

Landscape Agroecology: managing interactions between agriculture, nature and socio-economy

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Abstract

State of the art GIS and database technologies for landscape scale analysis and the modelling of land use and environmental impacts are presented. These methods have been developed at University of Aarhus in multidisciplinary collaboration with other research institutions throughout Europe; for example during the EU research projects www.mea-scope.org and www.sensor-ip.eu. In the years to come, these landscape scale research methods are further developed and integrated with similar frameworks in other EU countries, and used for scenario studies (see for example the landscape components of <http://www.nitroeuropa.eu/>, <http://www.darcof.dk/research/darcofiii/refugia.html> or <http://www.darcof.dk/research/darcofiii/bioconcens.html>).

Scenario studies, visualised in geographical information systems, are useful to evaluate possible future landscape developments, and to identify potentials and limitations in combining multiple landscape functions. Here we focus on scenario systems that focus on exploring interactions between landscape functions – e.g. the interactions between farm management, economy, nutrient losses, fauna population dynamics, plant community development etc. Among others, scenarios for drinking water protection via increased set-aside grassland or afforestation are presented. It shows that benefits from subsidies targeted to areas with special interests in protection of drinking waters from nitrogen pollution differ from non-targeted subsidies.

Experience has shown that working with scenarios and involving potential users at an early stage in development are important ways of focussing the work effort and ensuring that relevant tools are developed. Developments in data collection and collation at the EU level will allow similar systems to be developed elsewhere.

Key-words: Landscape, Agroecology, Scenarios, Multidisciplinarity, Geographical Information systems (GIS), Multifunctionality

Introduction

This paper and the presentation for the Berlin Green week conference on “Multi-level processes of integration and disintegration (Humboldt-Universität zu Berlin 2009) are synthesized from research carried out in relation to three European landscape research projects; MEA-scope (www.mea-scope.org), SENSOR (www.sensor-ip.eu) and Nitro-Europe (<http://www.nitroeurope.eu>), in addition to a number of Danish research projects (see for example ICROFS 2009 or Dalgaard et al. 2003a, 2007, 2009).

At the conference, examples from this work were presented together with some additional examples on research carried out within The Department of Agroecology and Environment, Aarhus University, Denmark. This also includes methods for upscaling (Dalgaard et al. 2003b). In this paper selected examples are described in more details, emphasising the needs for further research developments within the discipline of Landscape Ecology (Wojtkowski 2004, Dalgaard 2005).

New needs for landscape research

Today's demand for sustainability is not limited to agricultural production and profit but includes other aspects of rural life such as the environment and landscape. Proper utilisation of the future landscape requires a holistic approach where consequences of various different land uses are assessed and management adjusted. At the same time, regulatory authorities in member states have the task of implementing a range of EU directives that target specific policy areas e.g. the Nitrates Directive, National Emissions Ceilings Directive, Habitat Directive and the Water Framework Directive. If policy initiatives directed towards implementation are developed in isolation, there is a tendency for the resulting regulations to become antagonistic. For example, as part of the implementation of the Nitrates Directive in Denmark, farmers were obliged to plant more winter cereal crops. This has resulted in an increase in the frequency of pesticide applications, a development that threatens wildlife and conflicts with the objectives of the Habitat Directive.

The development of interdisciplinary landscape scenario systems

One example of an interdisciplinary landscape scenario system was developed in the project "Land use and landscape development, illustrated by scenarios - Interactions between nature, agriculture, environment and land management", initiated under the Danish research programme: Land use - the farmer as landscape manager (Hansen et al. 2002). This multi-disciplinary project involved collaboration between the Danish Institute of Agricultural Sciences, The National Environmental Research Institute, Geological Survey of Denmark and Greenland, University of Aarhus, Viborg County, The Danish Agricultural Advisory Centre, and Danish Institute of Agricultural and Fisheries Economics.

The focus of this scenario study is the farm as an integrated part of the rural landscape. The objective is to develop methods to enable interactions between policy areas to be identified and quantified. In this way, policymakers can seek to avoid antagonistic interactions and promote those that are synergistic.

The policy areas currently targeted by this scenario system are agricultural production, nutrient losses, landscape, and nature conservation. The process involved when investigating a policy initiative is as follows. The policy objective is defined and one or more policy measures are formulated. Often, these policy measures are in the form of regulations or economic incentives to achieve a certain change in land use or land management e.g. planting of woodland or extensification of livestock farming. These measures are then applied to the target area, either using an economic model or a decision tree or a combination of the two, using a GIS. The results are spatially explicit changes in land use or land management. The GIS is then used to generate input files for a number of models. The models included concern agricultural production and losses of nitrogen, hydrology and plant and animal wildlife (Figure 1). The main data sources for this scenario system are the national databases for cropping (GLR), livestock holdings (CHR), soil types and climate. The main function of these databases is to support Denmark's compliance with EU support schemes and directives, and for agro-environmental analysis purposes.

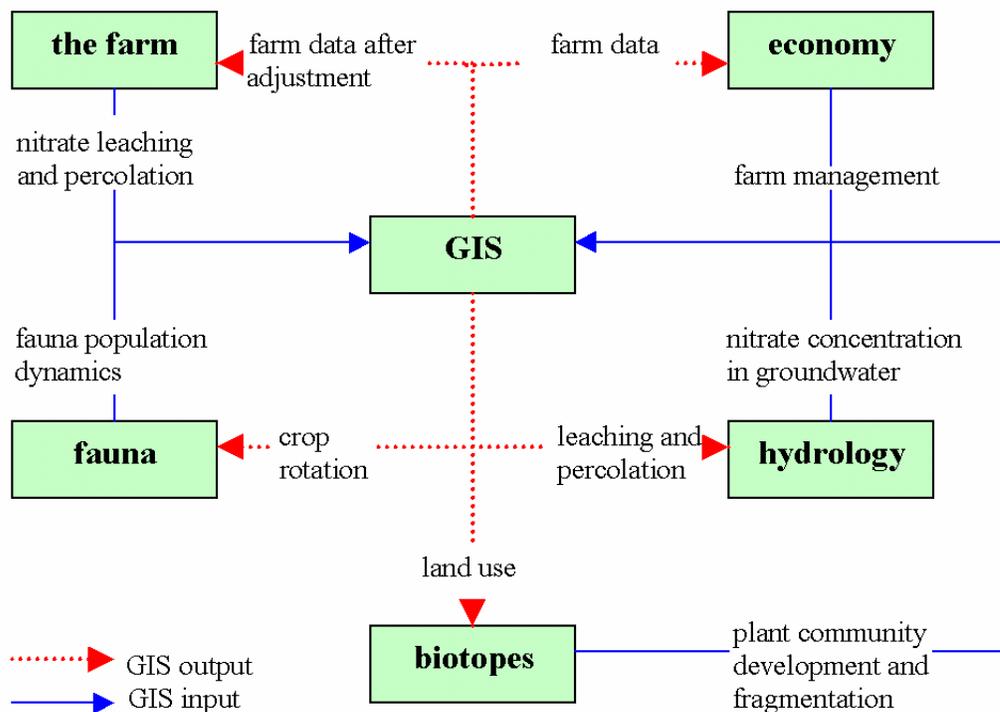


Figure 1: An example of an interdisciplinary landscape scenario system (Hansen et al., 2002).

The test site for the scenarios is an area of 100 km² in Viborg County, Denmark, Figure 2. Since the early 1990'es this area has been the focus for an intensive campaign of data collection, including a detailed mapping of the soil, geology, biotopes and even of small landscape features such as ditches and field boundaries. The detailed data were collected to enable the importance of the scale of available data on scenario outcomes to be investigated. Data are digitised and stored in a Geographical Information System (GIS), which is the basis for the subsequent analyses. Presently, this landscape is used for scenario building in relation

to effects of revisions in the EU agricultural and rural development policy (see Dalgaard et al. 2009), effects of mitigation options for the reduction of greenhouse gas emissions from agriculture (<http://www.nitroeuropa.eu>) and potentials for bioenergy production and nature conservation (ICROFS 2009).

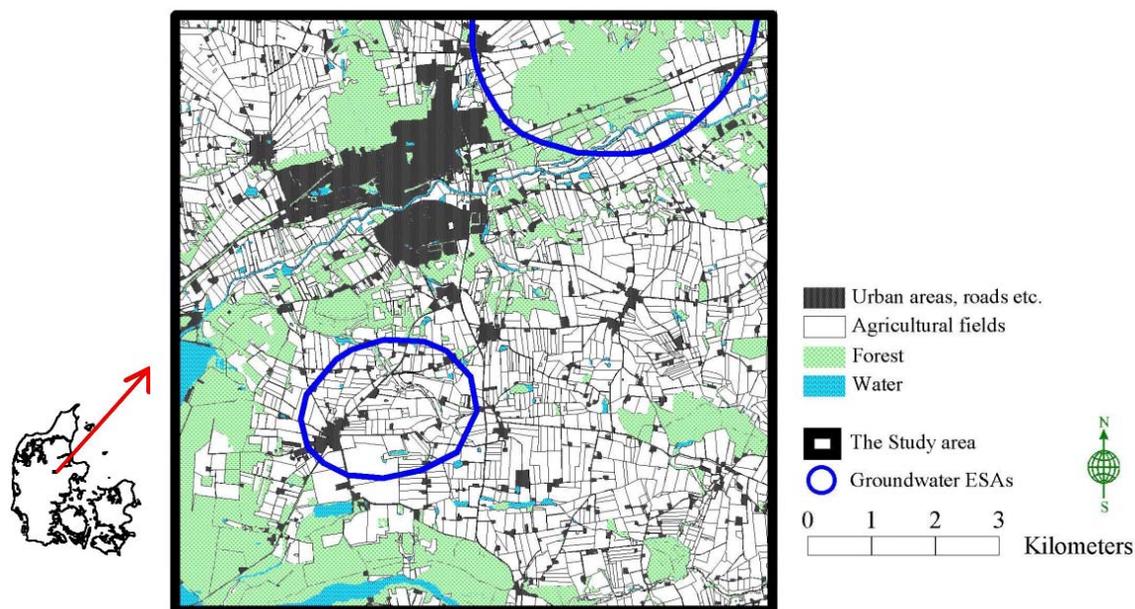


Figure 2. Land Use in the 10 x 10 km² study area, situated around the city of Bjerringbro in the midwest of Denmark. The ESA's are environmentally sensitive areas with respect to groundwater quality (Dalgaard et al. 2001c).

Example: A scenario for drinking water protection

As an example, it is illustrated how the Figure 1 scenario system was used to investigate measures for drinking water protection. Investigations have shown that spreading of livestock manure is closely related to N-losses (Dalgaard et al. 2002a), and the distribution of livestock manure and fertilisers is the main driving factor for nitrogen (N) leaching to ground- and surface waters. A model for the geographical distribution of N between fields within each farm and between farms within the study area was developed (Dalgaard et al. 2001c). In this model, the N-distribution within and between farms is simulated from number and types of animals on each farm, the crop rotation and the choice of cash and roughage crops for feeding livestock, soil types, distances to neighbouring farms and the N-need for fertilisation of the crops on these farms. Figure 3 pictures an example of simulated distribution of N in manure and fertilisers on agricultural land within the study area.

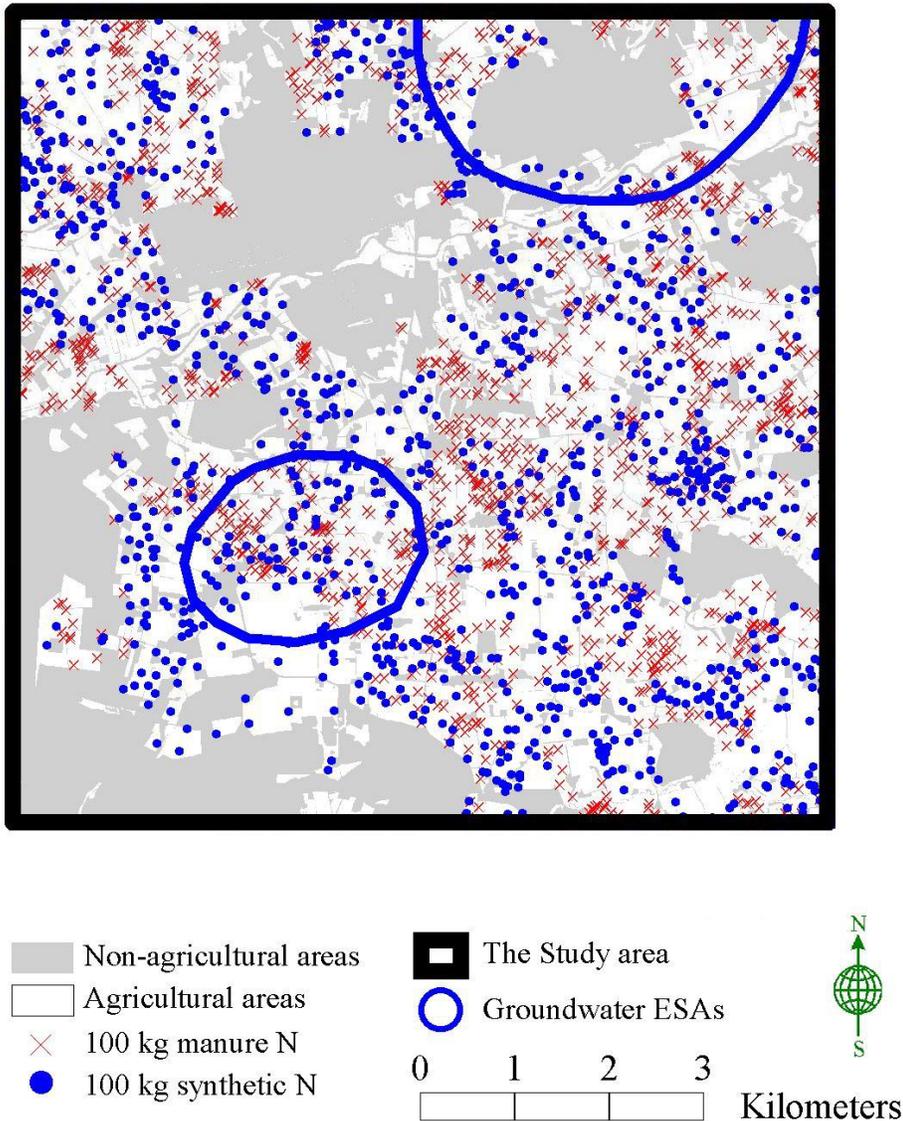


Figure 3. Example of simulated distribution of nitrogen (N) in manure and fertiliser on agricultural land inside and outside ground water protection areas (ESAs) in the project area. Especially manure N is a good indicator for N-losses, and drives the models for N-leaching to ground and surface waters (Dalgaard et al. 2001c).

In a scenario, the effect of drinking water protection via extensification in the form of grassland set-aside in the groundwater protection area (ESA) situated in the watershed of the stream “Tyrebækken” is investigated (Figure 4). This scenario is especially relevant in the context of the EU Nitrate and Water Framework Directives.

According to EU legislation, necessary measures should be implemented in order to protect drinking water quality in designated areas; i.e. the ESA in Figures 2, 3 and 4. When fields in

the ESA's are turned into permanent grassland set-aside, the areas are taken out of agricultural production. In the scenario system, each farmer's reaction to these measures, in form of changed animal and crop production, is decided from a set of rules, and the resulting change in fertilisation practice is decided from the model described above. In this way, the effect on N-leaching is estimated and interactions with other economic and ecological functions in the landscape assessed. As will be described in the following, these interactions are often non-linear and crucial to include in analysis of possibilities in creating multifunctional landscapes.

Tyrebæk watershed

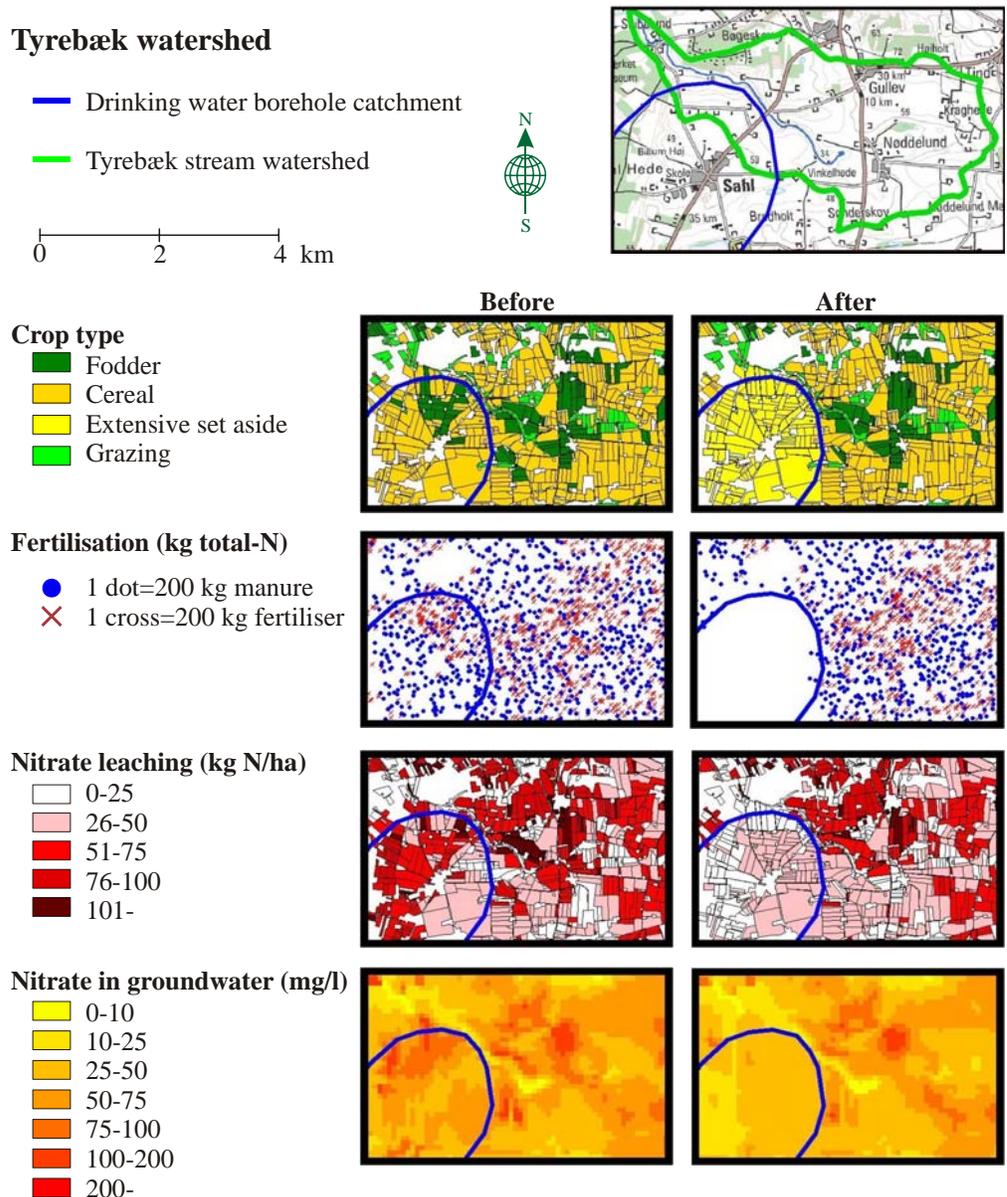


Figure 4. Case study site for the groundwater protection scenario, with the Tyrebæk stream watershed in green and the catchment area for the drinking water borehole in blue. The 'before' and 'after' maps show the results from the crop rotation, manure, farm and hydrogeological models, before and after extensifying the borehole catchment (after Hutchings et al. 2004).

Interactions between multiple functions

This section shows an example of the interactions between landscape functions, which the interdisciplinary scenario systems can help disentangling. The two functions included in the example are the economic benefit from farm production, given by the average farm level gross margin, and the reduction in nitrogen losses resulting from the introduction of afforestation on former agricultural land (see the drinking water protection scenario described above, and Rygnestad et. al. 2001, 2002). The policy measure investigated were two different auctions based measures, with an equal, total afforestation subsidy of 2.7 mio. DKK used (Figure 5). In the targeted measure, only farms within ground water protection areas (i.e. farms with most of their fields within the ESAs in figure 2 and figure 3) are invited to tender. In the uniform measure all farms in the study area are invited to tender, and in both the uniform and the targeted situation it is assumed that farmers choose afforestation, if the afforestation subsidy per ha is higher than the average farm level gross margin per ha.

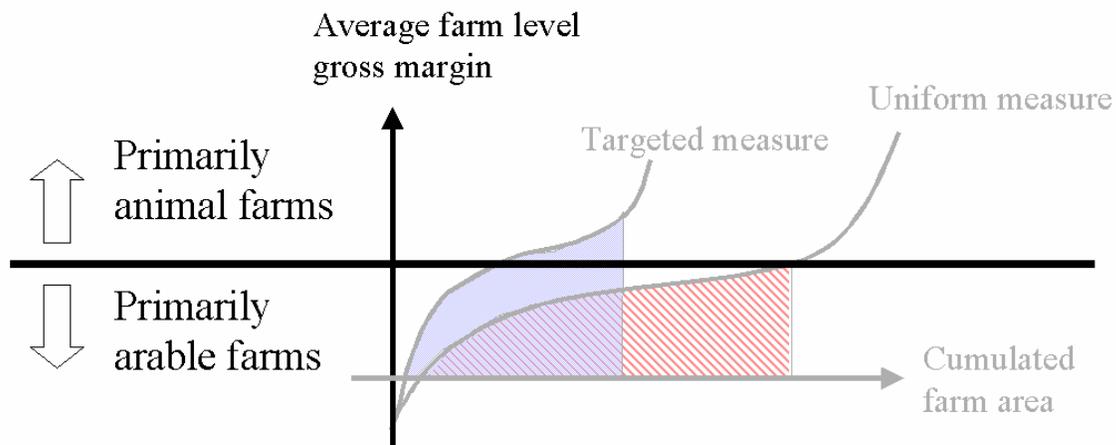


Figure 5. Example of interactions between farm income and drinking water protection via auction based afforestation. In the uniform measure all farms are invited to tender and the hatched area is afforested. In the targeted measure only farms within designated areas are invited to tender and a smaller area is afforested. However, the total protection effect of the targeted measure is equal to that of the uniform measure, because the targeted measure affects more of the animal farms that have a higher impact on N-pollution than the mainly arable farms affected by the uniform measure (after Dalgaard et al., 2003a).

As illustrated in figure 5, the uniform measure leads to the largest area afforested (the hatched area). This is because the marginal subsidy needed to make farmers plant woodland increases faster in the targeted than in the uniform measure. However, the farms with low average farm level gross margins which plant woodland as a result of the uniform measure, are primarily arable. In contrast, the targeted measure results in more animal farms, which typically have higher gross margins than arable farms, also planting woodland. Because N-losses are closely

related to high livestock density, the groundwater protection effect of the targeted measure will be as high as the effect of the uniform measure, even though the area included by the targeted measure is much smaller (Dalgaard 2001).

Conclusions and perspectives

The interdisciplinary landscape scenario systems illustrated are applicable at a range of scales, from small areas, in which each individual farm is considered as a separate entity, to larger scales, in which standard farm types are used.

Denmark has been in the forefront in the collection of digital farm data in national databases and in the development of methods to combine these data with other data types (Dalgaard et al. 2002b). In these years, similar data are becoming available in most EU countries e.g. from national censuses, the EUROSTAT Farm Accountancy Data Network (FADN), landscape study site inventory campaigns like the ones initiated in the NitroEurope and the MEA-scope EU research projects, or in less details data available from national area support scheme databases (Petit et al. 2008). Therefore it is interesting to explore the opportunities to develop methods to combine these data, in scenarios for landscape development in the different regions of Europe.

The ecological, economic, wildlife and visual functions of landscapes within a modern society are determined by processes that operate over a range of scales in space and time. Integrating knowledge of these processes into tools that can be used by people who have stewardship over the land, such as farmers and regulators, requires an interdisciplinary approach. Such an approach demands significant effort as it must work against the trend of specialisation and fragmentation of knowledge that has occurred over the recent centuries. It also requires substantial technical developments, relating to data collation from disparate sources, data manipulation, data management and integration of information about the multiple landscape functions (Vejre et al. 2007). An important note from this paper is therefore, that working with scenarios and involving potential users at an early stage in development are important ways of focussing the future research effort, and ensuring that relevant tools are developed.

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