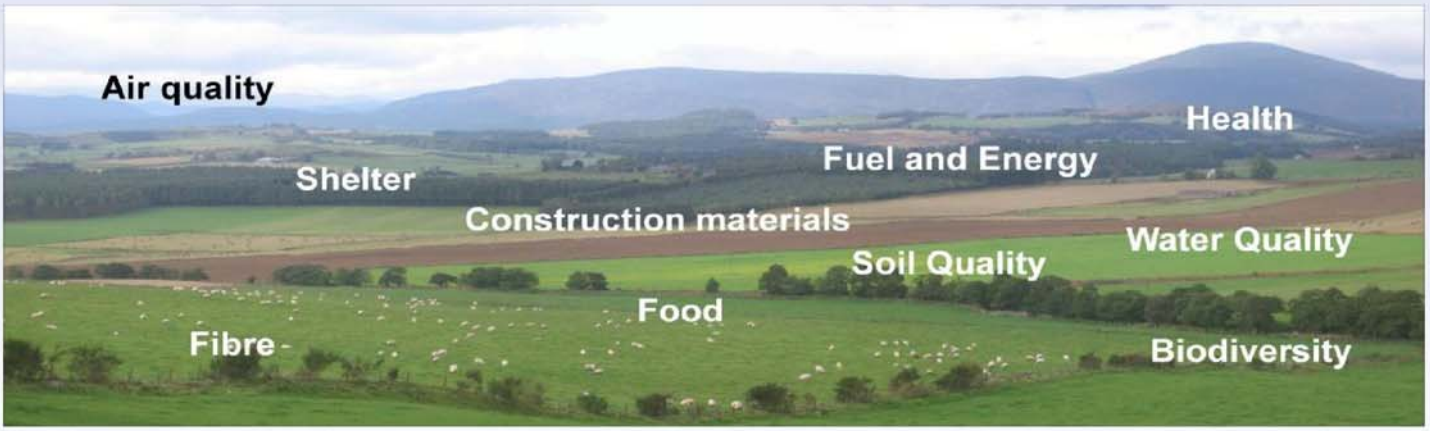
The Global Land Project Nodal Office on Integration and Modelling, Aberdeen, UK

GLOBAL LAND PROJECT WORKSHOP on 'Representation of ecosystem services in the modelling of land systems'

19th – 20th March 2010



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The Global Land Project Nodal Office on Integration and Modelling, Aberdeen, UK

GLP Workshop on

Representation of ecosystem services in the modelling of land systems

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‘Representation of ecosystem services in the modelling of land systems’

Understanding ecosystem services is increasingly important as land planners and policy makers make land management choices. Clear representation and description of ecosystem services provided by land systems is crucial to decision making and planning and contributes to understanding complex relationships between society and environment.

During the last half of the 20th century the structure of the world’s ecosystems changed more rapidly than at any other time in human history. Approximately a quarter of the Earth’s terrestrial surface has been now been transformed into cultivated land and one third of annual net primary production is estimated to be appropriated by humans (Vitousek et al 1986; Rojstaczer et al 2001). With the global population projected to increase to almost 9 billion by 2050 (United Nations, 2002), demands on the planet’s ecosystems will continue to intensify, with serious consequences for the goods and services that they provide.

The Millennium Ecosystem Assessment (MEA, 2005) defines ecosystem services as the benefits people obtain from ecosystems. Many tradeoffs are associated with human responses to, and use of, ecosystem services, with actions that benefit some services potentially having negative consequences for others. Modelling can provide useful tools to explore such tradeoffs, allowing the consequences of varying scenarios to be explored. However, models are only as good as our understanding of the complex system they seek to represent and therefore investment in the understanding and representation of the Earth’s systems is essential.

Models of ecosystem services as an integral part of land systems are needed, both to capture complex dynamics of human-environmental processes, and to explore consequences of land change in provision and management of ecosystem services. This workshop will explore measurement and representation of ecosystem services in land systems and models for application in policy and practice. It will provide an opportunity for leading international researchers in land system science, spatial and process modelling of coupled natural and human systems, and ecosystem services to produce a new research agenda on modelling ecosystem services.

Virtual Landscape Theatre
Macaulay Land Use Research Institute

The Virtual Landscape Theatre (VLT) is a curved screen projection facility, in which people can be 'immersed' in computer models of their environment to explore landscapes of the past, present and future.

Small groups have the opportunity to experience landscapes by moving around the virtual world – and they can even provide feedback by means of a voting handset. That way the public can be directly involved in the planning decisions that affect them.

A process-based model for soil multifunctionality

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Soils carry out many different functions, from carbon sequestration to preservation of archaeological artifacts. The determination of how well a particular soil carries out a range of these functions requires an understanding of how the soil will operate under different environmental and management conditions. Here we present a soil model under development that will allow us to ask 'how will a particular soil behave according to many different functional definitions in specific scenarios?' The model is process-based, and includes water movement, diffusion, carbon and nitrogen cycling, chemical equilibrium determination and many other soil processes. Initial validation runs against field trials show promising results, and we describe the current achievements and ongoing challenges to model development.

Representation and Mapping of Ecosystem Services in Land Systems

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Representation and mapping of ecosystem services play an important role in characterising the functions of land systems, contribute to measuring the value of services, and can also inform understanding of human and environmental systems interactions for scientific, policy and management application.

This paper uses examples of supporting, regulating, provisioning and cultural ecosystem services associated with land systems in Scotland to examine scientific and technical issues associated with representation, measurement, and mapping of services. The main focus of the mapping is on the location of production of services, rather than the location of consumption. Different ecosystem services are represented on the basis of the a) state, b) function, c) structure and d) land uses of different elements of land systems. Data needs and scale-related issues are considered using multi-scale representation for a subset of services. A variety of technical and practical issues are also identified, with landscape ecological approaches combined with GIS offering a framework for integrating state, function, structure, and use of ecosystems with mapping.

The results for Scotland are part of the UK National Ecosystem Assessment, a synthesis and review of the past and contemporary trends and status of ecosystems in the UK. The role of maps in inventory, valuation and management of ecosystem services is discussed in the broader scientific and policy contexts of the UK National Ecosystem Assessment.

Developing an iterative and multi-scale landscape modelling approach for ecosystem services

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Ecosystem-based approach (EBA) needs to integrate i) multiple scales, from parcels to regional landscapes, ii) flexible method for adaptive response and iii) stakeholders participation. Understanding complex inter-relationships between ecosystem functions and their services requires land use scenarios. We propose an iterative approach, which is multi-scale and user focused based upon the LandSFACTS toolkit to generate the required land use change scenarios. Scenarios are generated based upon spatio-temporal constraints on land uses, which are adaptable to the user's requirements. The complexity of the scenarios and knowledge of ecosystem services evaluated is refined iteratively with stakeholders. An example is presented on the development of scenarios of land use changes through EBA (e.g. food security, carbon sequestration, woodland habitat network) based on the integration of three scales (Tarland sub-catchment, Dee catchment and Grampian region in Scotland, UK).

Practical application of the Ecosystem Service approach: A case study of the UK Environmental Change Network

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In this presentation we examine the practicality of using data collected as part of a UK long-term monitoring network, the Environmental Change Network (ECN), to assess (i) the ecosystem services of eleven sites using the framework and tools devised by the Millennium Ecosystem Assessment (MA 2003) and (ii) the Cairngorm site using the ISSE framework. The Environmental change network was established to provide scientifically robust monitoring of the natural environment for the detection and attribution of the effects of environmental change on biodiversity. As such it has concentrated on the collection of biophysical data. ECN data was augmented by other data sources and a similarity analysis of the resulting 72 variables collated for each site revealed that the 11 sites were grouped essentially into four clusters: land with at least 50% forest cover, livestock farmland, uplands and a 'mixed use' group. Analysis of 'ECN only data' revealed erosion, floods and sulphur flux were associated with the upland sites while greater landscape diversity (e.g. higher number of vegetation classes and ordnance survey features) were associated with the two sites with significant forestry i.e. Alice Holt and Wytham. Greater diversity of carabid beetles and birds, a larger emission of greenhouse gases (GHGs) and more manmade spiritual features were associated with the other two groups farmland and 'mixed use'. Analysis of all 72 variables revealed the forest, upland and farmland sites remained clustered but that the 'mixed use' sites are now not closely clustered. While these sites (Rothamsted, Drayton and Porton Down) are biophysically similar (lowland, grass and arable systems) their cultural uses and the provisioning services delivered are very different. Public access to both Porton Down and Drayton is restricted as the former is a military base and the latter an animal research facility. In-depth analysis of the Cairngorm ECN site using the ISSE methodology reveals that water regulation was the most important service delivered to the landscape by this catchment. These study has shown the value of access to long term monitoring sites when assessing ecosystem services of landscapes.

Trade-offs between ecosystem services under conditions of changing land use: the urban perspective

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In 2009, a *Letter to Nature* argued that "… earth´s disturbed ecosystems have much more to offer than many would give them credit for" (page 435). Little is know so far about these specific *urban ecosystem services*. Since they have been less intensively investigated than those of open land systems we have only limited knowledge to what extent they exist and have been already impaired. Moreover, we do not know how far damages of urban ecosystem services endanger parts of the urban quality of life in general.

Particularly in dense urban areas, ecosystem services may also trade-off against each other either because they often compete for space or because they are causally linked. A crucial challenge thereby is the analysis of trade-offs and interrelations between different ecosystem services such as water regulation, recreation or climate regulation. Ecosystem services are not independent from each other and policies at different spatial levels targeting one specific service may well affect spatio-temporal patterns and provision of others.

In the EU-Project PLUREL (www.plurel.net) we relate land use change in urban regions to both supply of and demand on ecosystem services. Computed changes of ecosystem system supply, respectively, feed back to the drivers of the land use change model. Such feedbacks exist mainly in form of (changes of) behavioural heuristics of stakeholders and policy makers which can be "detected" using social science methods and whih are "translated" into model rules. Thus, feedbacks from impaired ecosystems become drivers of land use.

To contribute to the linkage between ecosystem service and land use change modelling research in urban regions, in my paper, I will firstly, draw a trade-off matrix of urban ecosystem services for a case study region of PLUREL and, secondly, uncover potential feedbacks of ecosystem services decline to drivers of urban land use change.

Own references related to the topic:

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From a diversity of stakeholders' representations to a complex model of ecosystem services

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Ecosystem services are a concept widely used by ecologists and environmental scientists, but which requires transdisciplinary skills. In order to study the services (beneficiaries needs) and not only the functions (potential to deliver services) of the ecosystem, an approach based on socio-ecological systems is needed to fill the gap between the demand and the supply of ecosystem services. Therefore our approach divides the system into two sub-systems: the human sub-system where stakeholders land management decisions are taken and are affected or not by ecosystem services, and the ecological sub-system where ecosystem functions are modified by land management and external drivers (climate, policy, markets). Using semi-structured individual interviews with experts and a focus group with local beneficiaries, we studied the representations (which, where, whom) of biodiversity and ecosystem services of mountain grasslands and the diversity of uses and values. The next step will be to study the spatio-temporal dynamics of ecosystem services due to land management change under different scenarios. This step could be carried out by a role playing game tool in conjunction with a modelling approach.

Participatory Strategic Planning Using A Virtual Reality Environment

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Sustainable development requires an understanding of natural resource management within a changing world, and a holistic appreciation of the complex interactions in coupled human and natural systems. Change is integral to landscapes (rural and urban) but appears to have intensified in pace and persistence towards the end of the 20th Century (Halfacree, 2006). Landscape features experience different dynamics and pathways of change, and are sensitive to different drivers and time periods over which change may take place. The significance of understanding these differences with respect to their sequencing, and the linkages of drivers (or factors) of change with processes, is illustrated by Aspinall (2009) when untangling sub-types of change, based upon the long-term implications for human well-being (de Groot, 2006).

Policies on sustainable development (e.g. European Commission, 2009) emphasise the need for capacity-building to increase levels of public and professional engagement in environmental decision-making. Arnstein (1969) defined a multi-level participatory classification within three main levels: (i) educational (primarily information dissemination), (ii) active participation (public opinions sought and considered in expert decision-making), (iii) citizen power (direct influence on the decision-making process), and Salter *et al.* (2009) argue that the impact of participation is linked to the level of involvement, with greater impact from more citizen power.

Communications between public and professionals, regarding the nature or geographic distribution of services and functions of the landscape, may be constrained by a lack of understanding of technical language or concepts. Similarly, public concerns may not be easily articulated, and issues of risk and impact as interpreted by domain experts may be obscured by use of probabilities, risk and caveats.

Visually representing the real world and scenarios of change aids in the engagement across the different communities of interest and place, assists planners and decision-makers, and can improve the effectiveness of communications. Such visual aids can operate at different levels of semiotic representations (e.g. from symbolic to pictorial quality). An example of a forum for the development and testing of effectiveness of such visual aids and mechanisms of engagement is the Virtual Landscape Theatre associated tools (www.macaulay.ac.uk/landscapes).

The example presented for discussion is the development of a local plan for a National Park, specifically identifying items for inclusion in the issues statement, representing those factors which stakeholders and the public identify as prospective positive and negative influences. The research challenge is to develop approaches to the selection of alternative futures for land use, and the investigation of possible outcomes of policy options with stakeholders and the public. This presentation describes the use of a mobile virtual reality theatre to facilitate consultation with 'hard to reach' public audiences on issues of landscape change.

The land use issues have been classified in relation to ecosystem services or functions for post-event analysis and interpretation with respect to articulation for different audiences. Drawing on the lessons learnt, a provisional list of criteria for filtering issues is prepared, and a range of mechanisms for communicating the meaning of example services and functions prepared for testing.

Acknowledgements
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Ecosystem Service in Lagos Megacity

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From a population of less than 1million on land area of about 200km^2 comprising three small islands (Lagos Island, Victoria Island and Ikoyi) and adjourn mainland of Ebute-Metta, Apapa, Mushin and Yaba at independent in 1960, Lagos has withness a great population explosion to over 17 million on land area of about 1,000km^2 as at 2008 projection. Until the last four years, ecosystem services were not taken into planning and developmental policy of the successive administrations. This paper identify and analyse the impact of various services being provided by the urban ecosystems in line with the initiatives of the present administration on land use planning, ecologically sound and local sustainable urban renewal policies. Seven local and direct services were identified, spatially represented in the urban land use systems and their impact on human livelihood measured. These include; street trees, lawns/parks, urban forest, cultivated land, wetlands, water fronts / coastal ecosystems and water bodies which include, lagoon, streams, creeks and ponds. Identification and spatial mapping of these unique urban ecosystems was achieved through extensive field works and the use of high resolution satellite imagery (IkONOS). The ecosystem sites were overlayed on the approved land use zoning of the state planning board. The relationship of the existing land use / land cover and the distribution of ecosystem sites were examined.

Ancillary data from existing maps and literature, minor measurements, structured questionnaire, in-depth interview, personal observations and secondary data sources were used to obtain information on ecosystem services while the impact of systemic effort to ensure sound and healthy environment through ecosystem services was measured and analysed using Cost Benefit Analysis (CBA).

The direct and locally generated services show that in Oshodi, a CBD notorious for traffic and other noise problems, the noise level have reduced by between 4db to 7db within a distance of 50m due mainly to greening programmes. Also, air pollution from Oshodi, Idumota, Custain and other hot spots within the city is said to have reduced by an average of 60% due largely to gas filtering and pollution absorption activities of mixed coniferous deciduous trees that now line the streets in these areas. Also, air temperature in the last 3 years have been noticed to have reduced by about 0.5^0c from the annual mean in some notable urban heat island areas within the city. Although the actual contribution of the unpaved policy and the development of lawns and parks to the reduction of storm runoff during rainfalls have not been properly documented, it has been identified that annual flood damages in some areas such as Idi-Araba and Ilaje have been marginally reduced. The recreational value was adjudged as the most significant ecosystem service to Lagosians with over a 100% increase in patronage to upgraded Lagos bar beach and the various waterfronts. The measured values of urban ecosystems in the landuse development and model of Lagos megacity were represented and mapped. Policy regulation that ensures an increase in the proportion of greening blueing of the megacity to enhance the quality of life was recommended.

Integrated Ecological Effects of land use change during 1986-2006 in Lijiang County of China

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Land use / land cover change (LUCC) is gaining recognitions as one of the key components and driving forces of global environmental change. Ecological effect of LUCC is regarded as the very reason for the importance of LUCC to global environmental change. And ecosystem services assessment of associated land use types are always applied to evaluating the integrated ecological effects of LUCC. However, all the studies failed to discuss the ecological effects of land use change in spatial patterns, but explored the change of ecosystem services associated with area ratio change of land use types.

In this case study in Lijiang County of China, ecological value of each land use type was assessed according to global average value of ecosystem services (Costanza et al., 1997), and the coefficients of spatial neighboring effects on ecosystem services for each land use type were developed to quantify ecological effects of land use pattern change, so as to make an assessment on integrated ecological effects of land use change in quantitative structure and spatial patterns.

The results showed that, along with slow but significant increase of grassland, bare land and forest land, decrease of crop land and glacier or snow-capped land, and patch fragmentation and regularization of land use patterns in Lijiang County during 1986-2006, there is distinct increase of ecosystem services with spatial differentiation. And land use patterns in Lijiang County were proved to be positive to ecosystem services in the study period, through calculating the coefficients of spatial neighboring effects.

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Costanza R., d'Arge R., de Groot R., et al. 1997. The value of the world's ecosystem services and natural capital. Nature, 387: 253-260

From biodiversity to ESS research - Building on BIOTA for TREES

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After nine years of integrated biodiversity research the BIOTA East Africa project will come to end. Although with Kakamega Forest in western Kenya having been focus, in total three East African forest areas have been studied to compare influences of different levels of disturbances, fragmentation, and human use. The project aimed at recommendations towards a sustainable use and conservation of forest biodiversity.

Within BIOTA numerous geodata have been processed. Among them are comparable land cover change timeseries, which allow us to trace changes in forest cover and types back over almost 100 years. The timeseries have been useful in modelling biodiversity change for selected faunal species/groups. We intend to apply them also for extrapolating the results of an assessment, where direct and indirect effects of three types of forest disturbance on the biodiversity and ecosystem functions of eight different functional groups in Kakamega Forest could be disentangled. Our detailed knowledge of in particular Kakamega Forest has also lead to the active involvement in participatory forest management planning.

For the TREES project we have proposed to perform an integrated analysis on land-use, ESF/ESS, the value of ESS, policy instruments and human livelihoods. Based on an assessment of a wide range of forest ESF/ESS in relation to land management, we aim at the development of a tool offering means to explore synergies and trade-offs between the various ESF/ESS provided in tropical forest landscapes, with the possibility to compare the valuation of these ESF/ESS in the view of different stakeholder groups. Through an implementation approach including the end-users, the Spatial Decision Support System will allow identifying land use options that balance ecosystem goods and service provision.

Use of dynamic, process-based models of soil C and N turnover to explore tradeoffs between land use change for agricultural production and carbon sequestration

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In order to explore tradeoffs between land use change for agricultural production and carbon sequestration, models are needed that accurately reflect the conditions of all soils across the area of interest. ECOSSE (*Estimation of Carbon in Organic Soils – Sequestration and Emissions*) is a model that allows simulations of soil carbon and nitrogen turnover in both mineral and organic soils using only the limited meteorological, land use and soil data that is available at the national scale. Because it is able to function at field as well as national scale, if appropriate input data is used, field scale evaluations can be used to determine uncertainty in national simulations. An evaluation of the uncertainty expected in national scale simulations of Scotland, using data from the National Soils Inventory of Scotland, suggests that the uncertainty in the national scale simulations will be ~11%. The ECOSSE estimate of annual change in soil C stocks for Scotland between 2000 and 2009 is -810 (±89) kt $year^{-1}$, equivalent to 0.037 (± 0.004)% yr^{-1}. Reducing land use change from grassland to arable has most potential to reduce soil C losses. If the area of land converted from grassland to arable was reduced to 28% of its current rate of conversion, the soil C losses across Scotland would be reduced to zero. However, given the current agricultural market, such a mitigation option may be unrealistic. Other significant losses of soil C occur due to the conversion of semi-natural land to arable or grassland. The results suggest that if policies were designed to reduce conversion of semi-natural land to arable or grassland, net losses of soil C could be reduced to 53% of the current emissions. If this were coupled with an increase in the conversion of grassland to semi-natural land by 125% of the current rate of conversion, net losses of soil C would be reduced to zero. Alternatively, a 63% increase in the current rate of conversion of arable to grassland would also result in zero net losses of soil C when coupled with the reduced conversion of semi-natural land to arable or grassland. This could equally be achieved by decreasing the current rate of conversion of grassland to arable to 77% of its current rate. The implications of these mitigation options are discussed in the context of the need for agricultural production.

A multi-scale approach for analysing landscape service dynamics

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Landscapes are continuously changing and therefore the provision of landscape goods and services is subject to permanent change. The presence of landscape functions and their supply of services are affected by landscape properties like social and biophysical properties and patterns. Changes in these properties can therefore result in a change in the provision of landscape services. Understanding, monitoring and exploring landscape function dynamics is not a straightforward task. Landscape functions cannot be directly observed and monitored by standard techniques, like used in land cover observation, which makes the use of models inevitable. Most of the current landscape-dynamics models are based on land cover and use data. However, as landscape functions are driven by both local and contextual factors, of which land cover or land use are only one aspect, these modelling approaches cannot be used. For example, landscape functions may drastically change without any change in land cover and vice versa. Additionally, landscapes are often multifunctional, meaning that at a single location more than one landscape service is being provided. Current landscape models assign one land use to a specific location (e.g. arable agriculture), not taking into account the multifunctional potential a site.

We propose an innovative modelling approach that allows analysing the multi-scale dynamics in landscape service supply as a result of a changing landscape and societal demand. Drawing on the insights from land use system and ecosystem modelling efforts, we explicitly address in this modelling approach (i) the multifunctional character of the landscape, (ii) the different spatial levels at which interactions between landscape service supply, demand and land management occur and, (iii) the trade-offs in service supply levels as a result of land management actions. In our research we focus on the exploration of possible spatial and temporal dynamics of landscape functions. Therefore our approach does not aim at finding an optimal configuration of landscape functions to maximize service supply for a region.

The proposed modelling approach is a first step to better identify, map and quantify dynamic patterns of multiple landscape functions and their service supply. So far, land use models could capture decision making, feedbacks and spatial and temporal dynamics, while ecosystem–based spatial models addressed complex processes relating to multiple service supply. We combined both approaches by explicitly addressing the interactions and feedbacks between landscape service supply, demand, and land management actions of the multifunctional landscape. The proposed modelling framework could be an example of new innovative landscape modelling approaches, which include multiple uses of the land, and which have a potential for quantitative assessments of ecosystem services provisioning for policy discussions on landscape management.

Based on: L. Willemen, A. Veldkamp, P. H. Verburg, L. Hein, R. Leemans, A multi-scale approach for analysing landscape service dynamics, Submitted

Modelling the influence of land use and land cover change on ecosystem services

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One of the main challenges in monitoring, modeling and communicating land change is the relation between land cover, land use and the provision of goods and services by the land system (ecosystem services or landscape functions). The capacities of the land system to provide goods and services are often referred to as landscape functions (Verburg et al., 2009b). Many studies have assessed the consequences of land use and land cover change on different socio-economic and environmental conditions as a post-analysis or impact assessment, e.g. by a series of indicators (Schröter et al., 2005; Helming et al., 2008). However, in reality the functionality of the land is intricately linked to the characteristics of the land system. A change in the provision of goods and services by the land is often not just a result of land cover change but an important driving factor of future land cover dynamics as well. The Millennium Ecosystem Assessment has requested specific attention for the way in which land cover change and ecosystem functioning are linked. Such assessments are difficult because there is no one-to-one relation between land cover and functionality. Functionality is often determined by both local and contextual factors synchronously. In addition, landscape function may not be observed and monitored by standard techniques used in land cover observation. In many cases landscape function may drastically change without any change in land cover and vice versa. Attempts to quantify landscape functions based on land cover information are often limited since land cover is not always a good indicator for the actual functions performed by the land at that location (Willemen et al., 2008). Therefore, impact assessments based on current monitoring and modeling techniques are often limited to landscape functions that can be quantified based on the land cover (change) map.

This presentation aims at providing an overview of the state of the art in methods and models for assessing land use and land cover change in relation to landscape functions. Methods include:

-top-down, spatially explicit land change models linking global dynamics to regional level impact on land use followed by an assessment of impacts on landscape functions (Kienast et al., 2009; Verburg et al., 2008).

-agent-based simulations of local decision making leading to changes in landscape composition and structure (Valbuena et al., ; Valbuena et al., 2008)

-regional scale methods to map and model landscape function response to policy and planning (Willemen et al.).

Each of the methods has its own range of typical applications, data needs and potential outcomes. The choice of method is largely dependent on the scale of analysis and dominant processes of land change.

Based on assessments and models of land change and landscape functions hot-spots of changes in landscape functions can be identified. Such hot-spots analysis may be used to target interventions and more detailed assessments. At the same time, it is not the change in single landscape functions at a specific location but rather the trade-off between functions as result of these changes that is of importance. The costs of increasing production at a location may be large in terms of a range of other functions at the location itself or in other areas as result of teleconnections. Therefore, tradeoff analysis tools to analyze the effects on multiple functions need to be used, both on-site and off-site. The quantification of land use change impacts on landscape functions is not straightforward and different methods are used depending on the scale of analysis and available data.

In order to be able to target policies to make best use of regional potentials of landscape functions methods are proposed that quantify the region-specific potentials of the landscape to support different landscape functions. The identification and simulation of the potentials of a location to provide landscape functions provides an additional layer of information complementary to the assessment of actual landscape functions and their change. At local level participatory scenarios may be used to identify the local potentials by confronting stakeholders with possible scenarios and visualisations (van Berkel et al., in prep). At larger scales simulation methods and indicator assessments are needed to quantify these potentials. Most critical is the assessment of pathways towards better using these potentials. Therefore, confronting explorative scenarios with visions on regional potentials may help to identify the region specific assets and constraints towards moving into sustainable development pathways.

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