ha. Farms A and B were situated in the municipality of Lund close to growing settlements of 4,000 and 6,000 inhabitants respectively. Farm C was directly adjacent to a town of 25,000 inhabitants. Farm D was in a more remote location close to the sea in an area that is a popular tourist attraction in spring and summer. Farm A was situated in a small-scale agricultural landscape, whereas the other three farms were in the more intensively used agricultural areas of Skåne. Farm A was recommended by the regional council as the owner was interested in participating in the study. The other three farms were selected by a farmer's organisation interested in combining economy and ecology at the farm level to achieve sustainable production. The farmers knew that the farm plans were an exercise and would not necessarily be put into practice.

19.2.2 Surveys

At the first meeting with the farmer, the focus was his view of the farm, its' values, history, production and also future prospects (Figure 19.1 see over). The farmer was asked to point out areas where he wished to make changes or areas that were especially important to him.

The farms were then surveyed for four different landscape values: biodiversity, cultural heritage, recreation, and aesthetic quality. A biologist conducted the survey, analysis, and evaluation and produced a farm plan for biodiversity. A landscape architect did the same for the other three values.

The biological field surveys included the mapping of land-uses and all semi-natural habitats and evaluating their quality. For the cultural survey, the farm area was investigated for cultural remnants such as cultural monuments, landscape pattern and place names. The recreational survey comprised the mapping of the existing infrastructure for recreation – on the investigated farms this was mostly roads and paths used for walking, cycling, and horse riding as well as areas with public access (mainly grasslands). The farmer, and in some cases visitors, were also asked about recreation patterns on the farm and existing conflicts. For the visual aspects, edges, rooms, spaces, nodes, landmarks and views were mapped.

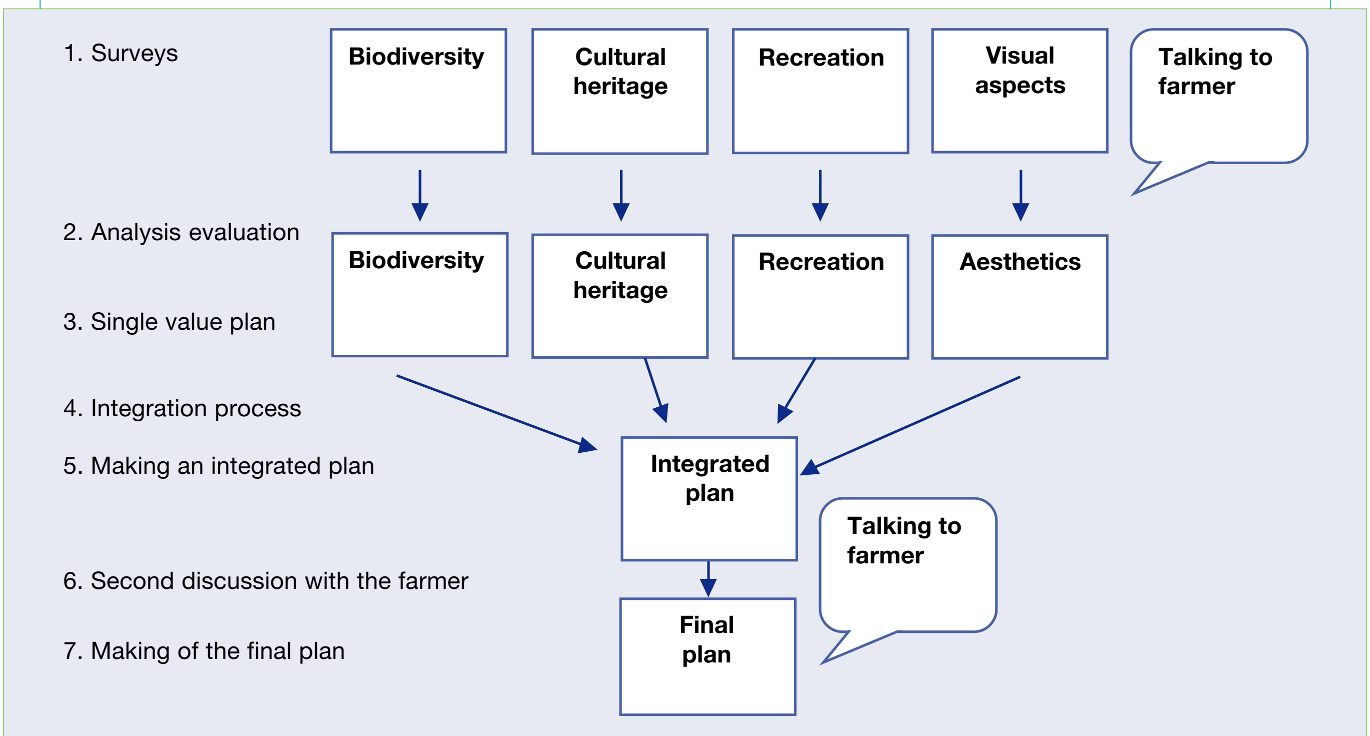
In addition to the new field inventories, existing material and surveys were considered, these included maps of valuable semi-natural grasslands and wooded pasture, aerial photographs, maps, and photographs of the farm supplied by the farmers. The plans of the municipality (Kommunens översiktsplan) were a source of information on the context of the farms and any planned development e.g. housing areas, road projects and improvement of access to agricultural land for recreation as well as biodiversity plans in the municipality.

19.2.3 Process of designing farm plans

After the inventories were completed, an evaluation was carried out on the quality of existing values and their potential for improvement. Features of special importance or those that were expected but missing on the farm were identified. For the evaluation of biological values, for example, the areas most important for maintaining biodiversity at the farm level were identified. On two farms (A and D) these were large areas of semi-natural, unfertilised grasslands. On Farm C these were reed areas. The land use of this farm was very intensive and the farm area large, so here it was important to improve the biological infrastructure and not only preserve the existing values. On Farm B, other than valuable edge habitats, there were few areas of importance for biodiversity, but the farm was adjacent to two nature reserves (grassland and woodland). Thus the need to improve the farm area for biodiversity was seen as a lower priority. For the evaluation of cultural traces, their age, condition and rarity were important criteria. Regarding the evaluation of the farm area for recreation, factors such as the proximity and size of nearby settlements, existing patterns and type of recreation were examined. Aesthetic evaluations were based on knowledge about public preferences and an expert judgement of what was beautiful.

Based on the inventories and their analysis, we developed a farm plan for each of the landscape values surveyed with recommendations for preservation, management and development. For the integrated farm plan, a design concept for the farm was identified based on the farm's situation in the landscape, its values and needs. Based on the design concept, each aspect of the single value plans was discussed between the two professionals (biologist and landscape architect). The

FIGURE 19.1. The process of designing a farm plan integrating four landscape values (biodiversity, cultural heritage, recreation, aesthetics).



integration of different landscape values was achieved through an iterative process between these professionals. By integration we mean the active process of incorporating diverse values on farmland in order to reach multifunctional aims. The integrated farm plan was made using a sketching technique to invite the farmer to make changes or visualise new solutions (Stacy, 1999). It has been shown that sketching and verbal descriptions make room for and promote flexibility (Eckert *et al*., 1999). A final plan was made based on the farmers input.

19.3 Results

The inventory of farms showed that they varied very much regarding the selected landscape values. During the integration process of the landscape values, both conflicts and synergies became evident. Some solutions in the farm plan lead to a win-win outcome were two or more landscape values were improved. In other situations, decisions had to be made where only one value could be supported (winner takes all). Compromises were often possible where the original ideas were modified, e.g. moved to another place to avoid conflicts. Table 19.1 shows typical examples of synergies (lower left part of the table) and conflicts (upper right part of the table) between the different landscape values. Figure 19.2b page 137 shows the integrated farm plan of Farm C with the farmer's comments indicated.

On Farm C the major challenge was to cope with the increase in recreation pressure, resulting from urban pressure on the farm with its location at the edge of a town of 25,000 inhabitants, while at the same time maintaining or enhancing the biodiversity values on the farm. The major recreation activity is walking, often as daily walks with the dog, and some horse riding. Possibilities for this type of recreation were increased. Additionally, the former common land (no.1 on Figure 19.2), which today is a set-aside area with sown grass, would be converted to permanent grassland. The farmer already cuts a path along the edges for visitors. In our farm plan about half of the grassland would be cut at midsummer time for the traditional celebration of the midsummer feast and for recreation during the rest of the season. The area has been used as common land in the past (for grazing), and our proposal would recreate common land, even if the land use was not the same (to recreation). Since increased access can lead to the disturbance of wildlife, the wooded areas and the reed areas would not be made more accessible (current access is almost impossible due to wetness). Improvement for wildlife would be planting hedges, reconstructing the water course, enlarging grazing areas, broadening arable edges, and converting further set-aside to permanent grassland. All these measures would increase landscape diversity and improve the recreational value of the landscape. In the design of new landscape elements, aesthetic aspects were considered through their form, structure and viewpoints. The most important cultural remnants on the farm are Bronze Age grave mounds, which are protected by law and managed by the regional council. The preservation of the typical openness of the landscape of the flat lands of this part of Sweden has not been given priority in order to fulfil other needs in the landscape.

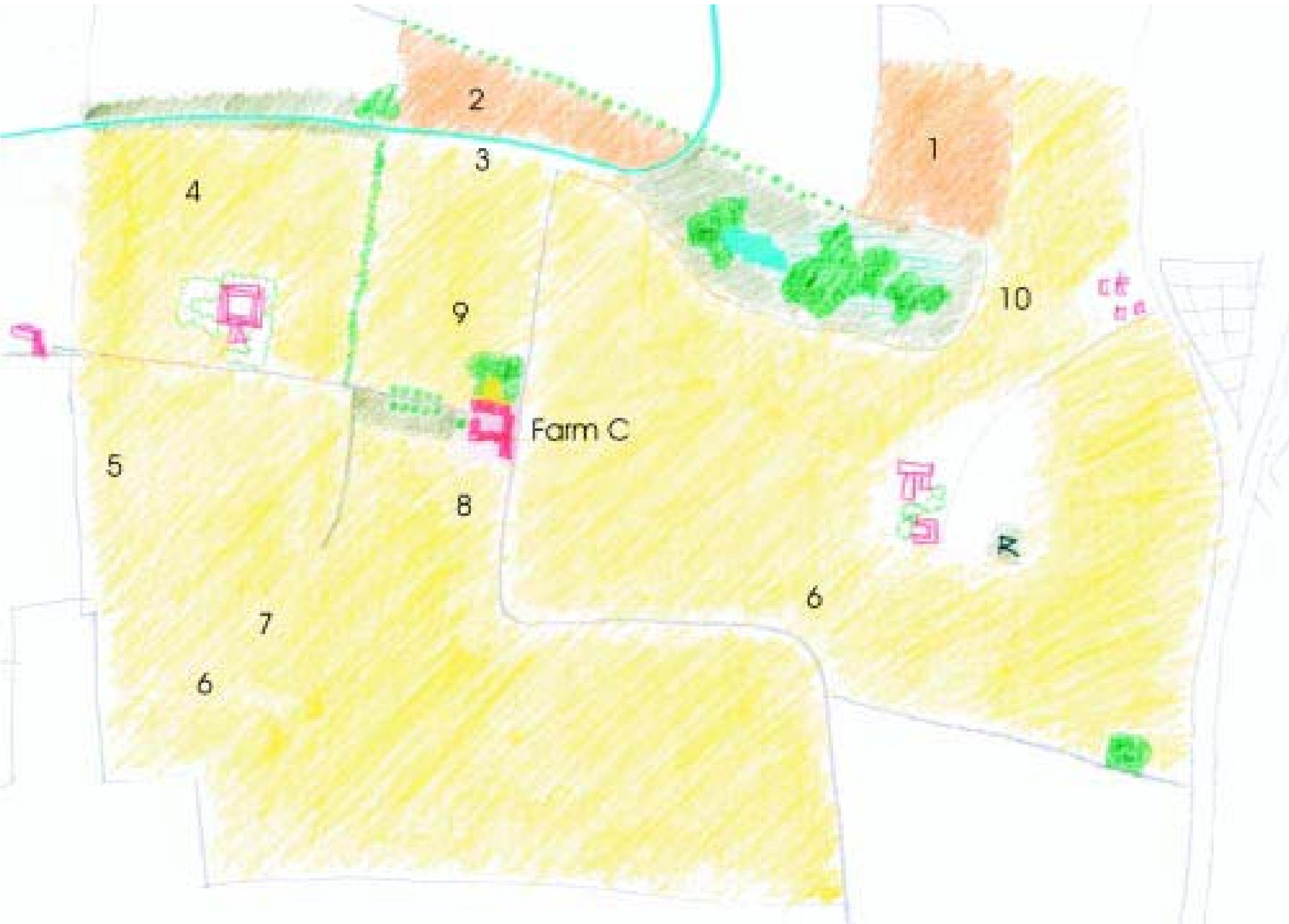
19.4 Discussion

The integration process revealed that some landscape values can be enhanced by improvements to other values but the benefit is not always reciprocal. For example, a farm often becomes more attractive to visitors by the addition of measures for improving biodiversity, but wildlife does not always profit from increased recreation. Another observation was that landscape values that are usually considered beneficial to each other, may be difficult to reconcile at the detailed level. For example, the grazing management of semi-

TABLE 19.1. Typical synergies and conflicts between landscape values that became apparent in the integration process for making farm plans on four farms in Scania, Sweden. Example of synergies are in the lower left corner of the Table (below the line), examples for conflicts are in the upper right corner of the Table (above the line).

		Conflicts			
		Biodiversity	**Culture**	**Recreation**	**Aesthetics**
Synergies	**Biodiversity**		Clearance of vegetation on cultural monuments	Disturbance through access	Untidy impression of natural habitats
	Culture	Preservation of traditional management, old structures		Damage through access	Authenticity, removal of vegetation
	Recreation	Experience of nature, diverse landscape	Experience of historicity and identity (coherence)		Visual disturbance
	Aesthetics	Beauty, variation, naturalness	Variation, views	Experience beauty	

FIGURE 19.2a. Farm C (core area). Map showing current land use. Suggested landscape changes are numbered.



Examples of conflicts that arose during the development of an integrated farm plan:

1. Transforming existing set-aside to permanent grassland: biodiversity versus recreation, what will be the impact of increasing access?
2. Transforming existing set-aside to permanent grassland: biodiversity versus recreation, impact of increased access.

4–6. Planting new hedges: cultural history versus biodiversity and aesthetics, the area has been open and without hedges for many centuries, adding hedges changes this aspect of cultural history and the character of the area, but improves other landscape values.

5. Making hedges gappy: aesthetics versus biodiversity, allowing for views, but interrupts the hedge.
6. Curved hedges: aesthetics versus cultural history, new uncommon features create a visual barrier towards the new housing area.
10. Creating green ways: recreation versus biodiversity and cultural history, allowing access, but causing disturbance close to reed beds and creating new uncommon landscape features.
11. Woodland, reed areas and wet grasslands: biodiversity versus recreation, question on allowing access.

Examples of non-conflicting values when developing an integrated farm plan:

3. Restoring the natural course of the brook in its meandering form
7. Producing a flower-rich field.
8. Planting avenues.
9. Re-design of garden.
12. Increasing the area of pasture.
13. Increasing the area of pasture.

FIGURE 19.2b. Integrated farm plan of Farm C and the farmer's comments. Suggested landscape changes are numbered.

1. Existing set-aside (former commons) with new function: permanent set-aside, parts with short vegetation for easy access, parts with tall meadow vegetation.
2. Existing set-aside, cut once a year: development to meadow vegetation, cut once a year.
3. Restoring the natural course of the brook in its meandering form.
4. New hedge.
5. New hedge with gaps for views.
6. Grassy banks with tree and bush vegetation.
7. Flower-rich field.
8. New tree lines.
9. Re-design of garden with new tree-groups.
10. Greenways for access.
11. Keeping the semi-natural vegetation with trees, pond and reed beds in present state.
12. Grazing of the existing but currently unused pasture.
13. Fencing and grazing of the existing grass vegetation.

The farmer did not want to put features (6) grassy banks or (7) flower-rich fields into practice. He wanted the greenway 10a moved to the east to follow the existing road. He would plant hedge (5), if the neighbour agreed and he got financial help for the planting. The farmer would allow the re-shaping of the brook (3), but would not want to carry out the task himself or financially support it. He was interested in the tree plantings (8) and (9) and saw no problems with managing set-aside areas (1) and (2). However, in re-establishing grazing in old pastures (12) and (13) the farmer had a problem finding grazing animals, it worked in some years, but not in others.

natural pastures benefits both biodiversity and cultural heritage. However, typical management recommendations aimed at conserving pasture (short sward, few bushes, and single trees rather than tree groups) might not always be optimal for biodiversity. Discussion with the farmers revealed great difficulties planning for the future due to insecurities in market prices of agricultural products and level of subsidies. In principle, they were open to changes on their farms but many suggestions in the plans were not economically practical. The Swedish subsidy system that pays farmers for certain landscape elements (such as hedges, tree lines, stone walls from before 1940) was seen as a barrier to the implementation of environmental plans. New plantations of trees are not supported by the grant system and farmers see this as a problem. On the other hand, the set-aside scheme offers opportunities for the improvement of biodiversity or recreation on farms (e.g. farmers could establish non-permanent greenways open for access in intensively used agricultural areas). Farmers have often taken an equivalent area of land out of production, but manage this as grassland and cut it once a year for aesthetic reasons. These grasslands could become a valuable addition to the existing wildlife biotopes in the long term (perhaps with the help of wildflower seeds) especially on farms that have no semi-natural grassland today. The farm level is where management decisions are made, subsidies are paid and the scale allows for discussion on detailed management options (Bosshard, 1997; Hendriks *et al*., 1997; Smeding and Joenje, 1999; Gibon, 2005; Kuiper, 2000). Nevertheless, it is clear that for to optimise landscape values the farm scale is often not large enough (ecological networks, footpaths for recreation, views).

The integration process between the two professionals in this study was characterised by many of the difficulties stated by other studies, including different research traditions, different language and different methodology (Dramstad *et al*., 2001; Fry, 2001). However, the small research group allowed for an intensive exchange on critical issues and a deeper understanding between professional viewpoints. The willingness to enter into compromise is seen as one of the key elements in the integration process and for finding the best solution for developing multifunctional farm plans.

19.5 Conclusion

We conclude that farm plans can be a valuable tool for integrating landscape values such as biodiversity, cultural heritage, recreation and aesthetics. At the farm level, synergies and conflicts between the different landscape values become apparent and detailed management solutions can be developed. Farmer participation is essential because the farmer has detailed and contextual knowledge of his land and has to be motivated to set the farm plan into practice. Our results indicate that multifunctionality on farms in Sweden could be improved through two measures. The first would be to include a wider range of landscape values (e.g. recreational and aesthetic aspects) in the existing advisory system for farmers. Secondly, the existing subsidy system seems to work better for farms with existing values that should be preserved, rather than for improving farms with few existing values. On farms with low landscape values, farmers could be encouraged to use set-aside areas for serving several functions (greenways, grasslands). Incentives for new hedge and tree planting would also be valuable.

The challenge for the future will be to integrate an even wider range of values on farmland, to be able to identify synergies but also the limitations of integrated plans where difficult decisions have to be taken in selecting between competing landscape values.

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20. Agriculture and biodiversity: assessing the contribution of agricultural and structural parameters to field margins plant diversity. A case study in a crop field region (Centre region, France)

Francesca Di Pietro (email: dipietro@univ-tours.fr)

Abstract

In intensively used agricultural regions, because of the scarcity of grasslands, field margins play a crucial role in allowing species dispersion and thus in enhancing biodiversity. In this paper we explore the relationships between plant diversity of field margins and some agricultural and structural parameters, in an intensively used agricultural region, the 'Gâtine lochoise' (France, Centre region). In order to deal with this issue, several units have been studied: farms, fields, field margins. The contribution of 31 variables to field margins' botanical composition of 267 margins has been analysed using Canonical Correspondence Analysis (CCA), and has led to a hierarchy of relevant variables. We emphasise the role played by some agricultural variables, especially spatial pattern of farms, farm size, and crop rotations involving grasslands on the one hand, and by some structural parameters such as forest edges on the other hand. The role of landscape factors, such as density and size of woodlots, is suggested.

Key words
Field margins, flora, spatial pattern, farming activities, crop rotation

20.1 Introduction

Plant and landscape diversity is generally studied in natural or little-managed ecosystems such as wetlands, marsh, Mediterranean, or mountain landscapes, while crop fields regions are usually devoted to agricultural production and thus considered as monofunctional landscapes of little interest from an ecological point of view. However, most rural regions are ordinary, cropping regions with no strong natural features and weak physical constraints to modern agriculture. In intensively used agricultural regions, one of the main challenges of sustainability is thus to make agricultural activities and environmental care convergent. In that kind of landscapes, fields are generally cropped and permanent grasslands are rare; field margins are thus an important support to plant biodiversity (Marshall, 2002).

The replacement of perennial species by annuals in field margins is related to changes in land use (notably loss of grasslands) and to more drastic margin' management, as herbicides spraying and roller chopping, instead of mechanical defoliation like mowing or grazing. Moreover, field margins management by farmers is linked to the perception of margins as a source of weeds (Marshall and Arnold, 1995). However, some authors suggest better control of some weeds such as *Avena* spp. in grassy field margins sown with perennial species and managed by mowing (Smith *et al*., 1999); they recommend to sow uncultivated buffer strips at the edge of cultivated fields and forest edges and, to a lesser extent, hedgerows, in order to reduce the use of herbicides and the impact of forest species on cultivated fields (Boutin and Jobin, 1998). Therefore, field margins flora depends on specific management practices (like mowing, grazing, roller chopping, herbicide spraying) linked to agricultural practices in the field itself, as crop rotations (Le Coeur *et al*., 2002), and to farms diversity.

In other respects, margins flora depends on margins physical structure (type and width of the boundary between the field and its adjacent land cover, presence of ditches, etc. Marshall *et al*., 1996). If agricultural practices are related to the farming activities themselves, the margins physical structure is also related to global land management at the local scale and possibly influenced by public policies and land planning run by local communities.

In this study, we examined the diversity of the botanical composition of field margins in an intensively used agricultural region with regard to some driving factors such as farming diversity and margins' physical structure: our main objective is thus to assess the contribution of both, agricultural and structural parameters to field margins botanical composition, and particularly weeds and annual vs. perennial species.

20.2 Material and methods

20.2.1 Area description

This work was carried out in the upper area of the Olivet basin: the Estang river basin, a small river basin (35 squared kilometres wide) notched in a plateau (Montrésor plateau) of an intensively used agricultural region, the 'Gâtine lochoise' (France, Centre region). This territory is probably representative of most of the farming landscapes in Central France, because it is composed of a mosaic of crop fields and forested patches of different size: large private or public forests, mainly in the upper basin and river bottoms, and smaller woods, generally owned by farmers and scattered all over the territory.

We addressed three levels of organisation of agriculture and environment relationships: the farm and the field, two levels of organisation required for assessing agricultural diversity, and the field margin and its local surroundings, a level required for assessing structural and plant diversity.

20.2.2 Farms and fields features and variables

The Estang river basin is used by 15 farms: 10 crop farms and five dairy farms. A farms survey has been carried out in order to collect data on the main features of farms (size, farming system) and of their fields, including land use (crop rotations and permanent land use) and field size, and location. We selected 38 fields representing the whole fields of three dairy farms, showing different degrees of intensification, and 31 fields representing the whole fields of one larger cereal farm. In this work, four variables were selected in order to describe the agricultural diversity of farming: two variables at the farm level (farm size and farm land fragmentation; see Table 20.1) and two variables at the field level (field size and land use). Field size spreads from 0.36 to 25.75 hectares; the main land uses and crop rotations are shown in Figure 20.1.

TABLE 20.1. Farm size and farm land fragmentation. Farm land fragmentation is assessed by the number of fields per hectare.

Farm	Farming system	Farm size (hectares)	Farm land fragmentation (no. of fields / farm size)
A	Cereal production	383.68	0.10
B	Dairy production	57.74	0.23
C	Dairy production	154.29	0.14
D	Dairy production	84.00	0.14

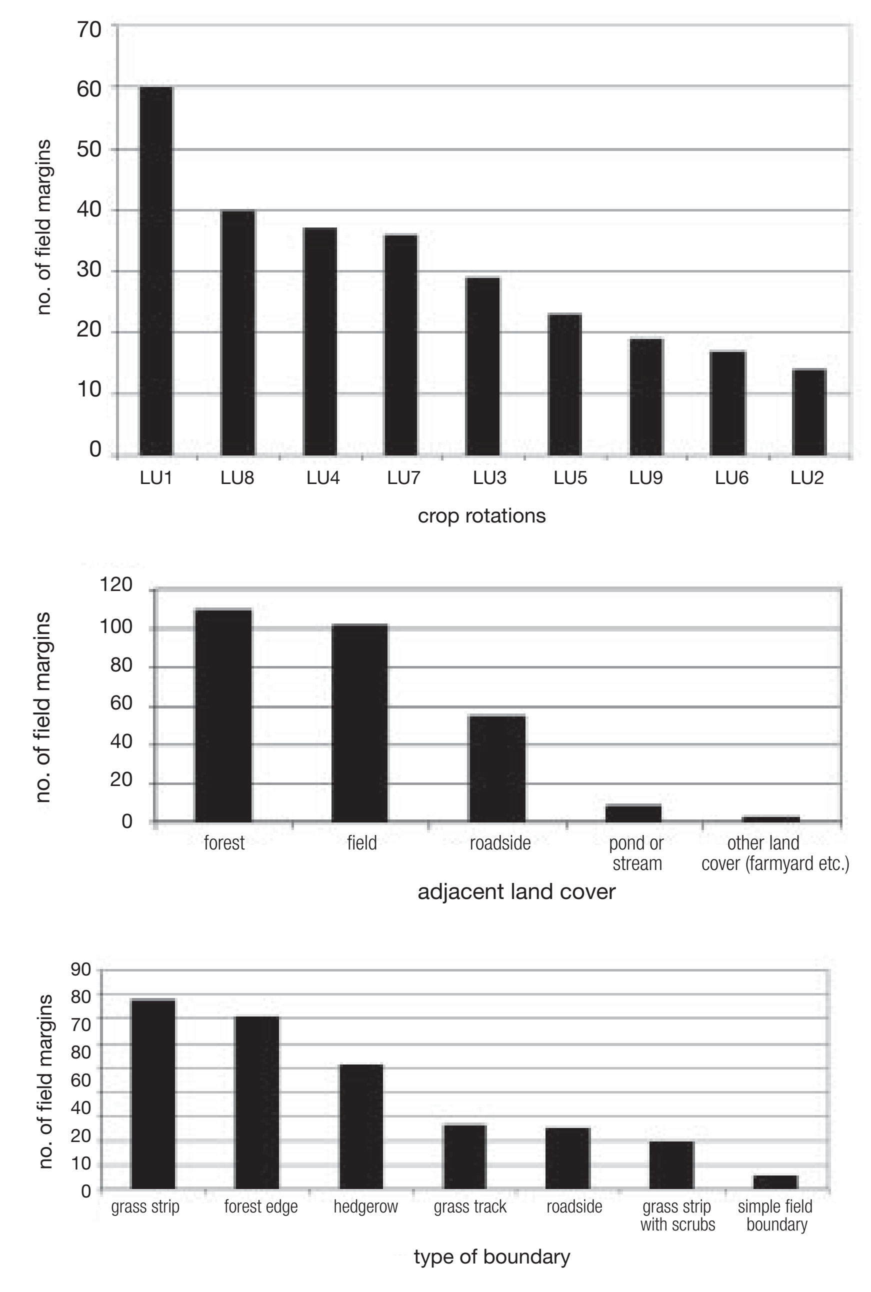


FIGURE 20.1. Main features of studied field margins (total: 267 field margins): land uses and crop rotations, types of boundary, adjacent land covers. For variable's names please see Table 20.4.

20.2.3 Field margins features and variables

The whole field margins of the above-mentioned farms were surveyed: 267 samples: 160 margins in dairy farms, and 107 margins in the crop farm. The field margins' survey involved a botanical survey of plant species abundance of 25 m-sections, according to the methodology used by Le Coeur *et al*. (2002), and a structure survey. The latest involved data collection of physical characteristics of field margins such as margin's width (varying among 0.20 and 12 m), width and height of the wooded and shrub layers (Table 20.2), presence and characteristics of a ditch bordering the field margin (46 field margins), adjacent land cover (field, forest, road, pond or stream, farmyard and other land covers), boundary type (hedgerow, forest edge, roadside, grass field margin, grass field margin with scrubs, grass track, simple field boundary). The main adjacent land covers and boundary types of field margins are shown in Figure 20.1.

Only herbaceous species have been analysed in this paper; rare species (present in less than 5% of the samples) have not been taken into account in this analysis, in order to focus on the structure of the vegetal community. Table 20.3 (see page 143) shows the list of the 112 analysed species.

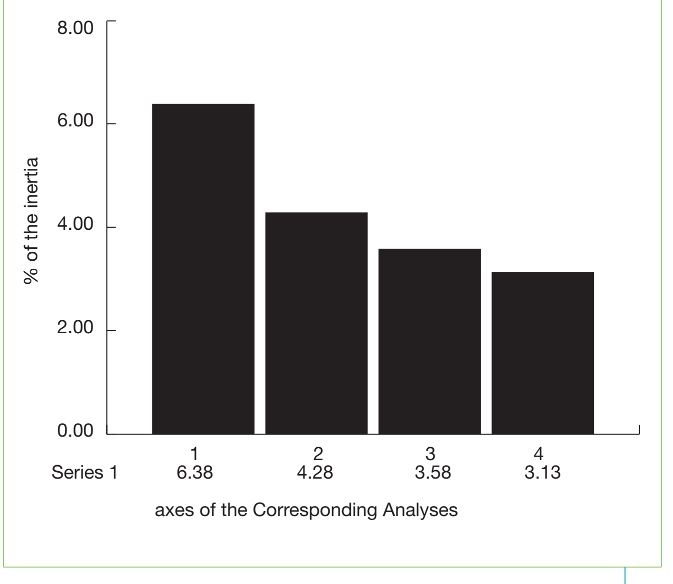
20.2.4 Methods of data analysis

We used Correspondence Analysis (CA) in order to analyse plant diversity of field margins, and Canonical Correspondence Analysis (CCA) in order to measure the contribution of agricultural and structural variables to plant diversity of margins (ter Braak, 1986; ter Braak, 1987). The whole variables are shown in Table 20.4 (see page 144). The programme used is Canoco 4.5 (ter Braak and Smilauer, 2002).

TABLE 20.2. Main values of distribution of width and height of tree (above 4 mt height) and shrub (1–4 mt height) layers. Width has been considered as the part of the canopy going beyond the forest or hedgerow toward the field margin.

	Tree layer width	Shrub layer width	Tree layer height	Shrub layer height
Min (metres)	0.3	0.2	5.0	1.0
Max (metres)	6.0	3.0	27.0	4.0
nb	*87*	*141*	*104*	*141*

FIGURE 20.2. Eigenvalues of the first four axes of the Correspondence Analysis compared to the total inertia: percentage of the total inertia explained by each of the first four axes.



20.3 Results

20.3.1 Diversity of botanical composition of field margins

The diversity of the botanical composition of field margins was analysed by a Correspondence Analysis (CA); the first three axes explain 14.20% of the total variability (Figure 20.2). Figure 20.3 (see page 145) shows the species mainly correlated to the first axis and their position on the ordination diagram: species present in the negative part of the axis mainly occur in light (meadow and crop fields) habitats while species present in the positive part of the axis mainly occur in forest habitats. Figure 20.4 (see page 146) shows the species mainly correlated to the second axis and their position on the ordination diagram: species present in the positive part of the axis mainly occur in xerophile habitats and are generally intolerant to nitrogen enrichment. Figure 20.5 (see page 147) shows the species mainly correlated to the third axis and their position on the ordination diagram: species present in the positive part of the axis are annual species and weeds.

20.3.2 Contribution of farming activities and field margin structure to field margins' plant diversity

In order to assess the contribution of agriculture and field margin structure on field margins' plant diversity, we used a Canonical Correspondence Analysis (CCA) of agricultural and structural variables (31 variables, see Table 20.4 page 144) over field margins' botanical composition. The selected variables explain 18.81% of the variability of the botanical composition of field margins. Figure 20.6 (see page 147) shows the hierarchy of variables according to their explanative power. Eighteen of the 31 variables are statistically significant according to the Montecarlo permutation test. Only crop rotations involving permanent or temporary grasslands (LU4, LU5, LU7, LU8, LU9) are statistically significant. None of the variables describing the adjacent land cover are statistically significant according to Montecarlo test. The most explanatory variables are structural ones: tree and shrub layers height and tree layer width, followed by farm size, which is the most explanatory agricultural variable.

TABLE 20.3. The 112 herbaceous species of field margins, present in more than eight samples (5% of the samples) (nomenclature: *Flora Europaea*).

	Abbreviation	Species
1	ACMM	*Achillea millefolium*
2	AGCA	*Agrostis capillaris*
3	AGEE	*Agrimonia eupatoria*
4	AGST	*Agrostis stolonifera*
5	ALMY	*Alopecurus myosuroides*
6	ALVI	*Allium vineale*
7	ANAR	*Anagallis arvensis*
8	ANOD	*Anthoxantum odoratum*
9	APAR	*Aphanes arvensis*
10	AREL	*Arrhenatherum elatius*
11	ARMA	*Arum maculatum*
12	ATPA	*Atriplex patula*
13	AVSA	*Avena sativa*
14	BRCO	*Bromus commutatus*
15	BRHH	*Bromus hordeaceus*
16	BRPI	*Brachypodium pinnatum*
17	BRSE	*Bromus secalinus*
18	BRST	*Bromus sterilis*
19	CABU	*Capsella bursa-pastoris*
20	CASI	*Carex spicata*
21	CEFT	*Cerastium fontanum*
22	CEGL	*Cerastium glomeratum*
23	CENI	*Centaurea nigra*
24	CESP	*Centaurea* sp.
25	CHAA	*Chenopodium album*
26	CHPO	*Chenopodium polyspermum*
27	CHTE	*Chaerophyllum temulem*
28	CIAR	*Cirsium arvense*
29	CIVU	*Cirsium vulgare*
30	COAR	*Convolvulus arvensis*
31	COCA	*Conyza canadensis*
32	CRCA	*Crepis capillaris*
33	CRSE	*Crepis setosa*
34	CRUL	*Cruciata laevipes*
35	CUBA	*Cucubalus baccifer*
36	DACC	*Daucus carota*
37	DAGG	*Dactylis glomerata*
38	ELCA	*Elymus caninus*
39	ELRR	*Elymus repens*
40	EPTT	*Epilobium tetragonum*
41	EQAR	*Equisetum arvense*
42	FEAA	*Festuca arundinacea*
43	FEHE	*Festuca heterophylla*
44	FERU	*Festuca rubra*
45	GAAP	*Galium aparine*
46	GAMO	*Galium mollugo*
47	GAVR	*Galium verum*
48	GEDI	*Geranium dissectum*
49	GEMO	*Geranium molle*
50	GERO	*Geranium robertianum*
51	GEUR	*Geum urbanum*
52	HESS	*Heracleum sphondylium*
53	HOLA	*Holcus lanatus*
54	HOMM	*Holcus mollis*
55	HYHU	*Hypericum humifusum*
56	HYPE	*Hypericum perforatum*
57	HYRA	*Hypochoeris radicata*
58	JUBU	*Juncus bufonius*
59	KIEE	*Kickxia elatine*
60	LACC	*Lapsana communis*
61	LAHI	*Lathyrus hirsutus*
62	LAPR	*Lathyrus pratensis*
63	LAPU	*Lamium purpureum*
64	LASE	*Lactuca serriola*
65	LEVU	*Leucanthemum vulgare*
66	LOCO	*Lotus corniculatus*
67	LOMU	*Lolium multiflorum*
68	LOPE	*Lolium perenne*
69	MAPE	*Matricaria perforata*
70	MYDD	*Myosotis discolor*
71	PHPP	*Phleum pratense*
72	PLLA	*Plantago lanceolata*
73	PLMM	*Plantago major*
74	POAN	*Poa annua*
75	POAV	*Polygonum aviculare*
76	PONE	*Poa nemoralis*
77	POPE	*Polygonum persicaria*
78	POPR	*Poa pratensis*
79	PORE	*Potentilla reptans*
80	POTT	*Poa trivialis*
81	PRVE	*Primula veris*
82	PRVU	*Prunella vulgaris*
83	PULO	*Pulmonaria longifolia*
84	RAAC	*Ranunculus acris*
85	RARE	*Ranunculus repens*
86	RARR	*Raphanus raphanistrum*
87	RASA	*Ranunculus sardous*
88	RUAC	*Rumex acetosa*
89	RUCR	*Rumex crispus*
90	RUOO	*Rumex obtusifolius*
91	SEJA	*Senecio jacobea*
92	SEVU	*Senecio vulgaris*
93	SOAY	*Sonchus asper*
94	STGR	*Stellaria graminea*
95	TAOF	*Taraxacum officinale*
96	TOJA	*Torilis japonica*
97	TRAE	*Triticum aestivum*
98	TRDU	*Trifolium dubium*
99	TRHH	*Trifolium hybridum*
100	TRPR	*Trifolium pratense*
101	TRRE	*Trifolium repens*
102	URDI	*Urtica dioica*
103	VEAR	*Veronica arvensis*
104	VECC	*Veronica chamaedrys*
105	VEOF	*Verbena officinalis*
106	VEPE	*Veronica persica*
107	VESS	*Veronica serpyllifolia*
108	VICH	*Vicia hirsuta*
109	VISN	*Vicia sativa* ssp. *nigra*
110	VISS	*Vicia sativa* ssp. *sativa*
111	VITE	*Vicia tetrasperma*
112	VUBR	*Vulpia bromoides*

TABLE 20.4. Explanatory variables: 18 structural variables and 13 agricultural variables; y/n = presence / absence.

		Variable	Abbreviation	Unit
Structural variables	1	Field margin width	LARG	metre
	2	Shrub layer width	AULARG	metre
	3	Shrub layer height	AUHT	metre
	4	Tree layer width	AOLARG	metre
	5	Tree layer height	AOHT	metre
	6	Type of boundary: simple field boundary	TAU	y/n
	7	Type of boundary: hedgerow	TH	y/n
	8	Type of boundary: forest edge	TL	y/n
	9	Type of boundary: roadside	TR	y/n
	10	Type of boundary: grass track	TBHC	y/n
	11	Type of boundary: grass strip	TBH	y/n
	12	Type of boundary: grass strip with shrubs	TBHE	y/n
	13	Adjacent land cover: field	OCIC	y/n
	14	Adjacent land cover: forest	OCBO	y/n
	15	Adjacent land cover: road	OCRO	y/n
	16	Adjacent land cover: pond or stream	OCET	y/n
	17	Adjacent land cover: farmyard and other land covers	OCBA	y/n
	18	Presence of a ditch	FOS	y/n
Agricultural variables	1	Farming system (cereal vs dairy production)	ORIENT	0/1
	2	Farm size	FARMSIZE	hectare
	3	Farm land fragmentation	LANDFRAG	Nb fields/hectare
	4	Field size	FIELDSIZE	hectare
	5	Crop rotation 'One or two years of winter cereals-oilseeds'	LU1	y/n
	6	Crop rotation 'Three years of winter cereals-oilseeds (sunflower)'	LU2	y/n
	7	Crop rotation 'Maize-winter cereals-sunflower'	LU3	y/n
	8	Crop rotation 'Maize-winter cereals-temporary grassland'	LU4	y/n
	9	Crop rotation 'Maize-temporary grassland'	LU5	y/n
	10	Crop rotation 'Maize-winter cereals-several years of temporary grassland'	LU6	y/n
	11	Land use 'Permanent grassland'	LU7	y/n
	12	Crop rotation 'Winter cereals-oilseeds-temporary fallow'	LU8	y/n
	13	Land use 'Fixed fallow'	LU9	y/n
		Total	**31 variables**	

The ordination diagram of the constrained analysis, plotting axes 1 and 2, is shown in Figure 20.7, page 148. This canonical diagram shows several groups of constraining variables and plant species, sharing neighbouring position in the diagram (Jongman *et al*., 1987).

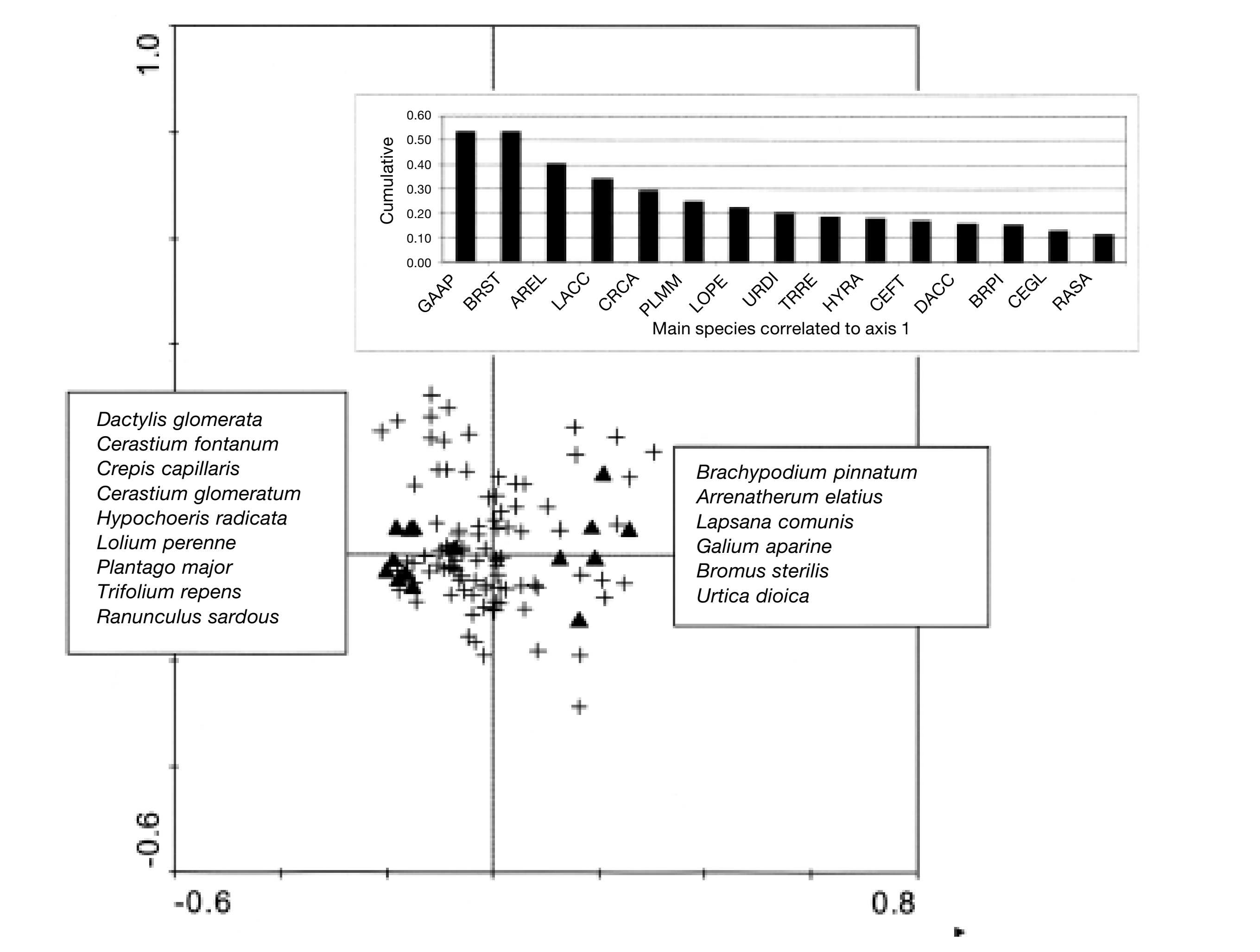
A) Grass strips (TBH), simple field boundaries (TAU), and margins adjacent to fields (OCIC), are associated to temporary or permanent grasslands (crop rotation 'Maize-temporary grassland': LU5; land uses 'Permanent grassland' and, secondarily, 'Fixed fallow') and belong mainly to dairy and fragmented farms (ORIENT, LANDFRAG). Dominant species (according to their position in the canonical diagram) in those margins are mainly **perennials** (*Taraxacum officinalis*, *Dactylis glomerata*, *Veronica serpyllifolia*, *Agrostis capillaris*, *Prunella vulgaris*, *Ranunculus repens* and free drainage soil perennials: *Trifolium repens*, *Plantago major*, *Verbena officinalis*). However, we also find **rich soils species**: *Chenopodium polyspermum*, *Cirsium vulgare*, moist species (*Juncus bufonius*, *Rumex obtusifolius*), meadows annuals (*Lolium multiflorum*, *Poa annua*, *Crepis capillaris*, *Ranunculus sardous*), annual weeds (*Senecio vulgaris*, *Lamium purpureum*, *Veronica arvensis* and weeds over trampled soils: *Cerastium glomeratum*) and perennial weeds of up-turned soils (*Cerastium fontanum*).

B) On the opposite side of the canonical diagram are shown large margins of large fields (LARG, FIELDSIZE), associated to crop rotations 'Winter cereals-oilseeds' (LU1, LU2), belonging to the large, less fragmented cereal farm (FARMSIZE). Dominant species in those margins are **annual weed species of cultivated lands** (*Avena sativa*, *Triticum aestivum*, *Bromus secalinus*) and either **heliophile species** (the invasive perennial grass *Brachypodium pinnatum*, and the meadow annual species *Vicia hirsuta*), xerophile species (*Cruciata laevipes*, *Festuca heterophylla*, *Elymus repens*) and some perennials *Galium mollugo*.

The main cereal crop rotation 'Winter cereals-oilseeds-temporary fallow' (LU8) is associated to heliophile species (the invasive perennial grass, *Arrhenaterum elatius*) and to the nitrophile annual weed *Lapsana communis*.

C) In wooded field margins (hedgerows, field margins next to forest edges and, to a lesser extent, grass strips with scrubs: TH, TL, TBHE), in margins adjacent to forests (OCBO), and in margins with large

FIGURE 20.3. Main species correlated to the first axis and their position on the ordination diagram (Correspondence Analysis: axes 1 and 2). 112 species are represented by crosses; the species mainly correlated to axis 1 are represented by up-triangles. For species' names please see Table 20.3.



and wide tree and shrub layers (AOLARG, AULARG; AOHT, AUTH), dominant species are **shadow species** (humid perennials promoted by the presence of ditches: *Pulmonaria longifolia*, *Cucubalus baccifer*, *Arum maculatum*), **nitrophile perennials** (*Geum urbanum*, *Urtica dioica*, *Elymus caninus*) and **annual weeds** (*Galium aparine*, *Veronica persica*, *Bromus sterilis*, *Geranium robertianum*, *Atriplex patula*).

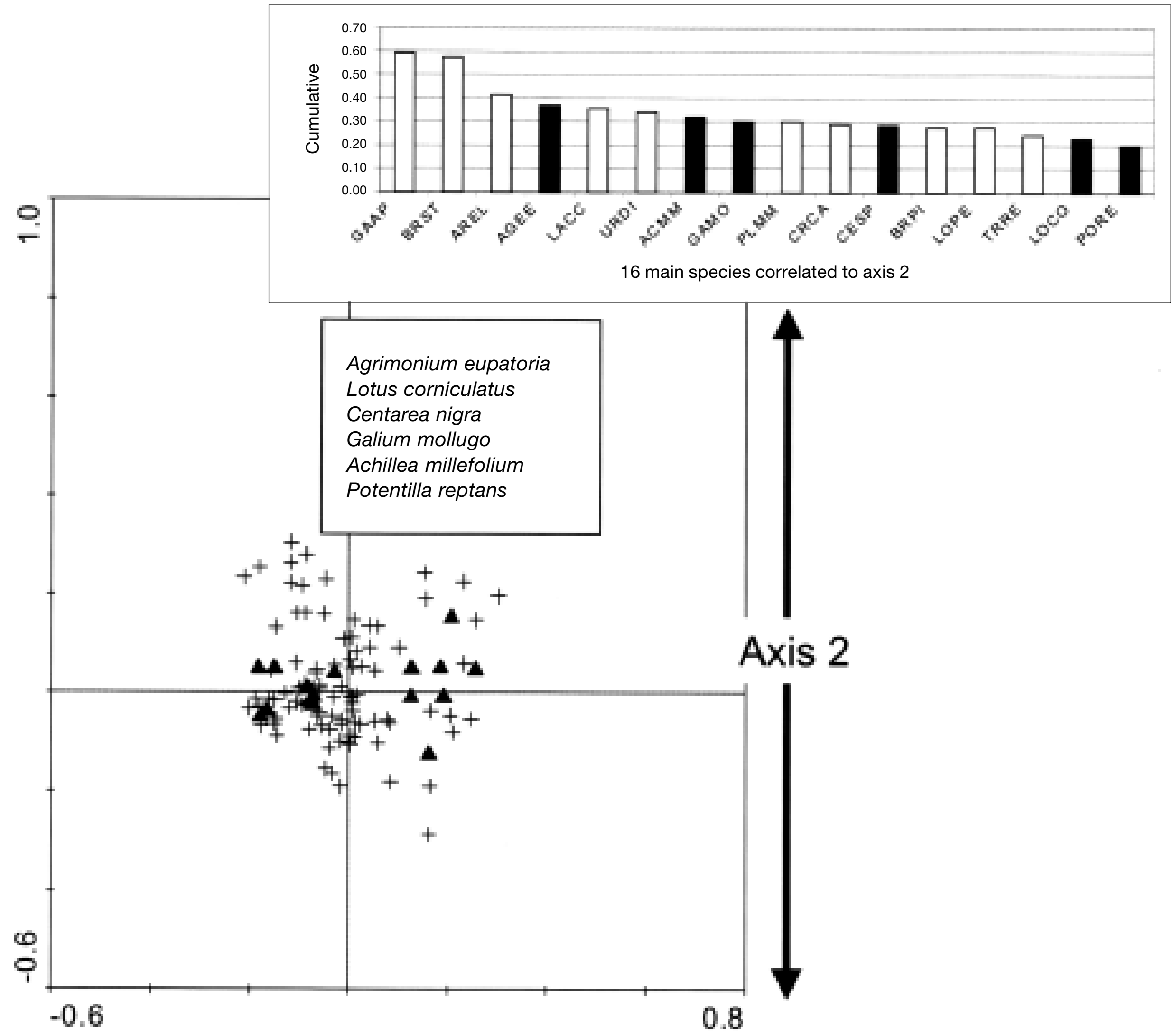
D) On the opposite side of the canonical diagram, we find grass tracks (TBHC) and margins adjacent to ponds or streams (OCET), associated to fields with crop rotations involving maize (LU3, LU4, LU6). Dominant species in those margins are **rich pastures species** (*Potentilla reptans*, in trampled soils; *Lathyrus hirsutus*), **nitrophile** overgrazed pastures species and **weeds** (*Capsella bursa-pastoris*, *Trifolium dubium*, *Polygonum persicaria*, *Conyza canadensis*, *Lactuca serriola*) or, in the opposite, **perennials** (*Leucanthemum vulgare*, *Plantago lanceolata*, *Achillea millefolium*) and species intolerant to nitrogen enrichment (*Centaurea nigra*).

E) Finally, in specific field margins such as roadsides (TR, OCRO), often lined by ditches (FOS), dominant species are **moist nitrophile species** (*Heracleum sphondylium*), **weeds** (*Equisetum arvense*, a nitrophile weed promoted by herbicides) and **dry perennials** (*Agrimonia eupatoria*, *Primula veris*, a meadow species resistant to roller chopping, *Lotus corniculatus*, *Lathyrus pratensis*, *Allium vineale*).

20.4 Discussion

With regard to the diversity of the botanical composition of field margins as it is described by the Correspondence Analysis, we suggest that the first axis is a forest gradient, mainly shaped by landscape features (such as density and size of woodlots); the second axis is a humidity and nutrients gradient, related to fertilisation practices; the third axis is related to field margins defoliation practices and particularly to herbicides effects. We thus propose to consider the first axis as a landscape gradient, while the second and third axes are two agricultural gradients representing the effects of fertilisation practices (axis 2) and herbicides effects (axis 3). Field margins belonging to dairy farms are mainly represented in the negative part of axis 2 (moist and nitrophile species) and axis 3 (perennial species; see Figures 20.8 and 20.9 see page 149).

Figure 20.4. Main species correlated to the second axis (in grey the ones different from the species correlated to axis 1) and their position on the ordination diagram (Correspondence Analysis: axes 1 and 2). 112 species are represented by crosses; the species mainly correlated to axis 2 are represented by up-triangles. For species' names please see Table 20.3.



If we observe the distribution of the field margins in the ordination diagram according to the field land use characteristics (Figure 20.10 page 150), it can be noticed that the margins of permanent grassland fields (LU7) are in the negative part of axis 3 (dominant species are perennials) and negative part of axis 1 (species which mainly occur in light habitats). Margins in fields with the crop rotation 'Maize-temporary grasslands' (LU5) are in the negative part of axis 1 (mainly light species) and in the negative part of axis 2 (mainly moist and nitrophile habitats). Finally, margins with fixed fallow (LU9) are in the negative part of axis 3 (perennials) and in the positive part of axis 2 (xerophile habitats).

Concerning the type of boundary characterising each field margin, we can observe that margins next to roadsides are in the positive part of axis 3 (annuals) and positive parts of axis 2 (species which mainly occur in xerophile habitats). Hedgerows and field margins next to forest edges are in the positive part of axis 1 (forest habitats). Grass tracks are in the positive part of axis 3 (annuals) and in the negative part of axis 1 (light habitats) (Figure 20.11, page 151).

With regard to the contribution of structural vs. agricultural factors to the botanical composition of field margins in this intensively used agricultural region, we found that structural parameters play a crucial role, six of the first nine variables in the hierarchy of explanative variables being related to margins physical structure: height and width of tree layer and shrub layer, types of boundary as forest edges and roadsides (see Figure 20.6). This structure seems to be strongly related to features of the surrounding landscape, more or less wooded: the botanical composition of field margins seems to be strongly linked to some landscape factors

Figure 20.5. Main species correlated to the third axis (in grey the ones different from the species correlated to axes 1 and 2) and their position on the ordination diagram (Correspondence Analysis: axes 1 and 3). 112 species are represented by crosses; the species mainly correlated to axis 3 are represented by up-triangles. For species' names please see Table 20.3.

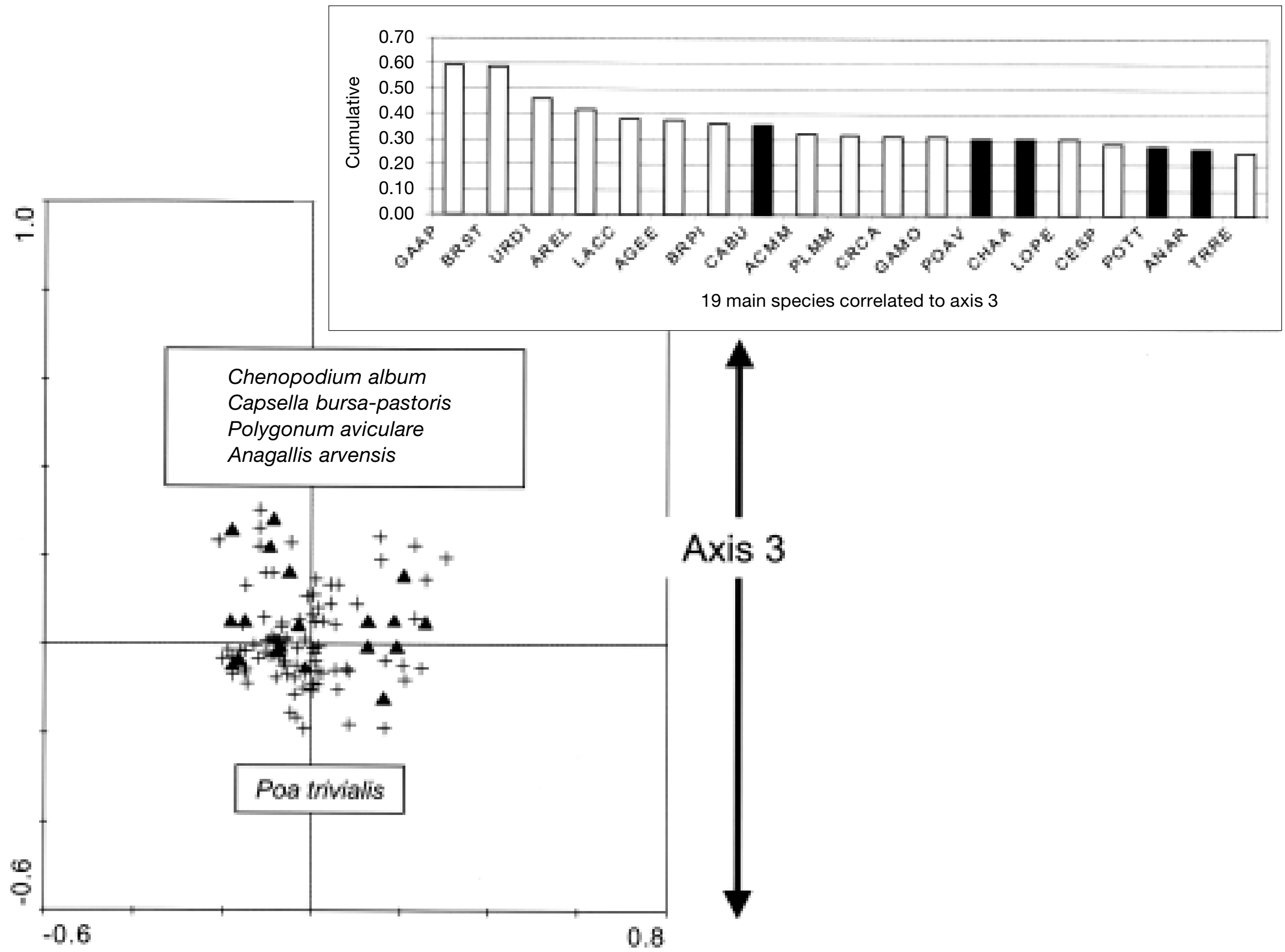
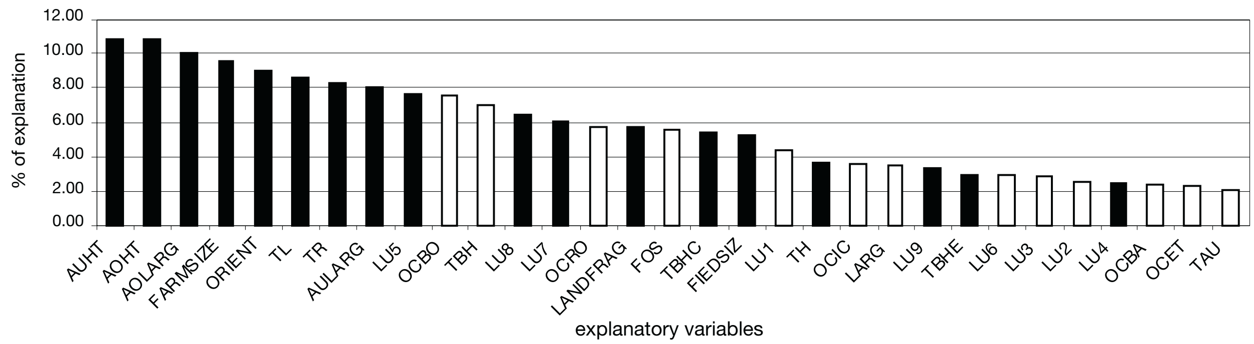


Figure 20.6. Percentage of explanation of the 31 tested agricultural and structural variables (extra-fit: eigenvalue of a CCA if the corresponding variable was the only environmental variable); the variables in white are not statistically significant according to the Montecarlo permutation test. For variables' names please see Table 20.4.



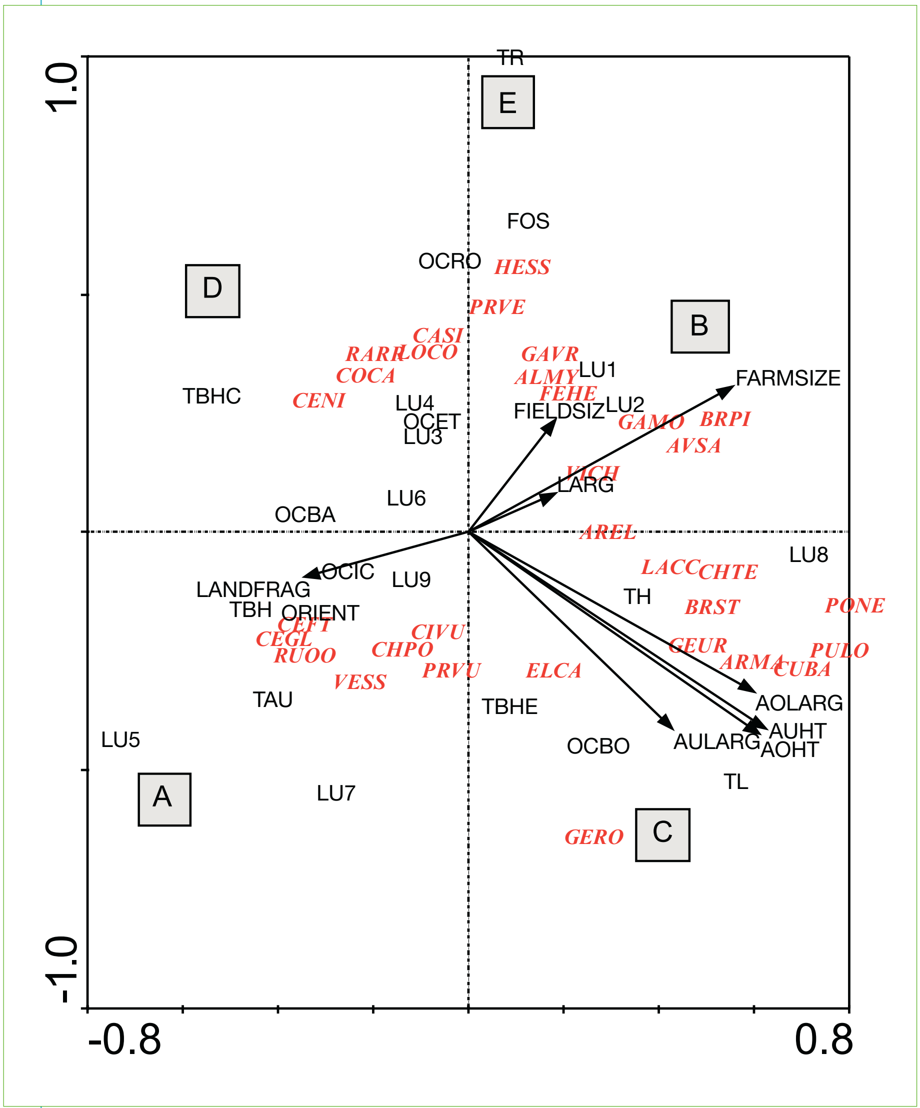


Figure 20.7. Canonical ordination diagram (Canonical Correspondence Analysis: horizontal axis 1 and vertical axis 2). Thirty-one explanatory variables: nominal variables are represented by their abbreviation only; quantitative variables are represented also by vectors; for variables' names please see Table 20.4. The main species, according to their position in the canonical diagram, are represented in red; for species' names please see Table 20.3. Letters' explanation is in the text.

suggested by our structural variables: the presence of wooded patches, enhancing forest edges as for field margins from group C, the presence of roads, enhancing roadsides as for field margins from group E, the presence of grass tracks, bounded to trampling, as for field margins from group D. This could suggest the important role probably played by landscape patterns, in particularly wooded patches density and size (Baudry *et al*., 2000; Thenail *et al*., 2000). However, the adjacent land cover does not seem to play an essential role, none of the five variables describing the adjacent land cover being relevant in respect of this hierarchy and none of them being statistically significant according to Montecarlo permutation test.

In other respects, we point out some agricultural factors. Firstly, the spatial pattern of fields (field size) and farms (linking variables such as farm size and land fragmentation), associated with the farming system: dairy production characterised by smaller and more fragmented farms and smaller fields (margins from group A) on the one hand, and cereal production characterised by the larger and concentrated farm and larger fields (such as margins from B group), on the other hand. The former include more grass strips (TBH: see Figure 20.7) and perennials than cereal farms; this might be linked to the higher proportion of grasslands in dairy farms.

Secondly, at the field level, crop rotations involving grasslands: permanent (permanent grassland or fixed fallow) or temporary grasslands (crop rotations LU5, LU4, LU8). Generally, grassland and perennial species are mostly located in the left and upper parts of the canonical diagram (species of A, D, E groups), and are linked to dairy farms and grassland land use. On the contrary, annuals, weeds and nitrophile species are spread everywhere in the canonical diagram. Without doubt, plant species behave according to the association of both, structural and agricultural factors (Le Coeur *et al*., 1997): as suggested by Le Coeur *et al*. (2002), the presence of annual species and weeds (*Veronica persica*, *Geranium robertianum*) in margins next to forest edges can be explained by the combination of disturbance (cropping) and sources of propagules (the woodlot).

FIGURE 20.8. Distribution of field margins in the ordination diagram (Correspondence Analysis: axes 1 and 2). 267 field margins; field margins belonging to cereal farms are represented by grey squares and field margins belonging to dairy farms are represented by black squares.

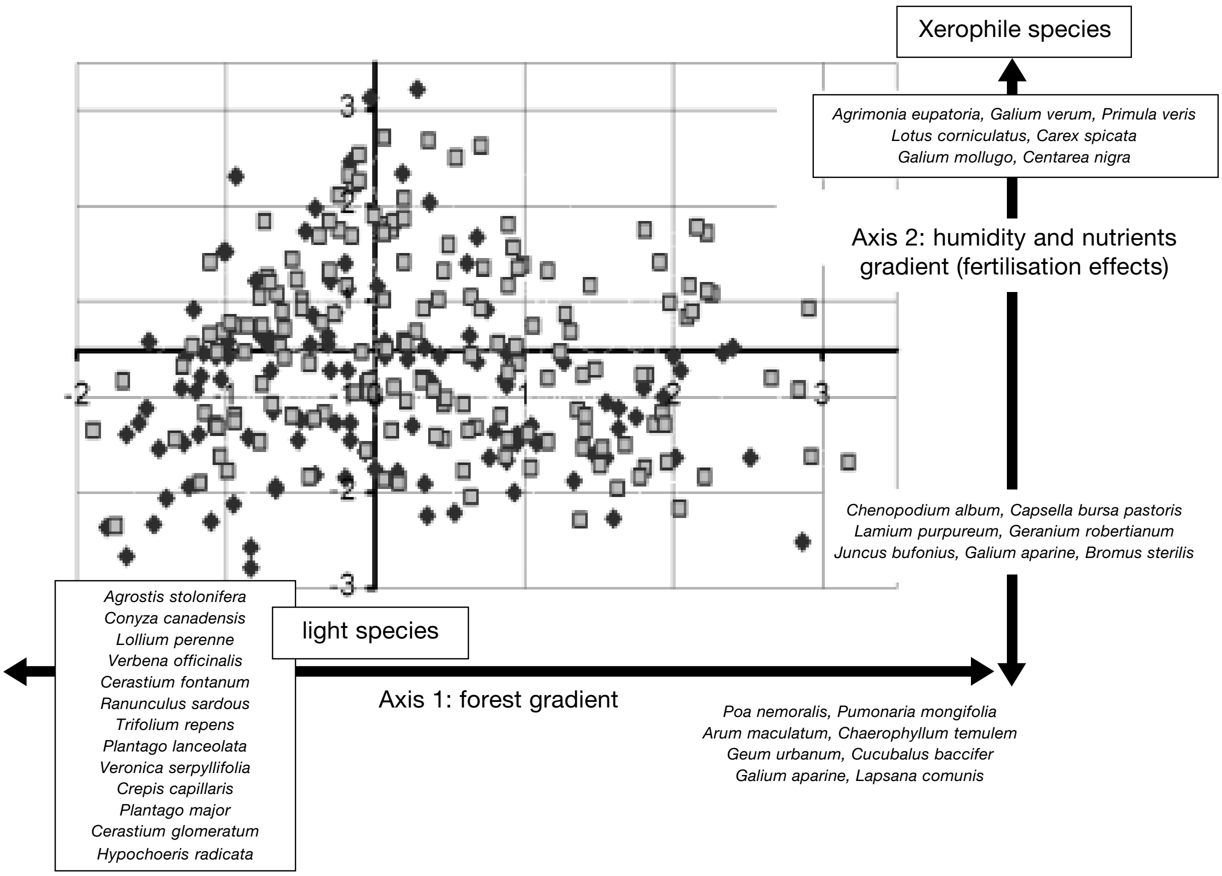
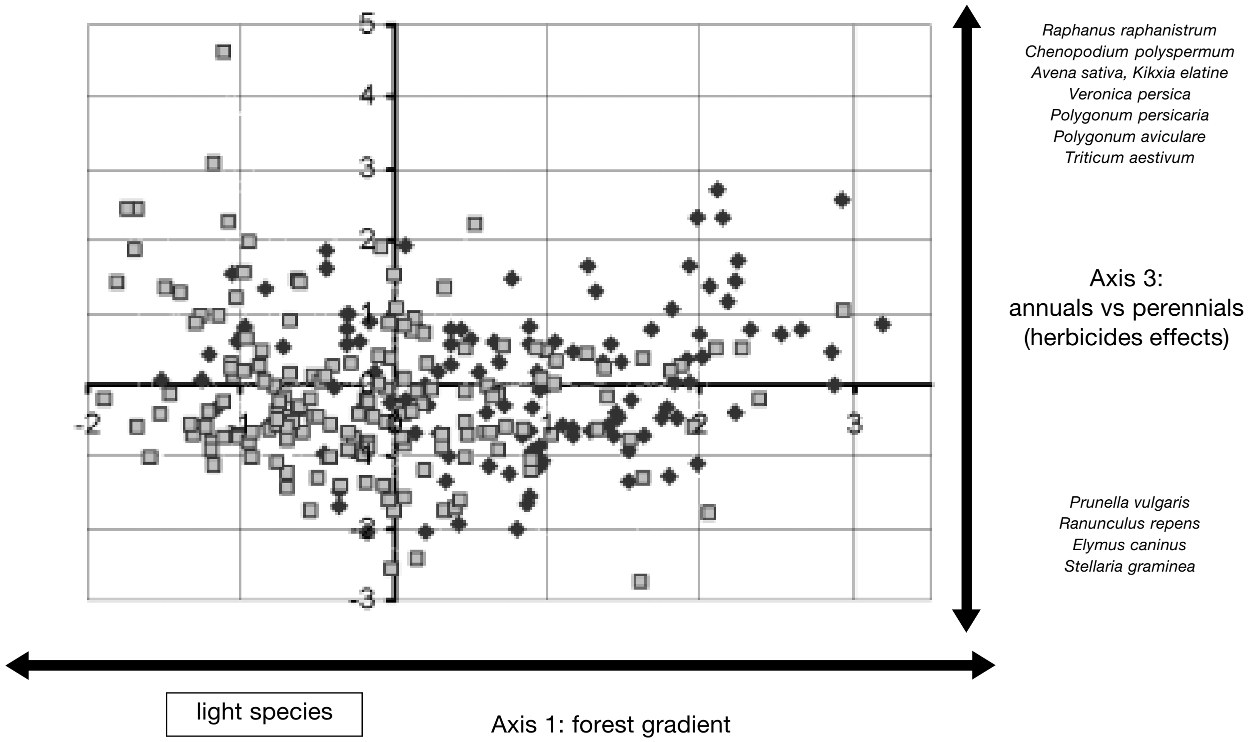


FIGURE 20.9. Distribution of field margins in the ordination diagram (Correspondence Analysis: axes 1 and 3). 267 field margins; field margins belonging to cereal farms are represented by grey squares and field margins belonging to dairy farms are represented by black squares.



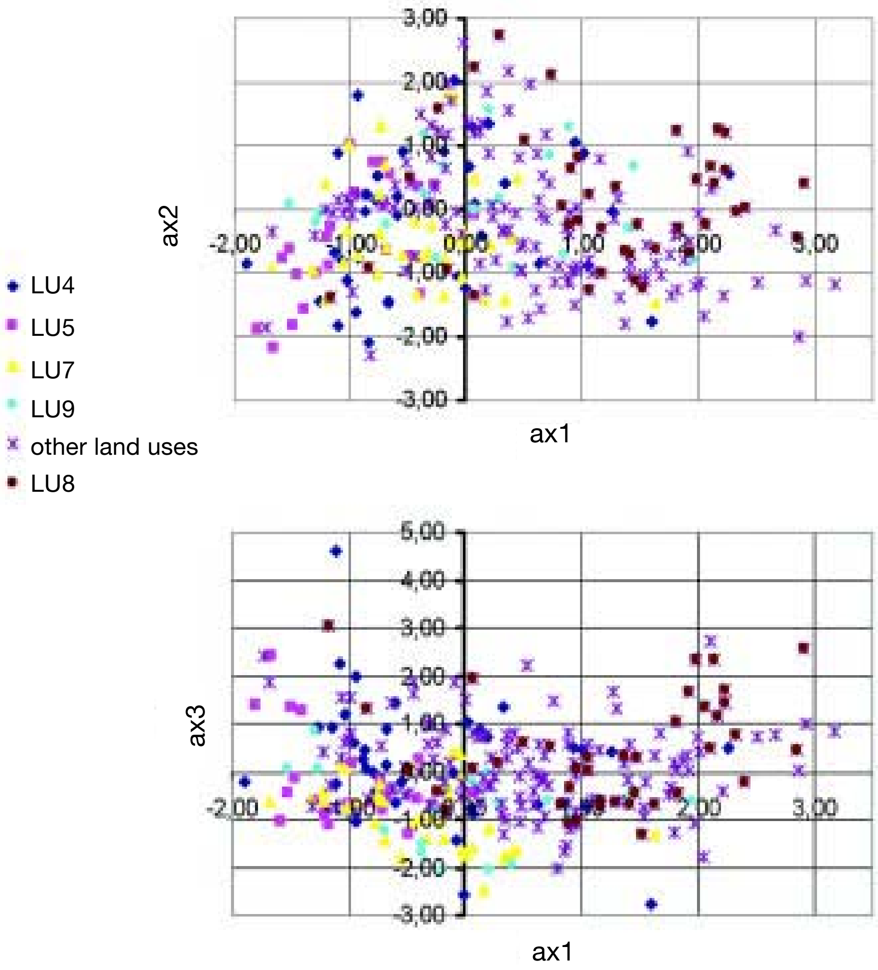


FIGURE 20.10. Distribution of field margins in the ordination diagram (Correspondence Analysis) according to land uses and crop rotations.

20.5 Conclusion

In this paper, we emphasise the major effect of farm size over the plant composition of field margins. The increase of field size is a major trend of modern agriculture; its effects on biodiversity, by related loss in habitats and corridors, are known. We suggest that also the increase of farms size has a dramatically harmful impact on biodiversity because of the more drastic management of field margins that it entails.

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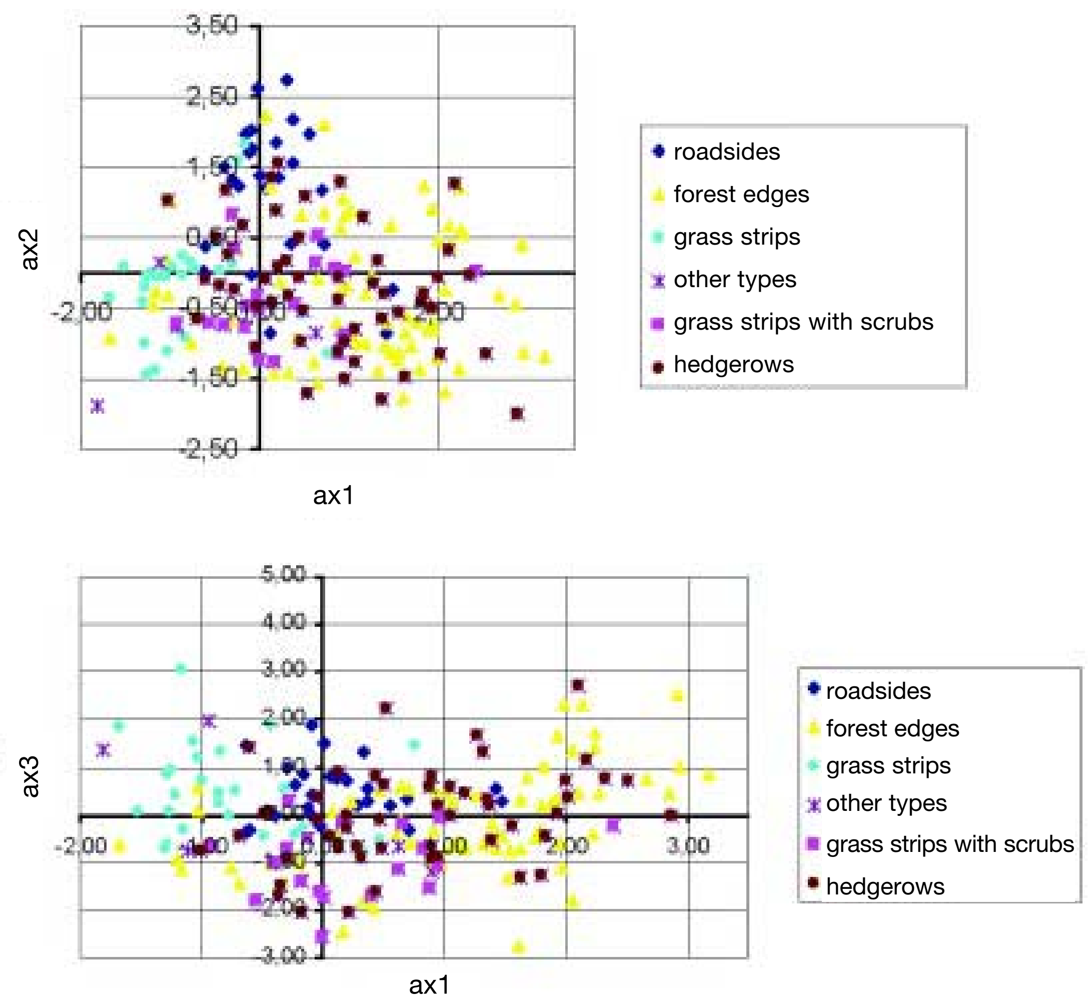
FIGURE 20.11. Distribution of field margins in the ordination diagram (Correspondence Analysis) according to types of field margins boundary.



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21. Auctioning ecological goods within agri-environmental schemes – a new approach and its implementation in species-rich grasslands

Anne Richter gen. Kemmermann, Sebastian Klimek, Elke Bertke and Johannes Isselstein
(Corresponding author: A. Richter gen. Kemmermann, email: Anne.Richter-Kemmermann@agr.uni-goettingen.de)

Abstract

The species richness of grasslands is dependent on an adapted low input management and cannot be conserved by a mere minimum maintenance of a 'good agricultural and environmental condition' – e.g. in the form of an annual mulching – as required by the cross-compliance agreements of the CAP. Existing agri-environmental programmes lack efficiency in nature conservation purposes, as well as acceptance among farmers and population. For this reason, an interdisciplinary research team at the University of Goettingen has developed and implemented a new regional approach in the district of Northeim, Lower Saxony[16]. Twenty-eight farmers have participated successfully in an auction, offering their ecological services concerning the production of species-rich grasslands. Differentiated prices have been paid for differentiated ecological goods, and 228 ha of species-rich grassland could be remunerated. Farmers began to appreciate their former non-commodity products as valuable goods. Result-oriented promotion of species-richness can therefore be highly sustainable and provide an effective countermeasure against the feared mulching of set-aside grasslands.

Key words
Agri-environmental schemes, ecological goods, biodiversity, grassland, auctions

21.1 Introduction

Within the Common Agricultural Policy (CAP) of the European Union, agri-environmental schemes play an important role to support nature conservation aims in agricultural landscapes. The usual programmes offer farmers fixed compensation payments for conducting certain measures which are supposed to have positive ecological effects, as may be late cutting dates or low stocking rates on grasslands. Even though these measure-oriented schemes cover a wide range of regulations, they often lack efficiency for nature conservation purposes (Kleijn *et al*., 2001; Kleijn and Sutherland, 2003; Whitfield, 2006). In Germany, uniform measures on federal state level often fail to reach regional or site-specific nature conservation aims. Furthermore, inflexible restrictions and standardised remuneration make the existing programmes less attractive to the majority of the farmers. Long-term effects for the environment cannot be assured by the common temporary measure-oriented contracts (SRU, 1996).

Concerning the special problem of European grasslands, the sites of high nature conservation value have dramatically declined both in spatial extension as well as in habitat quality and biodiversity, mainly caused by an increasingly intensive land use and further by the abandonment of infertile and unproductive sites (Bakker, 1989, 1998; Hodgson *et al*., 2005a, 2005b; Wenzel *et al*., 2006). No correlation has been found between the amount of subsidies invested and plant species richness in Austrian meadows (Zechmeister *et al*., 2003).

Current developments due to the latest reform of the CAP and its national implementation in Germany, expecting farmers to keep their land merely in 'good agricultural and environmental condition', might lead to a further aggravation of the situation for grassland biodiversity. The German regulation requires the grasslands which are no longer used for production purposes to be either mulched once a year or to be mown every second year with removal of the grown biomass. The cutting of these grasslands is not allowed between 1 April and 15 July. Briemle (2005) has pointed out that this kind of grassland management will have mostly negative ecological effects on plant and animal species richness as well as on the characteristic of landscapes.

To improve the ecological and economic efficiency of agri-environmental schemes and to generate a countermeasure to the mere 'maintenance' of agricultural land, an interdisciplinary research team at the Research Centre for Agriculture and the Environment at the University of Goettingen developed a result-oriented auction for plant diversity (Gerowitt *et al*., 2003a). Within this new approach farmers receive financial reward for supplying ecological goods as results of their activities, e.g. plant biodiversity in grasslands or on arable land. These former non-commodity outputs should be seen as multifunctional services of agriculture and therefore should be rewarded by society, without imposing too many inflexible management restrictions on the farmers (Gerowitt *et al*., 2003b, Hampicke, 2000). Thus, the production of ecological goods will become more attractive to the farmers. The selection of appropriate sites for the production of these goods will give agri-environmental schemes a targeted precision. Farmers will use their local knowledge for an adequate

16 The project is financed by the German Federal Ministry of Education and Research (BMBF) within the framework of BIOPLEX (Biodiversity and spatial complexity in agricultural landscapes under global change) in the research programme BIOLOG (Biodiversity and Global Change). The implementation of the pilot programme in Northeim has been supported by "Bingo!", the Lottery Foundation of Lower Saxony.

management of the sites. Compared to common measure-oriented programmes – which e.g. cause whole grassland landscapes to be mown on the same date, leading to a dramatic loss of habitat structures for the fauna – the result-oriented approach will increase the diversity of land use and habitats. The ecological efficiency will be further increased by adjusting the programme to a specific region, where visible results in the agricultural landscape will promote acceptance of agri-environmental schemes among farmers and the population. To enhance the efficient use of public funds the payments will be conducted with the help of auctions, allowing differentiated rewards for differentiated goods and production costs.

21.2 The study region

The administrative district of Northeim is situated in the southern part of Lower Saxony, Germany. It covers an area of approximately 1,267 km² and is characterised by its diversity in landscapes (Figures 21.1a–c). Elevation above sea level ranges from around 100 m in the plains up to more than 500 m in the highlands.

The floodplain of the river Leine is located in the central part of the district, providing highly productive loess soils which are mainly used for crop or sugar beet production. The few remaining grasslands in this area are mostly intensively used, with usually three to four cutting events per year. In this area, few ecologically valuable structures have been left.

The plain is interrupted and surrounded by hills of different bedrock, particularly limestone or sandstone soils. Due to the partially steep slope angles in this area, some extensively managed grasslands are left, producing little forage yield but providing habitats for rare plant associations. The steeper sites are usually managed as pastures.

The Solling highlands constitute the western part of the district. The forests in the Solling area are passed through by characteristic narrow valleys which are traditionally cultivated as grasslands. As those are mainly unproductive sites, agriculture is withdrawing from this area and former traditionally managed grasslands are in danger of either abandonment or pure 'maintenance' by mulching.

In general, the area of grassland within the district of Northeim has been declining constantly during the last decades, e.g. between 1999 and 2003 more than 1,000 ha were lost (NLS 2003, 1999). The grasslands have been replaced by afforestations on the unproductive sites, or by arable land on the better soils.

FIGURE 21.1a. Grasslands in Northeim. Intensively used grassland in the floodplain of the river Leine.

FIGURE 21.1b. Grasslands in Northeim. Remaining pasture in the hilly landscape, surrounded by arable land.

FIGURE 21.1c. Grasslands in Northeim. Typical valley in the Solling highlands, traditionally cultivated as grassland.

Due to this development, nature conservation aims in this region have to go beyond the protection of the highly endangered grassland vegetation types like limestone grasslands, wet grasslands and some relics of mat-grass swards. The need to protect and promote the mesotrophic grasslands as well is urging.

Referring to the agricultural sector, also structural changes can be observed: agricultural enterprises are abandoned while the average farm size is slowly increasing. In 1999 around 58,000 ha in Northeim were registered as agricultural land (NLS, 1999). Of around 1,400 farms in 1999, 1,175 had main incomes from producing cash crops (around 20,000 ha of wheat, 7,500 ha of winter barley, 5,000 ha of sugar beet) while 774 of the farms have been forage-growing (11,000 ha of grasslands, 1,600 ha of maize), although livestock rate is relatively low in Northeim (e.g. less than 20 dairy cows / 100 ha agricultural area). In 2003, 1,203 farms were left in the district, of which around 60% are part-time farms on a sideline basis. The average farm size rose from 42 ha to 48 ha (NLS, 1999 and 2003).

21.3 The payment system – auctioning ecological goods

The developed payment system is based on fundamental components of market economics such as supply and demand. It is designed as a regional programme and preferences of the population within the study region will be taken into account by a participatory approach (Hespelt, 2005; Rüffer, 2005). A regional advisory board – consisting of stakeholders of agriculture, nature conservation and regional government – decides about the demand for ecological goods und assigns proportions of the available budget to specific ecological goods. The ecological goods will be separately demanded within an auction, so that higher remuneration can be given for higher quality of the product. This proceeding requires a standardised comparability of ecological goods.

Farmers within the study region voluntarily offer ecological goods in the auction. They are invited to offer chosen fields fulfilling the criteria of the demanded ecological goods. Farmers rank the sites according to the ecological goods and define the necessary height of compensation per hectare for each of the fields they want to position into the programme. In general, prices should be related to the value and the scarcity of the ecological good. Within the budget of each ecological good, contracts can be made purely by considering the cheapest offers, as it was done during the implementation in Northeim. Further aspects that could be taken into account are the location of the offered field (e.g. vicinity to rivers or nature protection areas), the duration of the offered contract or the specific production costs (Richter gen. Kemmermann, 2001). Higher remuneration could also be possible, e.g. in regions with highly productive soils, without allowing windfall gains.

Auctions to conserve natural resources are already conducted in the United Kingdom, in Australia (Stoneham *et al*., 2003; Agriculture and Food Policy Reference Group, 2006) and in the United States. The American Conservation Reserve Program uses a detailed environmental benefits index to rank the offers within the auction (Osborn, 1997; Feather *et al*., 1999).

20.4 The definition of ecological goods in species-rich grassland

To guarantee the accordance with international agreements about subsidies for agri-environmental measures, the production of ecological goods needs to exceed the good agricultural practice and the cross-compliance requirements of the CAP.

A standardised definition of regional ecological goods – measured by floristic criteria – has been developed for the district of Northeim by Bertke (2005). This has been done for grasslands, arable land and linear elements. As the implemented pilot programme in 2004/2005 was confined to the ecological goods in grasslands, it is these that are described below.

The quality of the ecological goods in grasslands is determined by criteria which refer to the forb species richness within control plots. Three differentiated ecological goods of grassland biodiversity have been developed (Table 21.1), whose stages build on each other. While other result-oriented approaches are consistently based on indicator species (Oppermann and Gujer, 2003; Wittig *et al*., submitted), the system tested in Northeim also works with simple species numbers. Bertke *et al*. (2005) constitute that the interrelationship between the number of forb species and different variables of grassland management such as intensity of nitrogen fertilisation and the frequency of cutting or grazing make the number of forb species per area unit suitable as a criterion for remuneration.

TABLE 21.1. The definition of ecological goods for grasslands in Northeim (Bertke, 2005).

Ecological Good	Criteria to be fulfilled in the control plots [12.6 m²]
grassland I	>= 8 forb species in all plots
grassland II	>= 8 forb species in all plots + 2 indicator species in all plots
grassland III	>= 8 forb species in all plots + 2 indicator species in all plots + 50 % of the control plots contain either four indicator species, or two indicator species of rare plant associations (group II of the catalogue)

So, first of all the number of forb species per control plot was defined as a minimum requirement (eight forb species in round control plots with a radius of 2 m = 12.6 m²). The existence of regionally defined indicator species – mainly forbs which are listed in a catalogue of 40 grassland species – will lead to a higher classification. The catalogue is divided into two groups of species. The first group is listing relatively widespread species connected to a low input management (e.g. *Alchemilla vulgaris* agg., *Cardamine pratensis*, *Ranunculus acris*, *Stellaria graminea*). The second group is listing indicator species of rare plant associations (e.g. *Caltha palustris*, *Galium saxatile*, *Primula veris*).

The number of necessary control plots depends on the size of the grassland field. A minimum of three control plots per field have to be analysed (Bertke, 2005).

The aims to be achieved by the production of these ecological goods in the district of Northeim are (i) the maintenance of grassland management particularly on marginal sites, (ii) the promotion of regional species-rich types of grassland, and (iii) the conservation of rare plant associations.

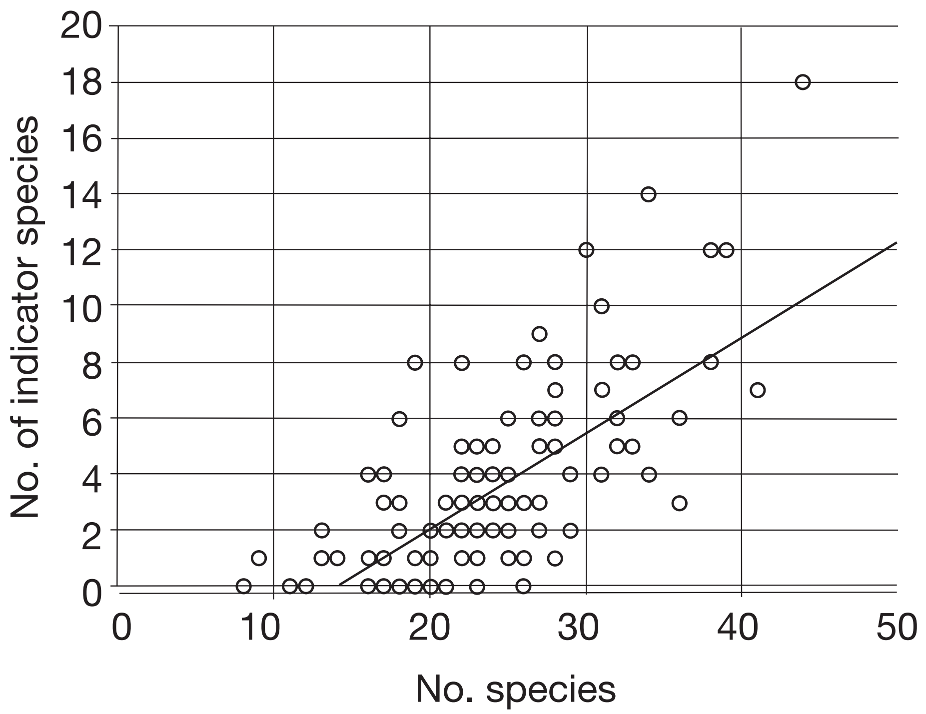
In previous investigations on grassland vegetation in Northeim in 2002 and 2004 it has been shown that there is a significant relationship between the chosen 40 indicator species and the total number of species occurring in the grassland sites (Figure 21.2). The investigation covered 571 control plots on 122 grassland fields. The most frequently found indicator species were *Cardamine pratensis*, *Ranunculus acris*, *Alchemilla vulgaris* agg., and *Stellaria graminea* (Klimek and Richter gen. Kemmermann, 2005).

Examples for grassland fields reaching the three different ecological goods are given in the Appendix of this article (Appendix Table I to III).

21.5 The implementation of the pilot programme in Northeim, Lower Saxony

During the period of 2004/2005 the presented agri-environmental scheme for species-rich grassland was applied for the first time within a pilot programme in the district of Northeim. Its implementation began in 2004 with the auction. During the specified period of six weeks for the tendering procedure 38 farmers offered their species-rich grassland fields in the three categories of ecological quality. With the closure of the auction process 28 farmers could be contracted within the available budget. They had to provide the ecological goods for a contract duration of one year. Thus, the pilot programme contained an amount of 159 grassland sites covering an area of 288 ha. The 159 contracted grassland fields divide into the three defined ecological goods as follows: 198 ha of the basic 'good I', 53 hectares of the 'good II' and 37 hectares of the most demanding 'good III'.

FIGURE 21.2. Relationship between indicator species and the total number of species within the grassland fields investigated in Northeim in 2002 and 2004.



N = 122 grassland sites
R^2-value = 0.475
P < 0.001
The number of species is corrected for autocorrelation by subtraction of the indicator species.

The participating farms are of different size and structure. Eighteen of the participants are main-income farmers and 10 are part-time farmers. Conventional farmers with up to 130 ha of grassland and up to 160 dairy cows have been as interested in the programme as organic and part-time farmers. While the organic main-income farmers own herds of up to 40 suckler cows, the part-time farmers often own only two to five suckler cows, or some sheep, goats or horses. Many of the contracted farmers participate with single fields of small size. The average size of participating grassland fields is 1.8 ha. Nearly half of the participants (13 out of 28) got contracts for less than 5 ha. Only a few farmers offered larger areas of grassland to the auction. A maximum of 23 grassland fields per farm were positioned in the programme.

21.6 Results

21.6.1 Results of the auction

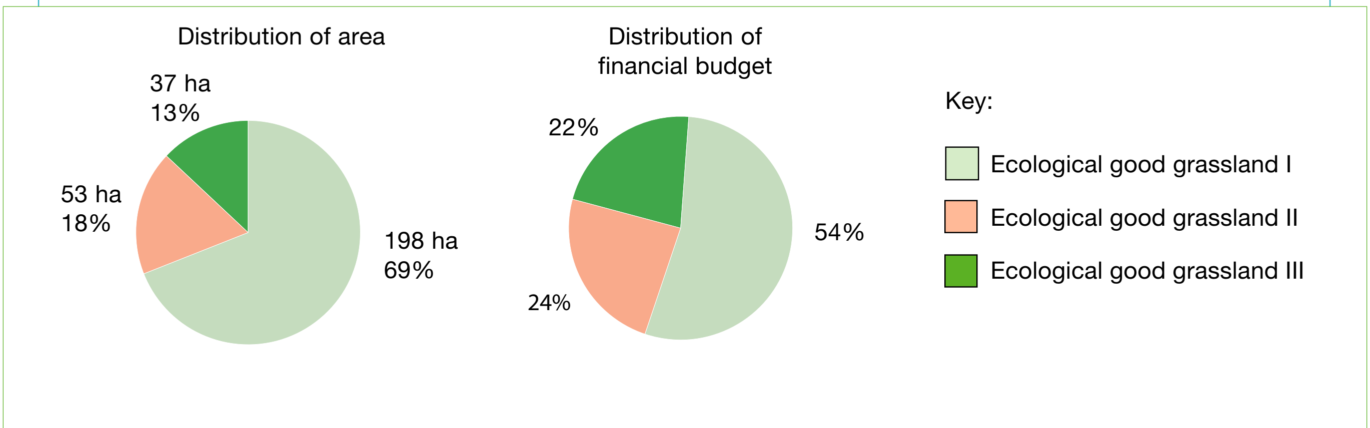
The demanded remuneration for the ecological goods has shown a wide range of prices, and prices have risen with the ecological value of the goods (Table 21.2). As the three goods have been treated separately within the auction, and as there has been less competition for the more demanding ecological goods, farmers have been able to claim higher remuneration for the ecological goods 'II' and 'III' as for the good 'I'. Anyway, the grasslands of the goods 'II' and 'III' belong to at least mesotrophic grasslands, if not even to meadows on wet soils, limestone grasslands or to relics of matgrass swards. All those vegetation types used to be typical for the hilly countryside in the district of Northeim but are increasingly endangered. The management of these scarce vegetation types, especially on unproductive soils or steep slope angles, requires high production costs and justifies the higher remuneration. The maximum remuneration of €350 per ha within the pilot programme in Northeim still remains much lower than rewards paid within the measure-oriented programmes of Lower Saxony e.g. for the management of limestone grasslands, which can go up to €1,390, depending on the concrete measures.

In general, the higher ecological goods 'II' and 'III' represent only a relatively small proportion (18% and 13% respectively) of the total contracted area but claim nearly half of the budget spent in the pilot programme (Figure 21.3). Due to the decision of the regional advisory board about the allocation of the financial budget, those higher ecological goods had to be contracted preferably. For this reason mainly in the category of the good 'I' refusals had to be made. Nevertheless, the ecological good 'I' has been offered at relatively low prices, so that within its budget the largest number of farmers and fields could be contracted, thus leading to a broad effect of the programme in the study area.

TABLE 21.2. Results of the auction for species-rich grasslands in the administrative district of Northeim in 2004/2005.

ecological goods		offers	contracts	Ø remuneration in € / hectare
good grassland I	fields	146	109	
	hectares	251	198	81 €
good grassland II	fields	35	32	
	hectares	61	53	132 €
good grassland III	fields	18	18	
	hectares	37	37	173 €
participating grasslands (total)	fields	199	159	
	hectares	349	288	102 €

FIGURE 21.3. Distribution of area and financial budget within the pilot programme referring to the three ecological goods after contract conclusion in 2004.



21.6.2 Results of the control for species richness

The control of the demanded species richness has taken place from the beginning of May until the end of July 2005. Three of the farmers withdrew their bids for 13 grassland fields in 2005, so that 26 farmers with 260 ha and 146 grassland fields remained to be controlled. A nearly complete control (95%) of the contracted fields has proved the practicability of the new method, verifying the ability of farmers to rank the ecological value of their grassland fields by the defined criteria and the used catalogue of indicator species. This control has been carried out by the team of the Research Centre, mostly accompanied by the farmers who have shown great interest in the expert confirmation of the occurring plant species on their grassland sites.

Before the pilot programme started farmers' knowledge about grassland forbs was often limited to a number of few agriculturally important species or weeds. Thus, many farmers were cautious in assigning their fields to the ecological goods. Within the 'ecological good I', there are several fields which could have been allocated to the higher goods 'II' or 'III'. On the other hand, there were also some fields which did not meet demanded criteria (Figure 21.4). This was especially true in the case of farmers who followed organic or low input agricultural guidelines and offered a large amount of fields to the programme without controlling the single sites for their specific species richness. This fact underscores that the production of 'biodiversity' is a service exceeding common extensification programmes, which are often focused on the conservation of abiotic resources.

Next to the conclusion about farmers' ability to recognise grassland species, a further finding of the result-oriented programme is that farmers obviously changed their attitude towards species richness in grasslands. Actually the farmers' interest and knowledge in species richness increased whilst participating in the result-oriented programme, as is often assumed theoretically (Richter gen. Kemmermann, 2001). After the expiration of common measure-oriented contracts, farmers will usually go back to their former level of land use in order to maximise their profit. In contrast to that, result-oriented programmes should have enduring effects by influencing the farmers' ecological awareness.

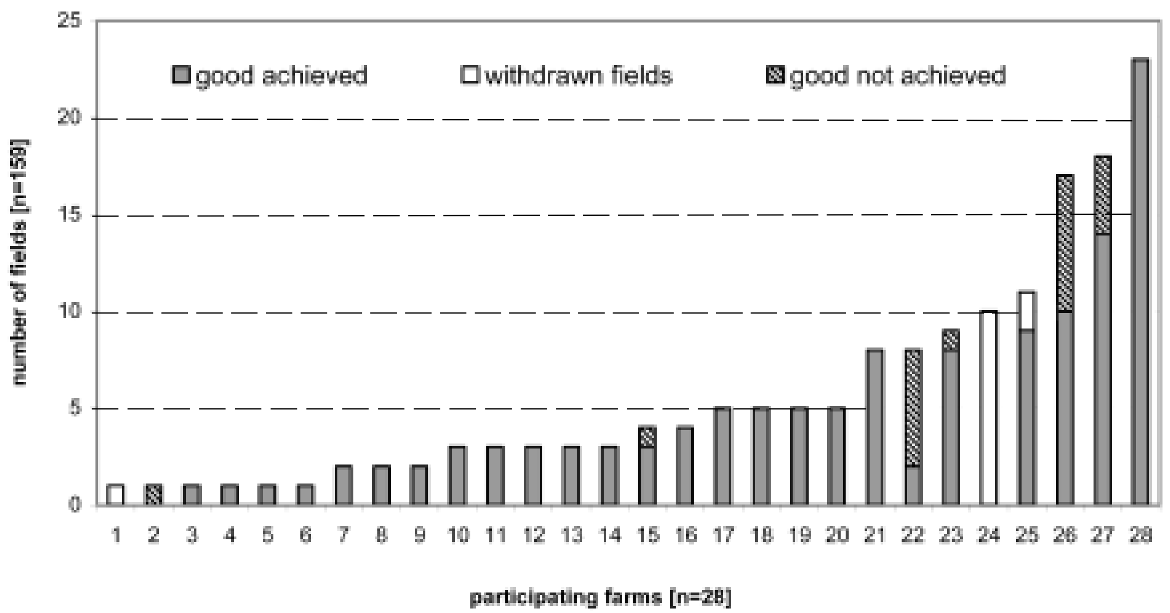
With the closure of the controls 228 ha of species-rich grasslands in Northeim achieved the defined ecological goods and could be remunerated.

21.7 Conclusions and perspectives

The presented pilot programme in Northeim was the first attempt in Germany to implement the combination of the two components result-oriented remuneration and auctions. The successfully conducted pilot programme in the district of Northeim shows (i) that the result-oriented reward of ecological services is practicable for farmers, and (ii) that it can be implemented by the means of auctions and that farmers' demand differentiated prices. The new approach allows a targeted reward of species-rich grasslands and therewith contributes to the conservation and promotion of biodiversity in agricultural landscapes.

The result-oriented payment for species richness will provide economic incentives to hold up an adjusted management of species-rich grasslands. Thus, e.g. the feared large-area mulching of whole landscape sceneries can be prevented. Furthermore, liberating farmers from inflexible guidelines and focusing on the results of their

FIGURE 21.4. Results of the control for ecological goods on the participating farms in 2005.



activities instead will arouse farmers´ awareness for biodiversity and make the effects of this approach more enduring than common measure-oriented agri-environmental schemes. Though this new result-oriented approach can be applied to ecological goods of different values, in certain cases it may be useful to keep up management restrictions. Both approaches – result-oriented and measure-oriented programmes – can be implemented in coexistence. For example, the agriculture and nature conservation authorities in Lower Saxony plan to implement a result-oriented programme for mesotrophic grasslands from 2007 on, while specific nature conservation interests e.g. in limestone grasslands and wet grasslands should still be guaranteed by measure-oriented programmes.

Auctioning ecological goods can be a further step in raising the efficiency of agri-environmental schemes. While a flat rate of remuneration per hectare brings no incentives to participation for farmers with high land values or high productions costs for ecological goods, flexible prices allow the valuation of scarce ecological goods and their production costs.

Visible results of agri-environmental programmes in the regions document the reasonable assignment of public funds. These aspects will improve the ecological and the economic efficiency of agri-environmental schemes with regard to the conservation of biodiversity in agricultural landscapes as well as the acceptance of these schemes within agriculture and society.

The new approach presented in this paper is generally suitable to be used within agri-environmental schemes co-financed by the European Union. The EAFRD regulation on support for the rural development – for the programming period 2007–2013 of the European Union – opens up new options for the design and implementation of agri-environmental programmes within the second pillar of the CAP, e.g. auctions within its programmes will be possible. The new approach tested in Northeim utilises the new options and presents a concrete way to accelerate a sustainable rural development by integrating priorities like regionality, participation, result-orientation, and auctions.

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APPENDIX TABLE 21.3. Example of a grassland field reaching the Ecological Good I *.

No. of control plot	Species names	Indicator species	No. of species /12.6 m²
1	*Achillea millefolium*		
	Galium album		
	Glechoma hederacea		
	Plantago lanceolata		
	Rumex acetosa		
	Rumex crispus		
	Taraxacum officinale		
	Trifolium pratense		
	Trifolium repens		
	Veronica serpyllifolia		10
2	*Achillea millefolium*		
	Cerastium holosteoides		
	Cirsium vulgare		
	Galium album		
	Plantago lanceolata		
	Ranunculus repens		
	Rumex acetosa		
	Rumex crispus		
	Taraxacum officinale		
	Urtica dioica		10
3	*Achillea millefolium*		
	Bellis perennis		
	Galium album		
	Plantago lanceolata		
	Ranunculus acris	group I	
	Ranunculus repens		
	Rumex acetosa		
	Taraxacum officinale		
	Trifolium repens		9
Total number of occuring forb species in three control plots			16
Total number of occuring indicator species in three control plots			1

* Method according to Bertke (2005), grassland investigation in 2005 by Anne Richter gen. Kemmermann.

APPENDIX TABLE 21.4. Example of a grassland field reaching the Ecological Good II *.

No. of control plot	Species names	Indicator species	No. of species /12.6 m²
1	*Achillea millefolium*		
	Alchemilla vulgaris	group I	
	Cerastium holosteoides		
	Heracleum sphondylium		
	Plantago lanceolata		
	Ranunculus acris	group I	
	Ranunculus repens		
	Rumex acetosa		
	Taraxacum officinale		
	Trifolium pratense		
	Trifolium repens		
	Veronica chamaedrys		12
2	*Achillea millefolium*		
	Cerastium holosteoides		
	Heracleum sphondylium		
	Hypochaeris radiacata	group II	
	Plantago lanceolata		
	Ranunculus acris	group I	
	Ranunculus repens		
	Taraxacum officinale		
	Trifolium pratense		
	Trifolium repens		
	Veronica arvensis		
	Veronica chamaedrys		12
3	*Cerastium holosteoides*		
	Crepis biennis	group I	
	Heracleum sphondylium		
	Plantago lanceolata		
	Ranunculus acris	group I	
	Ranunculus repens		
	Rumex acetosa		
	Stellaria graminea	group I	
	Taraxacum officinale		
	Trifolium pratense		
	Trifolium repens		
	Veronica arvensis		
	Veronica chamaedrys		13
Total number of occuring forb species in three control plots			16
Total number of occuring indicator species in three control plots			5

* Method according to Bertke (2005), grassland investigation in 2005 by Anne Richter gen. Kemmermann.

APPENDIX TABLE 21.5. Example of a grassland field reaching the Ecological Good III *.

No. of control plot	Species names	Indicator species	No. of species /12.6 m²
1	*Galium album*		
	Primula veris	group II	
	Ranunculus auricomus		
	Convolvulus arvensis		
	Hypericum perforatum	group II	
	Trifolium pratense		
	Medicago lupulina	group II	
	Achillea millefolium		
	Veronica chamaedrys		
	Daucus carota		
	Plantago lanceolata		
	Salvia pratensis		
	Centaurea jacea		
	Knautia arvensis		
	Vicia cracca	group I	15
2	*Achillea millefolium*		
	Centaurea jacea		
	Convolvulus arvensis		
	Galium album		
	Hypericum perforatum	group II	
	Medicago lupulina	group II	
	Primula veris	group II	
	Ranunculus auricomus		
	Ranunculus bulbosus		
	Trifolium pratense		
	Veronica chamaedrys		
	Vicia cracca	group I	12
3	*Achillea millefolium*		
	Aegopodium podagraria		
	Centaurea jacea		
	Galium album		
	Knautia arvensis		
	Medicago lupulina	group II	
	Pimpinella saxifraga	group II	
	Primula veris	group II	
	Ranunculus auricomus		
	Sanguisorba minor	group II	
	Trifolium pratense		
	Veronica chamaedrys		
	Vicia cracca	group I	13
Total number of occuring forb species in three control plots			19
Total number of occuring indicator species in three control plots			6

* Method according to Bertke (2005), grassland investigation in 2005 by Anne Richter gen. Kemmermann.

22. Encompassing sustainability concerns in policy evaluation and assessment: some critical considerations

Karlheinz Knickel and Melanie Kröger
(Corresponding author: K. Knickel, email: Knickel@em.uni-frankfurt.de)

Abstract

In this contribution we address the question of the integration of multifunctionality goals and concerns into evaluation concepts and practice. We ask how far methods of evaluation and assessment are up to the new requirements that reflect current political and societal trends and changes. While trying to answer this question we pay attention especially to two current EU-funded research projects – Multagri and Sustainability A-Test – that both deal with the identification and advancement of appropriate evaluation and assessment methods. We first examine the demand side of policy evaluation. We refer to sustainable development concerns and the practical side of the multifunctionality debate. This is followed by a critical appraisal of current evaluation practice. We refer to the needs of policy processes and evaluation interfaces, and we discuss research struggling with needs of a more integrated assessment. In the concluding section, we refer to some promising lines of research and some starting points for a more integrative policy evaluation and assessment. We emphasise the usefulness of the multifunctionality of agriculture and rural space as a conceptual and analytical framework. The article as a whole is meant as a constructive contribution to the ongoing discussion about the advancement of conceptual frameworks and tools towards more integrative approaches.

Keywords
Rural development, sustainability, policy evaluation, integrated assessment, multifunctionality, policy processes, Europe

22.1 Introduction

The increasing importance of the notion of sustainability in the political arena since UNCED 1972 poses a challenge for the evaluation and assessment of policy. Classical quantitative instruments and tools of policy evaluation appear to have major restrictions in their capacity to deal with the different dimensions of sustainability in a truly integrated manner. A similar appraisal applies to the more recent notion of the multifunctionality of agriculture and rural space. Both notions have become more and more important in international and national political debates but also, more practically, in support programmes and measures at EU, member states and regional level. At the same time, the evaluation of policy instruments and programmes – especially at EU level – has become increasingly important. At the latest, with the reform of the EU structural funds in 1988 the evaluation of policies has become a key component of the policy process. Policy evaluation and, more specifically, the integrated assessment of policy impacts are increasingly understood as part of a learning process – learning towards a continuous improvement of the efficiency of policy interventions. With the adoption of Agenda 2000 in 1999 evaluation has become closely tied to policy formulation and implementation. The importance of the mid-term review underpins that.

The integration of multifunctionality goals and concerns into evaluation concepts and practice is a more recent question. In the Agenda 2000 it is, for the first time, an explicit goal to secure a 'multifunctional, sustainable and competitive agriculture throughout Europe'. Thus, the important question arises if methods of evaluation and assessment are up to the new requirements that themselves reflect current political and societal trends and changes. While trying to answer this question we pay attention especially on two current EU-funded research projects. Both projects – Multagri and Sustainability A-Test[17] – deal with the identification and advancement of appropriate evaluation and assessment methods.

In this article, we first address the questions of the demand side of policy evaluation. We refer to sustainable development concerns and the practical side of the multifunctionality debate. This is followed by a critical appraisal of current evaluation practice. We refer to the needs of policy processes and evaluation interfaces, and we discuss research struggling with needs of a more integrated assessment. In the final section, we conclude with some promising lines of research (and thinking), and we formulate concrete recommendations for a more integrative policy evaluation and assessment. We emphasise the usefulness of the multifunctionality of agriculture and rural space as a conceptual and analytical framework. The article as a whole is meant as a constructive contribution to the ongoing discussion about the advancement of conceptual frameworks and tools towards more integrative approaches.

22.2 The demand side of policy evaluation

It is self-evident that the appearance and mainstreaming of new political orientations causes new demands on evaluation and assessment tools and instruments. Sustainability clearly has attained the status of a generally acknowledged vision statement while at the same time it remains a highly political notion and

17 For further information on the projects see www.multagri.net and www.sustainabilitya-test.net.

normative by its very nature. Dovers (2005, p. 8), for example, sees sustainability as a higher order social goal whose natural partners are other goals such as democracy, justice, freedom, equity, and the rule of law. As it is – or at least seems to be – relatively straightforward to define policies, production systems or individual behaviour as unsustainable the positive determination is much more difficult. The latter is particularly true if we look at the environmental or natural sciences dimension of sustainability.

22.2.1 Addressing sustainability demands goes far beyond classical environmental questions

In the past, policy decisions were made without much regard to environmental or sustainability concerns. Environmental concerns have entered political debates and research in the 1980s. During the 1990s it has been more and more accepted that environmental impacts are related with a multitude of policy sectors and (economic) activities. An increasing range of portfolios, disciplines and professional domains address relevant interrelations. And yet, there still is the need to spread environment and sustainability concerns more widely in policy systems. The consideration of sustainability needs to be enforced rigorously and transparently in a wide range of policy processes and decisions. Evaluation and impact assessment are particularly important in this respect. Appropriate conceptual frameworks and tools for an integrated sustainability assessment and evaluation, however, are scarcely developed until now.

At this point it is interesting to distinguish between the notion of sustainability and the multifunctionality concept. Cairol *et al*. (2006) found a notable lack of scientific attention for the interrelations between these two concepts. They stress that the multiple functions of agriculture are often referred to in terms of sustainability concerns, externalities related to agricultural production (positive and negative), food quality, farm diversification, and pluriactivity among farm households. Cairol *et al*. (2006) try to clarify both terms:

- Sustainability is a normative approach that has to do with society's wish and ability to develop lifestyles and consumption levels that are enduring and long-lasting. It is a resource-oriented notion: It requires maintaining some aggregate measure of capital (stocks of physical or economic, natural, and social capital, and the possibility of trade-offs between them), in order to fulfil the needs of future generations. Thus, it has a clear temporal dimension.
- Multifunctionality, in contrast, is an activity or outcome oriented notion that describes the characteristics of farm production or diverse functions of land, focusing on relationships. It lacks a direct or immediate temporal dimension. Multifunctionality may help to define sustainability and sustainable development concerns in more operational terms. It places complexity and contextuality into the centre of analysis. […] '*By understanding more about multifunctionality, it will be possible to better address sustainable development*'.

The question of the appropriate level of assessment and the necessity to take into account contextuality brings us back to the links between multifunctionality and the territory. Current evaluation practice until now clearly does not meet the challenges and requirements of the new territorial approaches that are both multidimensional and multilevel. Against this background the evaluation of classical sectoral policies – like environmental or social programmes – seems to be comparatively simple.

22.2.2 The social dimension of environmental problems

In order to address the related methodological difficulties it helps to ask what the specific constitution and characteristics of the sustainability problems is. What makes the difference when dealing with sustainability instead of economic or ecological topics and problems separately? One can trace back the sustainability discourse – amongst other theoretical and practical discussions – on the 'risk society' discussion of the late 1980s. The German sociologist Ulrich Beck counts as the originator of this debate that was centred on the idea of a new kind of modern society, which replaces the classical industrial society (Beck, 1992). His theory can be seen as the first attempt to integrate ecological issues into social sciences and to recognise the social dimension of ecological problems. Before this, the interrelations between social and ecological issues were not recognised as such. Insofar there is a causal connection between the debate on ecological risks and sustainable development: the latter can be deduced from the former.

Against this background it is also clear that a strict implementation of sustainability principles would clearly precondition drastic changes in social systems, consumption patterns and lifestyle. Besides, fundamental institutional changes would be required to really advance sustainability as a new model of societal development. In line with that see Umweltbundesamt (2002), Enquete-Kommission (1998) and others who describe the causes of unsustainability as systemic, located deep in patterns of production and consumption, settlement and governance. Dovers (2005, p. 1) emphasises that '*these patterns are determined by institutional settings that evolved in the past in response to other imperatives and knowledge, and it is now accepted that policy and institutional systems are themselves causes of sustainability problems and barriers to addressing the problems. These systems are resilient, powerful and often resistant to change*.'

22.2.3 Assessment and evaluation practice needs to be examined against this background

How do these considerations relate more precisely to the question of assessment and evaluation practice? Dovers (2005, p. 7) provides a first clue: '*Discussions of risk, the precautionary principle and decision making in the face of uncertainty suggest that we cannot rely solely on the resolving power of reductionist, quantitative science. This issue is even more important for assessment of broad policy approaches. The most detailed policy assessment will produce uncertain findings*.' Thus, the management of uncertainty characterises not only the modern or even risk society and its policies but also the related evaluation, assessment, and research in general. If in turn it is accepted that uncertainty is an important characteristic of modern society then the implication is that research-based predictions are only possible to a certain extent. Recognition of the fact that environmental degradation is often caused by sectoral policies outside the environmental arena means that such indirect impacts must be taken into account. The question is how far such indirect impacts are predictable quantitatively and whether a more comprehensive qualitative data-supported approach based on stakeholder consultation is not more enlightening.

As uncertainties are central and constitutive for sustainability problems, research has to reconsider its *own* orientation and constitution. The sustainability discourse does not permit a 'business as usual' research mentality. It provokes a discussion that goes deeper than a continued enhancement of well-established, proven and tested methods and tools. Sustainability concerns should actually trigger a rethinking of the previous hierarchy of research disciplines – economics, natural, and social science – and a more or less equal treatment in principle. The nature of the questions asked itself, suggests a range of inputs into the assessment, including natural science, social science, community opinion, and traditional knowledge. The limited significance of research-based findings in the policy process must be taken into account. Values and political judgement will always play a major role in final decisions, *along with* scientific assessments. Following this argumentation means also to be more modest with respect to: first, the assumed 'rational' and 'objective' scientific outcomes, and second, the consideration of different forms of knowledge, information and values. Having the systemic causes of sustainability problems in mind, it seems obvious that quantitative natural science must be accompanied by more qualitative judgment of political sciences and public administration. The idea that policy processes can be directly informed on the basis of neoclassical economic models totally ignores the complexity of societal change, political debates and decision-making. Research and assessment frameworks need to reflect the multidimensional, multilevel and multiactor nature of decision-making processes. Against this background we will now come to a critical appraisal of current evaluation practice.

22.3 Critical appraisal of current evaluation practice

22.3.1 Understanding assessment and evaluation as an integral part of policy processes

It is helpful to briefly reflect upon the goals of evaluation within the policy cycle. On its website the European Commission defines evaluation as follows: '*Evaluation examines particular results and impacts at certain stages in the life cycle of a programme. Recognised procedures are used in a systematic manner to judge the supported interventions. Evaluation helps in designing […] programmes, in improving and adjusting them at the mid-term stage, in planning an appropriate follow-up and in informing the public or the budgetary authorities about the effects and the value of the public intervention*.'[18]

Evaluation as defined by the European Commission has to be an integral element of the policy cycle as a whole. What does this mean for evaluation practice? And which kinds of problems occur in evaluation practice? Forstner *et al*. (2002) note that evaluation should ideally be an interactive, process oriented co-operation of evaluator and administration. In this process the evaluator can be seen as a moderator even more than a controller. Ideally evaluation promotes a public discussion and a collective learning process. A data based assessment can deliver valuable insights that are fed into this process.

In reality evaluation does not normally function like this. It helps distinguish two different approaches of evaluation: the summative evaluation, which can be seen primarily as an account, and the formative evaluation, which seeks after improvement opportunities. Particularly in the second approach evaluation is seen as a process of interaction between policymakers and evaluators and not as an activity merely directed to the production of an account of the effectiveness of some measures. While the awareness among policymakers of the utility of evaluation has increased in recent years, policymakers and administrations still often see evaluation as an instrument of control. Evaluation still needs to be seen more as a useful tool for future decisions and used pro-actively (Knickel and Kröger, 2006).

By understanding evaluation as a tool of institutional and collective learning instead of controlling, the continued improvement of programmes and measures takes centre stage. The dialogue between participants and beneficiaries as well as between evaluator and administration should help to identify deficits and to persistently improve measures (Geißendörfer, 2004). As for evaluation concepts and tools it follows that they must support the joint learning of different actors and stakeholders. In this alternative perception evaluation is no longer a mere measurement of results and control of success but – even more – a comprehensive process of attendance and valuation, which is co-ordinated with the policy cycle as a whole. The aim of this process is to answer questions about policy innovations and impacts and supporting the decision-making for future programmes (Knickel and Kröger, 2006).

Against this background Forstner *et al*. (2005) and others refer to the overemphasis of quantitative analysis and methods in evaluation practice. Because of the concentration on quantifiable indicators the studies are only apparently comparable. They argue that the

18 http://europa.eu.int/comm/agriculture/rur/eval/index_en.htm

informational values of such evaluations are often not that high. Knickel and Kröger (2006) note that public policies like agri-environmental schemes produce multiple effects that can hardly be quantified and that often a qualitative approach based on stakeholder consultation is more informative.

22.3.2 Still struggling with disciplinary boundaries?

So far we have argued that the unsatisfactory practice of policy evaluation is deeply connected with the predominance of quantitative methods in assessment and evaluation. Another main reason for the failure to really reach the policy process is the mono-disciplinary constitution of sciences. While the more recent research programmes clearly have become multidisciplinary in their orientation and claims, they still struggle with the foundations of the conceptual frameworks and methods available. Especially agricultural economics – as other economics – still tends to use quantitative methods in an exclusive manner. Institutional economics is a notable exception (see for example the work of Hagedorn and his research group on institutional change in agriculture and natural resources, Gatzweiler and Hagedorn, 2001).

Bitsch (2000a, p. 235) argues that it is not very effective to divide reality into manageable fragments or to concentrate on a precise data-based analysis of specific dimensions. It is clearly questionable whether the 'reduction of complexity' that is necessary in the practical application of quantitative models, methods and tools can be reconciled with the intricate complexity of goals and attributes. Contextual information, for example, will always be needed in order to be able to fully appreciate interdependencies and the importance of specific impacts. If interrelations and connections are ignored in favour of a better handling of reality the risk of problem reduction occurs. Important problem sources and elements might then remain overlooked. More extensive models try to circumvent this trap. It is questionable though whether the way the vast amount of information and interrelations is being processed is sufficiently transparent for decision-makers. Kasperczyk and Knickel (2006) see communication as a key issue and a critical constraint within the research community (communication between social and natural scientists for example) and, probably even more, between the research community and (potential) users. They underline that if the aim of an integrated assessment and policy evaluation is indeed the supporting of decision-making processes, it is absolutely essential that the way complex information is processed and assessment outcomes are arrived at remains sufficiently transparent for non-experts.

22.3.3 If 'good' questions cannot be quantified and 'quantifiable' questions are not that good

Voituriez (2005, p.15) sees present methods, at the moment, at a dead end as far as multifunctionality policies are concerned. Indeed, from all the country studies carried out in the Multagri research project it is clear that the extent to which the results of quantitative methods and particularly the outcomes of econometric modelling were used in practice has been extremely limited. The main reason for that is on the one hand the limitedness of conceptual frameworks and on the other hand the lack of relevant indicators and/or sufficiently disaggregated data. A consequence, that not necessarily is good, is that methods tend towards being qualitative and *ad hoc*, that is without having a sound qualitative evaluation framework. Again, what is urgently needed are more comprehensive and more integrative research tools that explicitly take into account multifunctionality and sustainability goals and attributes, and that still are sufficiently transparent (Knickel and Renting, 2000). In the following we briefly review modelling tools and ask what their scope is concerning sustainability and multifunctionality evaluation and assessment.

Canenbley *et al*. (2004) examined which agricultural functions four well-established modelling land use models covered[19].

The models were confronted with a list of economic, ecological and social functions. The synthesis shows that respectively two models – RAUMIS and ProLand – primarily cover economic functions while the other two models – MODAM and KUL – represent mainly ecological functions. Canenbley *et al*. (2004) argue that current models grasp the complexity of the multifunctionality concept only to a limited extent and that they are only convincing in covering certain dimensions of reality. The integration of different dimensions of reality and subsystems – both sustainability and multifunctionality by definition have an economic, an ecological and a social dimension – seems hard to deal with using classical, quantitative tools (Canenbley *et al*., 2004; Weinmann and Kuhlmann, 2003).

This assessment is in line with Kleinhanß (2000) and Ahrens and Bernhardt (1999) who also examined the capacities of different modelling tools under different perspectives and questions. Ahrens and Bernhardt (1999, p.9) found that the most convincing outcome of models concerning multifunctionality and sustainability relates to questions in the agri-environmental sphere. The authors stress that modelling results are able to direct the view on important cause-effect connections. The predictive capacity of the models used, however, was found to be restricted because of the very specific assumptions made and preconditions.

Ahrens and Bernhardt (1999, p.9) also bring us back to our discussion of the different functions of policy evaluation. They refer to the essential distinction between 'positive' and 'normative' approaches. While model-based analyses can, for example through different scenarios, stimulate political debates they will always have limitations in respect of the complexity of societal demands and the question of the valuation of different objectives (Long and Long, 1992). Maximising an income

19 The four tested tools are: KUL, MODAM, RAUMIS and ProLand.

function can never be an adequate approximation of decision-making in complex societal situations. Van der Ploeg (2003) goes a step further arguing that the images generated by agricultural expert systems diverge seriously from farm level realities.

Moreover, going beyond impact assessments evaluations are increasingly used to design public policies. Thus, the inclusion of societal objectives in the evaluation and assessment is inevitable. Ahrens and Bernhardt (1999) conclude that the strict division in normative and positive approaches should be overcome. Considering the above it must be concluded that while the potential contribution of models to a more formative evaluation are obvious, it is the limits of the tools available so far that are more predominant.

22.4 Recommendations for a more integrative policy evaluation and assessment

22.4.1 Reconsidering the role of research

One main implication of the discussion so far is that the self-image of research has to change if research outcomes are to become more meaningful in real life decision-making. Researchers and evaluators do not longer only play the role of experts but they increasingly act also as moderator of evaluation and policy formulation processes. As such they moderate the policy process – including the formulation and advancement of political goals. They have to integrate different concerns and interests in the evaluation process. This does not mean that classical research is redundant – researchers still have to play a major role in evaluation and assessment processes. But their understanding of the aims of evaluation must change. It is their very own function and exercise to consider interrelations, to find ways to balance different interests, bring in stakeholder views and to reflect and confront them with the results of data-based analyses. The role of experts has to become more moderate against the background of scientific uncertainty. In this process, the position of research, the role of researchers and the function of stakeholders will change too: stakeholders will not be understood any longer as (passive) research objects and instead they will be seen as (active) decision-makers and collaborators who can contribute their experiences and knowledge.

22.4.2 Organising platforms for collective learning

The involvement of stakeholders in evaluation processes has to be facilitated. One approach is to organise platforms for collective learning and decision-making. Röling and Pretty (1997) found that participation is the key tool for effective sustainability policies. They argue: '*Effective policy processes will have to bring together a range of actors and institutions for creative interaction and address multiple realities and unpredictability. What is required is the development of approaches that put participation, negotiation, and mediation at the centre of policy formulation so as to create a much wider common ownership in the practices. (…) The management of higher level systems, whether common grazing lands, coastal fisheries resources, communal forests, national parks, polders, or watersheds, requires social organisation comprising the key stakeholders. All successful moves to more sustainable agriculture have in common co-ordinated action by groups or communities at the local level. But the problem is that platforms for resource use negotiation generally do not exist, and so need to be created and facilitated*.' (Röling and Pretty, 1997).

A platform in this meaning is a space for negotiation created in situations where different actors define and struggle for the same set of resources and yet depend on one another to realise their objectives. The aim therefore is to create win-win-situations for the different parties. Within the platform, the actors discuss and clarify their points of view and seek common ground for joint action planning. A platform can in this respect be defined as a decision-making body, comprising different stakeholders who perceive the same resources management problem, realise their interdependence in solving it, and come together to agree on action strategies for solving the problem (Röling, 1994; Water-Bayer *et al*., 2005; Steins and Edwards 2005).

22.4.3 Towards more integrative analytical frameworks

In order to find a way to a more integrative research that adequately addresses the sustainability concept, Bitsch (2000b) asks for a triangulation of qualitative and quantitative approaches. Besides the application of different theories, methods and tools, triangulation implies the using of different data sources and the integration of different scientific disciplines and schools. The claim for 'objectivity' – in the meaning of one reality and verity which can be captured by science – is no longer, if ever, appropriate for research that aims to support the solving of complex problems or the assessing of complex policies. Integrated assessment is understood in this context as an interdisciplinary process of combining, interpreting and communicating knowledge from various scientific disciplines and/or stakeholders to inform decision-makers on complex societal problems (Rotmans *et al*., 2001; Greeuw *et al*., 2000).

In order to translate the notion of sustainability in research terms, it is necessary to integrate ecological, economic and social concerns – and goals – in one consistent conceptual and analytical framework. Moreover, sustainability is not simply a 'hard' property that can be captured scientifically like other properties and measured according to some objective scale. It is not a set of practices or measures than can easily be allocated in time and space either. Sustainability is much more an inherent quality that emerges when people individually or collectively achieve to maintain the long-term productivity of the natural resources on which they depend (Knickel, 2001; Knickel and Peter, 2005). In other words, sustainability emerges out of shared human experiences, objectives, knowledge, decisions, technology, and organisation (Röling and Pretty, 1997).

Evaluation is increasingly seen as an important element in the policy cycle. Indicator-based approaches and quantitative (modelling) tools alone, however, have severe limitations to address the complexities of a multifunctional rural space. More consultative, discursive approaches that are supported by hard data are vastly neglected. Overall, there is a need for more integrative analytical frameworks that combine quantitative and qualitative elements (Kröger and Knickel, 2005, p.18).

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23. Transcending the tensions: an emerging shift to ecosystem service production in the rural landscape of Victoria, Australia

Alistair Phillips (email: Alistair.Phillips@dse.vic.gov.au)

Abstract

The recently completed Rural Land Stewardship policy and programme investigation has revealed constructive new approaches to better position delivery of Government programmes for rural landscape change. Key to the shift is that ecosystem function and health, and ecosystem services – such as habitat, surface and ground water quality, and carbon sequestering – (as indicators of ecosystem health) provides a practical framework to compel integration of currently unsystematic issue-based approaches to land management actions. Applying the ecosystem services concept at the planning stage allows land use change proposals to be envisioned, or modelled at a scale that might be sufficient to re-balance ecosystem health deficits.

New directions emerging from the Rural Land Stewardship project include project planning using a 'place-based' approach in which local biophysical analysis and modelling to assess actions to deliver ecosystem health is used equally with an understanding of the capacity, interest and cultural profiles of land holder communities. Appropriate and project specific social analysis contributes to selection of suitable combinations from within the paradigms choices of; information, regulation, merit-based grants and competitively allocated contracts in devising project programme packages (policy tools). This paper draws on the ideas of the Rural Land Stewardship project and contemporary literature on rural landscapes. Attention is drawn to the interplay between biophysical site analysis and land holder capacity research in programme design is discussed with an emphasis on the connection between land holder analysis and the selection of suitable policy tool combinations.

Key words
Ecosystem services, land stewardship, community, biophysical analysis, social analysis

23.1 Introduction and context

Vast areas of the world have been modified to suit agricultural needs (Millennium Ecosystem Assessment, 2005). Some of the broadest examples of landscape change for agriculture can be observed by reflecting on the degraded fate of many landscapes in the southern-hemisphere colonies of European nations during the 18th and 19th centuries (Crosby, 1993). In regions such as Australasia, southern Africa, India and South America the economic and biophysical characteristics of northern European farming systems were often unknowingly imposed on land and weather systems that were vastly different to those of the colonising countries. From time to time these exploits have resulted in longer-term unsustainable outcomes for landscape health (MacKenzie, 1997).

In the example of European establishment of agriculture in Australia the land management approach of indigenous people (often argued as being a land use within land capacity), was disregarded and whole ecosystems erased or significantly altered to allow for the introduction of European grasses, crops and animals (Kirkpatrick, 1994; Williams, 1997). Where such changes to landscape have taken place in Australia, negative ecosystem impacts have arisen over comparatively short time scales. For example, a century or less after the comprehensive removal of the water table regulating, deep-rooted perennial native vegetation to make way for agriculture in south-west and eastern Australia the mobilisation of ancient marine sediments (as saline water tables) is now observable as saline land or land at saline risk (Pannell *et al*., 2004).

The State of Victoria approximates 23 million ha in land area, of which 12.8 million ha or 56% of the naturally occurring vegetation systems have either been removed or significantly modified to accommodate agriculture (Annett, 2003). In general biodiversity terms, Victoria's estimated ratio of 6:4 cultivated to natural landscape compares unfavourably with the global average of 3:7 cultivated to natural landscape (Millennium Ecosystem Assessment, 2005).

Victoria is a State of contrasting landscapes. It is the most intensively occupied in terms of human settlement while also being the second smallest Australian State. Victoria also has some of Australia's most important natural landscapes ranging from low dry Eucalypt woodland in the north-west to tall wet Eucalypt forest in eastern Victoria (National Land and Water Resources Audit, 2001). The Victorian landscape also supports a diverse agricultural industry, which generates $7.4 billion per year, representing 23% of Australian agricultural production (Annett *et al*., 2005). However, this relative success of agriculture has come at a significant ecological cost such as biodiversity loss and increases in saline land – all of which have a tendency to leave landholders (and land) less able to contend with climatic extremes and recurring hazards under climate change such as drought (Lindesay, 2003). Meanwhile, the biophysical issues of rural land are located within a political tension in which negative ecological impacts of agriculture, while historic in origin, contrast conversely with contemporary community attitudes to landscape use which are shifting toward favouring a greater environmental duty of care (Young *et al*., 2003; Roberts and Colwell, 2001).

In response to rural biophysical decline and community concern over this decline the government of Victoria has initiated a number of innovative steps in partnership with land holders. Perhaps the most significant of these, known as 'Landcare', originated in Victoria in 1986 as a government-farmer partnership that heralded a significant shift in community working with government (Ewing, 1996). Being both a farm management community of interest and a government programme, Landcare has expanded out of Victoria to now exist in all Australian States. It is worth bearing in mind that enduring community-based land holder movements such as Landcare, often represent effective forums for promoting contemporary practices and new institutional programmes in stewardship of our natural resources.

Since the early years of Victorian Landcare, and its often one-dimensional foundation in weed management alone, Landcare programmes have unfolded to include native vegetation management, responsible agricultural practices, and water management which, when partnered by government, are delivered through community capacity building programmes. While emerging policy and programme directions are positive the reality of current biophysical contexts remain sobering and despite at least two decades of Government-community partnerships on rural natural resource management the trends in rural landscape condition in Victoria continue to decline (Annett *et al*., 2005). For example, land condition vulnerability is reported across indicators such as: dryland salinity intensification, increased incidence of pest organisms, diminishing distribution of native vegetation (habitat) and deterioration soil health (Victorian Catchment Management Council, 2002) with Victoria also noted as having some Australia's most 'stressed' landscapes (Morgan, 2001). In commenting on Victoria's natural resource management challenges the Victorian Catchment Management Council (2002) observes that: 'Under current resourcing and management paradigms our efforts to protect and sustainably manage natural capital are not keeping pace with the breadth of degradation symptoms depreciating our natural capital base'.

23.2 Moving forward with new approaches

In responding to both global and local sustainability imperatives the Victorian State Government has examined various strategic directions and processes to increase the effectiveness of public investment in sustaining the rural landscape. An initiative of the Victorian Government, with support from the Victorian Catchment Management Council and the Australian Government, the Rural Land Stewardship policy and programme investigation has been part of that effort. This work, aimed at establishing new directions in sustainable rural land use and developing integrated and strategic approaches to ecosystem service provision from agricultural land, has now been completed.

The methodology used in the Rural Land Stewardship project was a typical policy proposal development method set (Bridgman and Davis, 2000). In summary: problems and challenges were identified (problem definition), analysis of current policy completed (context), many ideas for new directions canvassed (consultation), fifteen authors from economics, ecological and social sciences were commissioned to prepare/publish six cornerstone background papers (ideas co-ordination)[20] and finally an extensive consultation programme rounded off the effort (decision). Central concepts such as ecosystem services[21] and connecting social and biophysical data to inform and orchestrate large scale change, canvassed under the Rural Land Stewardship project, are now steering the next generations of the Victorian Landcare Programme and other significant budget Victorian Government rural landscape programmes.

Underpinning the progress into new approaches in Victoria is the proposition that addressing landscape decline can only be achieved through appropriately scaled and integrated land use change – leading to the capacity for both ecosystem services and commodity production from agricultural landscapes. Integration of actions at the multiple-farm, sub-regional and regional scales is pivotal in the argument that ecosystem services can only be produced if 'landscape scale' rates of land use change are achieved (Department of Sustainability and Environment, 2003). The challenges in this new direction are significant. Foremost is the need for continued development of techniques to spatially orchestrate actions in project planning and to improve on the current limited use of community analysis to better inform selection of project implementation tools. The latter – needing to understand community characteristics in order to improve implementation tools selection – is an important aspect of this paper.

23.3 Ecosystem services

In 2000 the United Nations commenced a large-scale assessment of the world's ecosystems – the Millennium Ecosystem Assessment. This study concluded early in 2005 with the release of the report Ecosystems and Human Well-being which noted a significant decline in all the world's ecosystems and accordingly the ecosystem services that humans rely on to support all life (Millennium Ecosystem Assessment, 2005). This report examines many human impacts on ecosystems with

20 These papers are available as pdf files at http://www.dse.vic.gov.au/dse/nrenlwm.nsf/ and following the links to Land, then Land Stewardship.

21 The Millennium Ecosystem Assessment (2005) proposes the following definition of ecosystem services – **Supporting**: nutrient cycling, soil formation, primary production. **Provisioning**: food, fresh water, wood and fibre, fuel. **Regulating**: climate regulation, flood regulation, disease regulation, water purification. **Cultural**: aesthetic, spiritual, educational, recreational.

farming singled out as among the significant contributors to ecosystem decline. The Millennium Ecosystem Assessment (2005) notes that:

While degradation of some services may sometimes be warranted to produce a greater gain in other services, often more degradation of ecosystem services takes place than is in society's interest because many of the services degraded are 'public goods'.

The provision of ecosystem services from multiple-use agricultural landscapes has been discussed variously in current literature. Hodge (2001) and, Latacz-Lohmann and Hodge (2003) observe the unambiguous potential of government policy to steer production of environmental goods within a broader package of countryside goods and services as an innovative outcome of rural environmental governance. Concurrently, De Groot *et al*. (2002) and Costanza *et al*. (1997) propose an extensive system for nominating, understanding and valuing myriad ecosystem services. On the challenge to develop methods to value and/or price ecosystem services Batabyal *et al*. (2003) and Birkin (2003) for example suggest and debate various pricing and valuing techniques. Stoneham *et al*. (2003) refine tendering processes to drive better costing of actions for land use change that may in the fullness of time deliver ecosystem services. In parallel, modelling of ecosystem service (for example Münier *et al*., 2004 provides a discussion combining ecological and economic modelling) and quantification of habitat values (Parkes *et al*., 2003) in landscape change continues to progress.

At a government policy and programme level Britain's Department for Environment, Food and Rural Affairs (2002, 2004 and 2005) have developed a notable strategic framework to drive a broader shift toward sustaining the economic and ecological health of the English rural landscape through land stewardship for 'environmental services'. In Victoria the Rural Land Stewardship strategic directions for ecosystem service production (for ecosystem health) has been accepted as five provisions from sustainable land use:

1. healthy surface water;
2. healthy sub-surface water;
3. terrestrial habitat (native vegetation);
4. carbon sequestration; and
5. soil health (potential for food and fibre production) (Phillips and Lowe, 2005).

In general, current ecological, economic and political sciences literature reveals an emerging interest ecosystem service production in agricultural landscapes. While advances continue to be made within a number of disciplines in the planning of large scale integrated projects for ecosystem service production in agricultural landscapes, it is desirable that growth in methods to understand the social contexts of such projects (rural land holder circumstances) also occur. While economics is producing ever more refined systems to more accurately value government funded environmental management actions by farmers – questions remain beyond developments in tendering methods regarding how durable, or inter-generational change in land management practices are achieved. That is, how is enduring change secured to land being used within its immediate capacities or 'ecosystem service budgets'? What are the internal social motivations, cultural circumstances and external economic settings that are the antecedents to reaching this change? Observations from these questions may emerge in two parts.

Firstly, as the combined weight of ecological and economic sciences begin to reveal the value to economies (and therefore to society) of clean water, sequestered carbon and properly maintained biodiversity etc. as public good ecosystem services *produced* by extant natural *landscapes*, the possibilities open for answering the complex questions around valuing ecosystem services *projected to be produced* by changed land use in current *agricultural landscapes*. The initial responses to these challenges are most evident in the advancements provided by the Millennium Ecosystems Assessment in which the provisioning, regulating, cultural and supporting services of terrestrial and marine ecosystems around the world are assessed. In this report various ecosystem services are described, valued and comparatively priced against other land uses. In just one of myriad examples, an intact wetland system in Canada was assessed as producing almost three times the dollar per hectare value as net community benefit than adjacent intensive farming (Millennium Ecosystems Assessment, 2005). How then might the emerging methodologies for comparative financial valuations of ecosystem services from natural landscapes be further developed to allow practical valuation of projected ecosystem services that may be produced from prospective (modelled) land use change in agriculture? This question – as it is progressively answered – is certain to increase planning capacities for appropriately scaled landscape change.

A second reflection arises in reference to understanding social permanency in changed approaches to agricultural landscape use. Are changes in attitudes linked temporarily to the duration of contracts, or are deeper levels of social change possible through dedicated community information and capacity development programmes? This question resides in the instinctive and sometimes polarised attitudes of people toward nature itself. At one end of the spectrum nature is viewed as a cold abstraction, and at the other nature is understood as being core to human identity (Anderson, 2005). How then in that context can institutions like government effectively assist communities to navigate between utilitarian and post-utilitarian (multifunctional) landscape tensions? This is further considered in the section *Project tool selection 2*: below.

23.4 Orchestrating actions and tailoring project tool selection

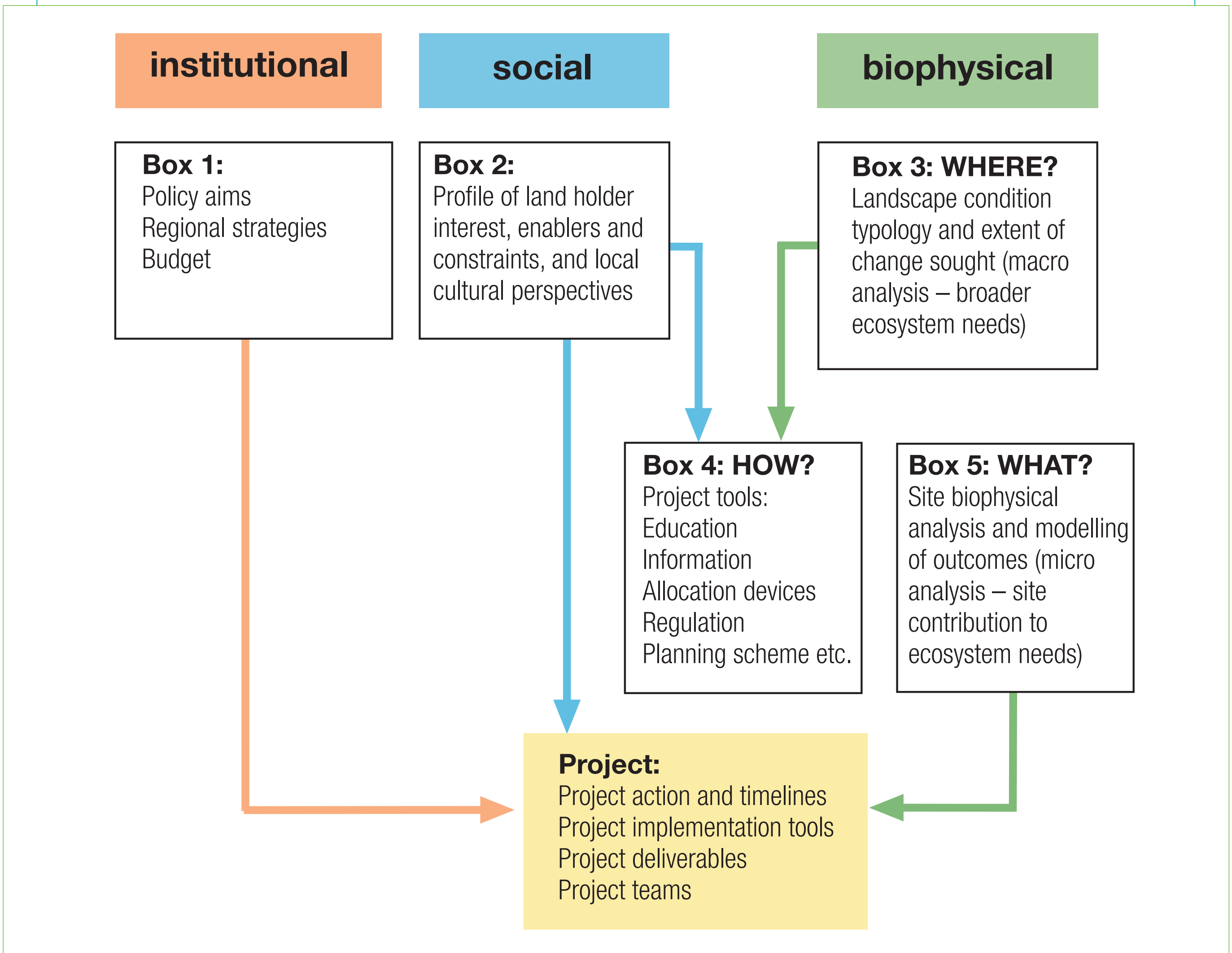
The implied message of sustainable development is that integration is critical if we are to accomplish development sustainably. Yet, under the 30 year-old banner of 'sustainability' we remain some distance away from achieving cross-discipline integration in research and government programme effort (Quinlan and Scogings, 2004; Newton and Freyfogle, 2005) and policy continues to lag behind in achieving practical connectivity between disciplines and objectives (Dovers, 1997). Moving forward to feasible, systematic and long-term platforms to plan and implement landscape-scale land use change projects has considerable challenges. A fundamental prerequisite is being able to effectively facilitate the communication and use of advice from the biophysical and social sciences in project design. To successfully merge *project activity information* such as weed control actions and revegetation siting for optimum water quality (orchestrating actions) with *project driver information* like the financial and skill capacities of participating land holders is needed to produce an overall *project blueprint* of actions and tailored project tool selection.

An ecosystem service focus in planning land use change requires integrating investment and orchestrating actions to marshal actions on issues like weeds, pest animals, salinity, soil health, water quality and native vegetation under a common ecosystem health objective. The point to be made here is that the scale of activity and change required to produce ecosystem service projects is likely to need a rigorous process for selection of the most appropriate programme (implementation) tools. For example, a data-driven project tool selection process that assembles the most effective combinations of education and information, voluntary support systems, regulatory and contract-based approaches. It is likely that a multiple criteria selection system of project tools will be necessary. In particular, the broad information categories to evaluate and inform project tools selection might include:

- the general condition of landscape (typology) and consequent level of change sought (Box 3, Figure 23.1);
- information on attitudes to environmental change, the structural (skills for example) and financial constraints and enablers (Box 2, Figure 23.1); or
- cultural contexts (normative or parochial behaviours) for land holders in project areas (Box 2, Figure 23.1).

To increase the likelihood of a project tool selection process being effective (Box 4, Figure 23.1) it is imperative that biophysical and social scientists – all of

FIGURE 23.1. Project design model for landscape-scaled ecosystem service projects.



whom are likely to be exceptional thinkers, passionate and focused on progression of sustainablity imperatives within their fields – have methods through which to collaborate. Being able to capitalise on the 'neutrality' of data from biophysical scientific investigation and the disclosure of the human role in biophysical conditions from the social sciences is the heart of the challenge. Figure 23.1 sets out a framework through which the biophysical and social science disciplines may transcend any tensions in 'cultural divides' between disciplines and overcome the clumsiness of informal or haphazard cross-discipline input in project planning.

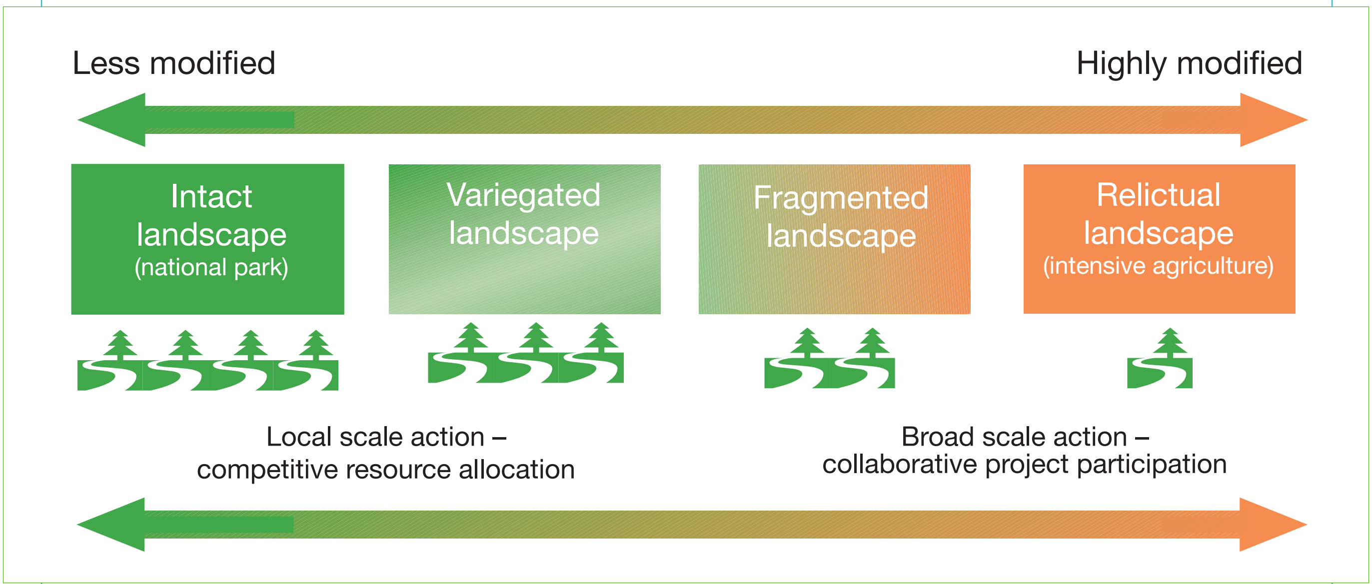
23.5 Project tool selection 1: Landscape condition typology and extent of landscape change sought

Project tools are defined here as being the types of active approaches used by institutions (government in the case of this paper) to assist project participants achieve project goals. Project tools are classified into three broad areas – education and information, resource allocation devices and regulation (including legally required duties of care to farmland) (Box 4, Figure 23.1). Understanding the extent and quality of landscape change sought in response to policy aims represents a component of the inter-discipline guide in selection of project tools (Box 3, Figure 23.1). McIntyre and Hobbs (1999) set out a general model for classifying landscape condition – which they further developed five years later with biome specific management implications (Hobbs and McIntyre, 2004). Linking a typology of landscape condition to a preliminary project tool selection allows greater clarity between project purpose and the type of approach likely to best fit that purpose (see Figure 23.2).

Intact or variegated landscapes

In healthy rural landscapes – for example, agricultural landscapes that are characterised by intact or variegated distributions of natural vegetation cover (Figure 23.2) – local scale ecological restoration of a vegetation class to connect fragmented habitat remains important then competitive or tendered resource allocation may be most appropriate. Particularly as the variegated landscapes in this broad typology may have issue-specific or limited ecological imperatives, making it possible to narrowly define the services being sought. For that reason, a competitive process where land holders *compete* with each other has the highest potential to secure greatest quantity and quality rehabilitation hectares per public dollar (Stoneham and Chaudhri, 2000). This closed tender approach has the facility to re-balance the information asymmetry that may otherwise encumber efforts to plan environmental actions with private land holders. This is a particular strength of the auctioned or tendered approach as it requires revelation of information on the ecological qualities of the participating land holder's property and some aspects of land holder capacities (Stoneham *et al*., 2003). Where landscape change is important, but land holders decide not to participate in the tendering for ecosystem service provision process, contemplation of other approaches may be prudent. While the competitive tender process may specify priority preferences, through higher scores for example for particular actions and locations, it may sometimes be the case that the transparent qualities of a genuinely competitive tender process will not allow explicit specification of where in the landscape activities must occur. The challenge of guaranteeing that private rural property in most need of change (for public good) being successful in a tendered service process is an area in economic methodology that may benefit from continued development.

FIGURE 23.2. Landscape condition typology and programme tool continuum – after McIntyre and Hobbs (1999).



Fragmented or relictual landscapes

In situations of extensive landscape modification ('fragmented' or 'relictual' landscapes Figure 23.2) where extensive ecosystem change has occurred historically (to accommodate agriculture) landscape-scale change may be required to meet ecosystem service delivery objectives. This broad level of change is likely to require an approach that encourages *collaboration* between land holders to achieve longer-term, durable success in ecosystem enhancement – and ultimately sustainable land use. Project design for this scale of landscape change is likely to be complex. An initial challenge in this approach is to describe the extent of change needed to deliver the ecosystem services sought and to then frame those ecosystem services as modelled outcomes of land use change – thus revealing an outline of optimum actions by land holders (Box 5, Figure 23.1). Where the values, risks and threats to landscape assets[22] are reliably described and agreed then land holder actions can be transparently explored and developed, subsequently opening opportunities for orchestrated actions for landscape asset protection to be planned collaboratively – ultimately enhancing broader ecosystem services.

23.6 Project tool selection 2: Profile of local cultural perspective's – land holder interest, enablers, motivators and constraints

The use of land for agriculture as an economic activity is in essence a socially-based action to appropriate otherwise natural landscapes to the 'systematic' production of plants and animals. The tension (as social construct) between nature and productive land use has been well discussed in recent literature on changing social values moving from tolerating *laissez-faire* land use toward favouring environmentally sustainable management of land (see for example Borgman, 1995; Franklin, 2002; Macnaughten and Urry, 1998; Wilson, 2002). Farming, when regarded as a 'social activity' that alters nature or the naturally occurring qualities of landscape becomes an appropriate field for social analysis. In the context of seeking to achieve orchestrated land use change to allow land to produce ecosystem services, a dependable understanding the hurdles, motivations and cultural norms of land holder populations in a large project sites is highly desirable.

Designing projects that are successful and deliver measurably effective outcomes is more likely to be achieved if based on an understanding of the cultural constructs that surround and buffer a farmer group from change. Insight into the idiosyncratic social conventions of the study population is a vital component to well-informed programme design because it is local cultural norms that farmer groups may occasionally fall back on to marginalise externally driven attempts at change.

Culture norms confirm 'habit' and provide a framework for social groups or communities make sense of difference and keep order in chaos.

Habit is the enormous flywheel of society, its most precious conservative agent. It alone is what keeps us all within the bounds of ordinance, and saves the children of fortune from the envious uprisings of the poor... It keeps the fisherman and the deckhand at sea through the winter; it holds the miner in his darkness, and nails the countryman to his log-cabin and his lonely farm through all the months of snow... (James, 1983)

Cultural values, particularly as manifested in individual or community habit can be used to protect existing land management practices as if they are the only practices possible. It is a community's cultural norms that may actually assist in encouraging change, or simply deflects any chance of success in a project. The critical point is that if this layer of social information is not understood in programme or project design then the risk increases that projects will not achieve durable and more deeply ingrained changes in land use, and sustainable land management.

Social research methodologies offer broad choices in technique and data outputs. Understanding communities of land holders and their cultural environments will require complimentary qualitative and quantitative research methods. A range of socio-demographic information will allow a first tier insight into the project area land holder population. Through appropriate sampling of the broader land holder population important information on cultural and peer dynamics can be obtained for use considering project implementation tools. For example, Fielding *et al*. (2005) describe a social research methodology used in working with farmers in Queensland, Australia on actions to protect and enhance waterways on private farmland in the Fitzroy Basin. This research was based on quantitative methods which went beyond attitudinal statistics, working through a 'theory of reasoned action' and a 'theory of planned behaviour'. Vital programme planning information was obtained on normative beliefs (peer or cultural pressures), behavioural beliefs (individual attitude to actions) and motivations to change or comply – including identification of key referents or trusted agents of influence (e.g. Landcare co-ordinators or local government officers).

Extra value in project planning may be added to the richness of the above socio-cultural data with the addition of a qualitative analysis of future land condition and economic scenarios. For example: Based on participatory (qualitative) social research Lundqvist (2001) describes land holders in various regions of Sweden having low interest in changing practices for the environmental benefit of lakes within their catchment unless actions clearly result in individual financial advantage. In this study preferences were directed

22 Landscape assets are the variety of natural resources that society might either directly use or remotely appreciate. Landscape asset items may include geographically identifiable elements such as a remnant natural vegetation system, a wetland system, a geological site of significance through to important areas of agriculturally productive land.

towards locally negotiated individual management plans, over opportunities for co-operative activities for provision of public good environmental services.

As part of the Rural Land Stewardship set of papers, Cocklin *et al*. (2003) conducted qualitative investigations on attitudes of land holder groups from different parts of Victoria, Australia aimed at assessing sustainable land management policy scenarios. The findings revealed a broad range of ideas and opinions in which the use of market-like systems for payment allocation on environmental works was greeted cautiously and training, information and voluntary programmes were favoured. Regulation and better-defined duties of care were viewed by land holder participants as a necessary last resort requirement to protect minimum standards in land management.

In considering both the studies summarised above in the context of project implementation tool selection: Study 1 reveals farmer groups who may respond positively to a competitive tendering process for environmental or ecosystem service provision, which could be particularly applicable for works in variegated landscapes (Figure 23.2). Alternatively, Study 2 shows farmer groups that are more likely to engage in projects through community capacity building approaches (training, information and voluntary programmes) – a situation with greater relevance to works in fragmented or relictual landscapes (Figure 23.2). A key point also here is that land holders respond to project ideas differently and that information on community's of land holders needs to be place based – spatially and temporally specific.

It is emphasised here that in a systematic approach to planning projects aimed at achieving landscape-scale change, securing appropriate social data to provide a reliable appreciation of the motivators and constraints for farmers is vital for tailoring projects (Box 2, Figure 23.1). It represents a critical strand in a broader process of purposeful project design and the shift toward sustainable agricultural land use.

23.7 A system to orchestrate project planning

Post the UN Conference on Environment and Development in Rio de Janeiro 1992 a common theme in environmental agencies has been to promote social inclusion in decision making or project development. This approach, if not systematic can simply come to a standstill after revealing competing priorities (economy versus environment for example) and not go on to describe achievable, agreed and practical solutions. The dilemmas in rural project development may come down to biophysical analysis being at odds with social analysis. This paper has proposed an argument that both biophysical and social data are equally important in programme and project design.

While the biophysical analysis defines land management changes that may be needed to achieve landscape scale change to secure ecosystem health, it is the orchestrated actions of individual land holders operating as a community that is a prerequisite for reaching sustainable rural landscape goals. That biophysical and social scientists have a formal way of bringing their respective deliberations together is critical for planning of projects at this scale. If these two sciences are not positioned to deliver an integrated project design then the likelihood of success diminishes.

The rigour of bringing it all together is the challenge. To transcend tensions between disciplines and to contribute on well-understood lines of inquiry within commonly understood policy goals systems are needed to effectively direct project development inputs. In a systematic sense the optimum approach under Victoria's Rural Land Stewardship is a sequential process:

Strategic foundation:

1. Policy frameworks: Government policy in combination with regional strategies provides an over-arching framework to guide project aims, inform budg*et al*locations and clarify the general levels of programme effort sought for ecosystem protection and enhancement.
2. Landscape scale: The general landscape condition (perhaps at a catchment scale for example) informs project tool selection at a broad level. At this point it is important to understand if the extent of landscape change sought is extensive or limited and what is the scale of change required to produce particular ecosystem services and protect wider ecosystem health? If discrete, highly focused change is needed, such as might be required in an intact or variegated landscape (Figure 23.2) then an eco-tender or competitive resource allocation programmes may have strong potential as the best project tool. This may be the extent of project planning required. If the broader landscape condition indicates the need for extensive change, for example in a fragmented or relictual landscape (Figure 23.2) then a project may need to be completed to a more detailed sequence of planning steps.

Applying a 'place-based' approach:

3a. Social profiles: Once the extent of change is identified, and therefore the project site is defined within that broader landscape of change, the population of land holders who own and influence the land system of the project area can be documented. At this point research on local cultural norms in addition to understanding levels of land holder interest and attitudes to change, and a collective account of the individual enablers, motivators and constraints will be critical in project tool selection. Exploring and clarifying assumptions about local social contexts (such as who and what are the trusted local sources of information) is very important in this part of the process. Building on the strengths of the rural Landcare movement is a pre-existing advantage that Victoria has in describing reliable profiles of land holder capacities and subsequently developing targeted community development programmes in natural resource management.

3b. Biophysical profiles: The landscape assets either within or under the influence of the project area and the condition of the site provides the start point where project actions can be described. Modelling how, and to what extent certain changes in land use will positively contribute to landscape asset protection, the production of ecosystem services deemed important for both regional economies and general ecosystem health is essential. This biophysical analysis to produce the fundamental set of project actions required provides the structure through which the findings of the social analysis (3a) can be understood in terms of the programming of project requirements. For example, in order to deliver long-term landscape change of a particular quality (modelled) then what are the community development needs that would underpin that landscape objective?

The steps described above may seem self-evident, and in many ways they simply represent a logical way to think about the planning of landscape scale projects for positive ecosystem outcomes. However, bringing logical processes together in large institutions can, for many reasons, prove a challenge particularly through the tensions that may exist between disciplines and between institutional divisions. Transcending the challenges presented in those tensions can be made possible when systematic processes are described formally as a mandated requirement of project or programme planning.

23.8 Conclusion

The Victorian landscape has undergone significant modification since European colonisation through the 18th and 19th centuries. Fifty-six percent of the state's naturally occurring vegetation systems have undergone significant modification (sometimes erasure) to make way for agricultural enterprises, and many of Victoria's agricultural landscapes are now not considered sustainable in the 'ecosystem service budgets' within which they exist.

There are many challenges in shifting the agricultural land uses of various Victorian regions to being sustainable. Understanding the complex interaction between the cultural contexts, skills and financial capacities of land holders, and the broader ecological processes of landscape in a systematic way is paramount. To achieve this in parts of Victoria, and indeed unsustainable agricultural regions around the world, formal frameworks are likely to provide the most successful process for describing a practical mix of policy implementation tools. The completion of reliable, commonly applicable methods to value (and price) future ecosystem services that a changed agricultural landscape might produce is also a challenge in programme design. To meet global to local sustainability imperatives of rural landscapes resolution of these challenges is a very important.

The central conclusion of the Rural Land Stewardship project is that achieving the integration of single issue-based approaches to land management is most likely through the use of an ecosystem services framework. This framework opens the potential to consider the rural landscape at a significant scale. That is, to produce ecosystem services through appropriate land use change on private rural land for broader public benefit will require planning and implementation of orchestrated land holder actions at a landscape or sub-region scale, rather than at the individual property level. In moving to planning land use change for ecosystem services as large or landscape-scale project sites it is imperative that systems are created to necessitate collaborative input from both the biophysical and social sciences.

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Department of Environment, Farming and Rural Affairs, 2004. *Rural Strategy 2004*. Defra Publications, London.
Department of Environment, Farming and Rural Affairs, 2005. *Environmental Stewardship*. Defra Publications, London.
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Authors' addresses

Aguilera Benavente, Francisco
Area of Urban and Regional Planning,
University of Granada,
Edificio Politécnico, P.C. 18071-Granada, Spain

Bastian, Olaf
Saxon Academy of Sciences and Humanities,
Neustädter Markt 10 (Blockhaus),
D-01097 Dresden, Germany

Bertke, Elke
Department of Agricultural Economics, Environmental and Resource Economics,
Georg-August-University of Goettingen,
Platz der Göttinger Sieben 5,
37073 Goettingen, Germany

Bienkowski, Jerzy
Research Centre for Agricultural and Forest Environment,
Polish Academy of Science,
Research Unit for Agricultural Systems,
Szeherezady St. 74,
60-195 Poznan, Poland

Burgess, P.J.
Institute of Water and Environment,
Cranfield University,
Silsoe,
MK45 4DT,
United Kingdom

Di Pietro, Francesca
Institute 'Dynamiques environnementales et paysagères',
University of Tours,
UMR 6173 and CRITT-INNOPHYT,
Parc de Grandmont,
F-37200 Tours,
France

Düring, Rolf-Alexander
Institute of Landscape Ecology and Resources Management,
Justus Liebig University
Heinrich-Buff-Ring 26c,
35392 Giessen,
Germany

Fiorelli, Cécile
INRA-SAD, Unité de Recherche Transformations des Systèmes d'Elevage,
Centre INRA Clermont-Theix,
63122 Saint-Genes Champanelle,
France

Freese, Jan
Research Centre for Agriculture and the Environment (ZLU),
Georg-August Universität Göttingen,
Am Vogelsang 6, 37075 Göttingen,
Germany

Friedrich, Klaus E.
OLANIS Expertensysteme GmbH,
Permoserstr. 15 D-04318 Leipzig,
Germany

Fry, Gary
Department of Landscape Architecture and Spatial Planning,
Norwegian University of Life Sciences,
PO Box 5029,
N -1432 Ås,
Norway

Gäth, Stefan
Institute of Landscape Ecology and Resources Management,
Justus Liebig University,
Heinrich-Buff-Ring 26c,
35392 Giessen,
Germany

Gerowitt, Bärbel
Institute for Land Use - Crop Health,
University of Rostock,
Satower Str, 48,
D-18051 Rostock,
Germany

Gerung, Julia
Institute of Geography and Geoecology,
University Karlsruhe,
Karlsruhe,
Germany

Grabaum, Ralf
OLANIS Expertensysteme GmbH,
Permoserstr. 15 D-04318 Leipzig,
Germany

Graves, A. Riccardo
Institute of Water and Environment,
Cranfield University,
Silsoe,
MK45 4DT,
United Kingdom

Happe, Kathrin
Institute of Agricultural Development in Central and Eastern Europe (IAMO),
Germany

Herzog, Felix
Ecological Controlling Research Group,
Agroscope FAL Reckenholz,
Reckenholzstrasse 191,
8046 Zurich,
Switzerland

Hildmann, Christian
Institute of Geography,
Dept. of Spatial and Environmental Planning,
Martin-Luther-University of Halle-Wittenberg,
Von-Seckendorff-Platz 4,
06120 Halle a.d. Saale,
Germany

Isselstein, Johannes
Department of Crop Sciences, Grassland Science,
Georg-August-University of Goettingen,
Von-Siebold-Str. 8, 37075 Goettingen,
Germany

Jankowiak, Janusz
Research Centre for Agricultural and Forest Environment,
Polish Academy of Science,
Bukowska 19, 60-809 Poznan,
Poland

Jessel, Beate
Chair for Strategies of Landscape Management,
Weihenstephan Center of Life and Food Sciences,
Technical University of Munich,
Am Hochanger 13,
85354 Freising-Weihenstephan,
Germany

Josien, Etienne
Cemagref, Unité de Recherche Dynamiques et Fonctions des Espaces Ruraux,
24 avenue des Landais- B.P. 50085 - 63172 Aubière Cedex 1,
France

Kędziora, Andrzej
Research Centre for Agricultural and Forest Environment,
Polish Academy of Sciences,
Bukowska 19, 60-809 Poznan,
Poland

Kildal, Torsten
OLANIS Expertensysteme GmbH,
Permoserstr. 15 D-04318 Leipzig,
Germany

Klimek, Sebastian
Research Centre for Agriculture and the Environment (ZLU),
Georg-August-University of Goettingen,
Am Vogelsang 6, 37075 Goettingen,
Germany

Klug, Hermann
Centre for GeoInformatics (Z_GIS),
Salzburg University,
Hellbrunnerstraße 34,
5020 Salzburg,
Austria

Knickel, Karlheinz
Institute for Rural Development Research (IfLS),
Johann Wolfgang Goethe University Frankfurt,
Zeppelinallee 31,
60325 Frankfurt am Main,
Germany

König, Antje
Chair for Landscape Management and Geoecology,
Technical University of Dresden,
Helmholtzstr. 10, D-01069 Dresden,
Germany

Kröger, Melanie
Institute for Rural Development Research (IfLS),
Office Berlin,
Isingstr. 9, 12435 Berlin,
Germany

Lardon, Sylvie
INRA-SAD, ENGREF Politiques Publiques et développement des Territoires,
24 avenue des Landais - B.P. 90054 - 63171 Aubière Cedex 9,
France

Lütz, Michael
Saxon Academy of Sciences and Humanities,
Neustädter Markt 10 (Blockhaus),
D-01097 Dresden,
Germany

Mante, Juliane
Institute for Land Use - Crop Health,
University of Rostock,
Satower Str, 48,
D-18051 Rostock,
Germany

Matarán Ruiz, Alberto
Area of Urban and Regional Planning,
University of Granada,
Edificio Politécnico,
P.C. 18071-Granada,
Spain

Meyer, Burghard C.
Centre for Environmental Research (UFZ),
Permoserstraße 15, D-04318 Leipzig, Germany

Meyer, Thomas
OLANIS Expertensysteme GmbH,
Permoserstr. 15
D-04318 Leipzig,
Germany

Müller, Klaus
Leibniz- Centre for Agricultural Landscape Research (ZALF),
Eberswalder Str.84,
15374 Muencheberg,
Germany

Palma, João H.N.
Ecological Controlling Research Group,
Agroscope FAL Reckenholz,
Reckenholzstrasse 191,
8046 Zurich,
Switzerland

Peterson, Anna
Department of Landscape Planning,
Swedish University of Agricultural Sciences,
Box 58,
SE-230 53 Alnarp,
Sweden

Phillips, Alistair
Department of Sustainability and Environment,
PO Box 500, East Melbourne,
Victoria,
3002 Australia

Piorr, Annette
Leibniz- Centre for Agricultural Landscape Research (ZALF),
Eberswalder Str.84,
15374 Muencheberg,
Germany

Rapey, Helene
Cemagref, Unité de Recherche Dynamiques et Fonctions des Espaces Ruraux,
24 avenue des Landais- B.P. 50085 - 63172 Aubière Cedex 1,
France

Reiher, Wolfgang
Institute of Landscape Ecology and Resources Management,
Justus Liebig University,
Heinrich-Buff-Ring 26c,
35392 Giessen,
Germany

Reisner, Yvonne
Swiss College of Agriculture,
Laenggasse 85,
3052 Zollikofen,
Switzerland

Richter gen. Kemmermann, Anne
Research Centre for Agriculture and the Environment (ZLU),
Georg-August-University of Goettingen,
Am Vogelsang 6,
37075 Goettingen,
Germany

Röder, Matthias
Saxon Academy of Sciences and Humanities,
Neustädter Markt 10 (Blockhaus),
D-01097 Dresden,
Germany

Ryszkowski, Lech
Research Centre for Agricultural and Forest Environment,
Polish Academy of Sciences,
Bukowska 19,
60-809 Poznan,
Poland

Sattler, Claudia
Leibniz- Centre for Agricultural Landscape Research (ZALF),
Eberswalder Str.84,
15374 Muencheberg,
Germany

Schneider, Christine
Department of Landscape Planning,
Swedish University of Agricultural Sciences,
Box 58,
SE-230 53 Alnarp,
Sweden

Schreiner, Vera
Centre for Environmental Research (UFZ)
Permoserstr. 15,
D-04318 Leipzig,
Germany

Servière, Gerard
Institut de l'Elevage,
12 avenue Marx Dormoy - B.P. 455 - 63012 Clermont-Ferrand Cedex 1,
France

Sheridan, Patrick
Institute of Agricultural and Food Systems Management,
Justus Liebig University,
Senckenbergstr. 3, 35390 Giessen,
Germany

Silber, Rainer
Institute for Sustainable Economic Development,
University of Natural Resources and Applied Life Sciences,
Feistmantelstrasse 4,
1180 Vienna,
Austria

Steinmann, Horst-Henning
Research Centre for Agriculture and the Environment (ZLU),
Georg-August Universität Göttingen,
Am Vogelsang 6,
37075 Göttingen,
Germany

Syrbe, Ralf-Uwe
Saxon Academy of Sciences and Humanities,
Neustädter Markt 10 (Blockhaus),
D-01097 Dresden,
Germany

Uthes, Sandra
Leibniz-Centre for Agricultural Landscape Research (ZALF),
Eberswalder Str.84,
15374 Muencheberg,
Germany

Valenzuela Montes, Luis Miguel
Area of Urban and Regional Planning,
University of Granada,
Edificio Politécnico,
P.C. 18071-Granada,
Spain

Waarts, Yuca
European council of Nature Conservation (ECNC),
The Netherlands

Waldhardt, Rainer
Institute of Landscape Ecology and Resources
Management,
Justus Liebig University,
Heinrich-Buff-Ring 26c,
35392 Giessen,
Germany

Weinmann, Bernd
Institute of Agricultural and Food Systems Management,
Justus Liebig University,
Senckenbergstr. 3,
35390 Giessen,
Germany

Wolf, Torsten
OLANIS Expertensysteme GmbH,
Permoserstr. 15
D-04318 Leipzig,
Germany

Wytrzens, Hans Karl
Institute for Sustainable Economic Development,
University of Natural Resources and Applied Life Sciences,
Feistmantelstrasse 4,
1180 Vienna,
Austria

Zeil, Peter
Centre for GeoInformatics (Z_GIS),
Salzburg University,
Hellbrunnerstraße 34,
5020 Salzburg,
Austria

Research Contributions

LANDSCAPE EUROPE
Landscape Europe Secretariat,
Alterra Wageningen UR,
P.O. Box 47,
NL-6700 AA Wageningen (The Netherlands)