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A conceptual model for site-specific agricultural land-use

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ABSTRACT

Land-use concepts provide decision support for the most efficient usage options according to sustainable development and multifunctionality requirements. However, developments in landscape-related, agricultural production schemes are primarily driven by economic benefits. Therefore, most agricultural land-use concepts tackle particular problems or interests and lack a systemic perspective. As a result, we discuss a conceptual model for future site-specific agricultural land-use with an inbuilt requirement for adequate experimental sites to enable monitoring systems for a new generation of ecosystem models and for new approaches to address science–stakeholder interactions.

1. Background: the current agricultural land-use situation

Because agricultural land use is subject to the will and interests of the landowners within the boundaries of social obligations, an owner's benefit understandably follows current or expected future market conditions. Goods and services that are expected to provide a short-term maximum benefit for the owner are subsequently produced or provided (e.g., FAO, 2011), which typically causes a decoupling of uses from site-specific conditions and is necessarily associated with ecologically distorting effects that ultimately lead to non-sustainable management practices (Zhang et al., 2007). Even if there has to be distinguished between conventional and organic agriculture, it has to be considered that in the meantime also organic agriculture has to meet the challenge of bulk production and the competition about agricultural land. In general, the following question arises: why should land be made available for a certain use at all costs even though natural conditions make this practice unadvisable? Instead of decoupling land uses from the site-specific conditions, a resource-saving (or -preserving) use of land due to the specific site situation should be the general rule. Therefore, "site-specific land-usages" should be discussed to offer decision makers, land managers as well as politicians, potential options for both environmentally sound and economically viable land-use approaches (see also Sandhu et al., 2008).

Furthermore, future-oriented land use concepts should be more systemic in the sense of considering site-related factors like soil, landscape water balance, regional climate, etc. as well as the interdependencies between conventional agricultural as well as environmental sound agricultural production and market restrictions. This again applies first of all the decision-making of the land managers. Having said that, also the overall political framework requirements to provide an adequate scope of action have to be discussed. It requires a formalized process of the design of science/policy interaction that allows for an integrated and thorough analysis of the possible implications of the intended policy. Therefore research altogether and models particularly concerning future agriculture land-use concepts (e.g., Lambin et al., 2000; Verburg et al., 2002) should tightly focussed support policy consulting.

Examining ontologies (Maedche and Staab, 2001; Ichise, 2009) in the context of such land-use concepts might be partially encompassed by discussing multifunctionality (OECD, 2001; Van Huylenbroeck et al., 2007) and implementing procedures for sustainable development (according to UN, 2003). Nevertheless, discussions regarding agricultural land-use concepts should extend beyond the multifunctional agriculture political discussions. By definition and from a political perspective (OECD, 2001), land-use concepts provide several social and environmental benefits to a society (TEEB, 2009) by maintaining the economic and ecological

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structure of cultural landscapes. Ultimately, this approach can legitimize the continued financial support for agricultural production using the multifunctionality argument. Thus, the discussion should be directed back to those disciplines providing knowledgeable support for land sites and their particular "sensibilities".

A useful approach in this context is to develop systemic modeling tools (e.g., Ewert et al., 2005; Asseng et al., 2013; Bassu et al., 2014) that allow decision makers to explore particular land-use scenarios with approaches that cascade down to the specific site situation. Anxiously, continual exogenic changes (e.g., due to the Common Agricultural Policy of the EU) require proactive land-use concepts for the sustainable development and sustainable use of agricultural land (Karlstetter, 2011).

However, some key questions arise:

- How can a more systemic approach be established as an alternative to addressing particular land-use problems?
- How can modeling tools be used to support decision-making for future land-use schemes?

Box 1: Some definitions used within this paper.

Agricultural land use
Supposed is a use of land suitable for agricultural production. Due to standard classifications (e.g., used by FAO/Food and Agriculture Organization of the United Nations) agricultural land and its use is divided into arable land and permanent crops and pastures. Within this paper the focus is on the use of arable land.

Land-use concept
This refers to the "how" of land use. Thereby it should become apparent how land is committed. This implies the production of goods and services and management practices how to tweak this.

Site-specific
Relating to a site, in this case due to an overall agricultural landscape with its natural, (geobio)physical environment.

Systemic
Relating to an entire natural system

2. Methodological approach

Within the discussion about agricultural land-use concepts the approach becomes a systemic feature that can be satisfactorily observed only if the following basic requirements are fulfilled:

- *Systemic models* must be applied as conceptual bases.
- *Systemic measurement concepts* are prerequisites for this indication, in which the borders of environmental sectors or media must be transgressed.
- Data interpretation tools must be integrative such that *model applications* can be profitably used to attain a strategy of "predictive monitoring".

Therefore, within the discussion of future land-use concepts, there is an imminent duty to install new monitoring systems and to offer a new generation of data. Otherwise, it is impossible to address complex landscapes and the interdependencies between the ecosystems within these landscapes.

We suggest the following optional components for developing a conceptual model and installing future-oriented land-use concepts:

Box 2: Optional components for a conceptual model as prerequisite for future-oriented agricultural land use.

i) Establish landscape laboratories to ensure that the particular landscape exhibits a comprehensive function.
ii) Establish new monitoring approaches and guarantee a proper data basis to provide adequate indicators.
iii) Develop site-specific land-use scenarios together with stakeholders using an integrated approach.
iv) Develop systemic modeling tools to allow decision makers (land managers) to explore particular land-use scenarios with approaches that cascade down to site-specific situations.

2.1. Landscape laboratories

Landscape laboratories attempt to establish regions as a type of "innovation laboratory" that is equipped to identify foreseeable trends, e.g., in agricultural production, and to be a model for future progress. From both, a scientific and political perspective, it is important to test concepts based on the latest knowledge, innovations and technologies and to use the previous experiences. From a political perspective, there is an inherent need for information that addresses the following questions:

- What are the ramifications of possible land-use?
- Which potential conflicts relate various adaptation options to global changes?
- What influential opportunities exist?
- What control instruments are appropriate?
- What will be the economic and ecological effects of interventions by planners and public bodies?

From a scientific perspective, it is important to analyze the processes that are related to these changes to understand the interactions between adaptation options in different sectors and to identify the relevant drivers of change and their effects. To ensure a new approach, it is essential that relevant stakeholders are initially involved at all levels in the development process.

While research projects regarding the relationship between regional-individual land-use concepts and externally produced changes (see e.g., Helming, 2014; Werner et al., 2014; Burkhard et al., 2014; Baral et al., 2013; Brandt et al., 2013; Verburg et al., 2002; Lambin et al., 2000), there is still a gap between research and implementation. Nevertheless, publications about land cover types to ecosystem service supply capacities (see e.g., Burkhard et al., 2009; Crossman et al., 2013), the discussion about the ecosystem service "matrix" (e.g., Kandziora et al., 2013a,b; Kaiser et al., 2013) and ecosystem services mapping studies (e.g., Clerici et al., 2014; Baral et al., 2013) are about the integration of societal needs for goods and services and enhance currently applied landscape planning approaches and environmental management strategies. A final solution for assessments procedures within this context has not been found yet. This is one of the upcoming scientific and political challenges. Effects on climate-related gas emissions, on self-sufficiency and the export/import quotas of a region in terms of energy or food and on biodiversity and other aspects of resource conservation can only be evaluated if the reactions to adaptation in other areas are considered. The information required for this purpose necessitates both observational and proactive research in which the experimental conditions, control quantities and contexts are intentionally changed. Therefore, the relevant people at the local level must be involved in the design of the research project from the start rather than solely when implementing the project.