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A coherent set of future land use change scenarios for Europe

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Abstract

This paper presents a range of future, spatially explicit, land use change scenarios for the EU15, Norway and Switzerland based on an interpretation of the global storylines of the Intergovernmental Panel on Climate Change (IPCC) that are presented in the special report on emissions scenarios (SRES). The methodology is based on a qualitative interpretation of the SRES storylines for the European region, an estimation of the aggregate totals of land use change using various land use change models and the allocation of these aggregate quantities in space using spatially explicit rules. The spatial patterns are further downscaled from a resolution of 10 min to 250 m using statistical downscaling procedures. The scenarios include the major land use/land cover classes urban, cropland, grassland and forest land as well as introducing new land use classes such as bioenergy crops.

The scenario changes are most striking for the agricultural land uses, with large area declines resulting from assumptions about future crop yield development with respect to changes in the demand for agricultural commodities. Abandoned agricultural land is a consequence of these assumptions. Increases in urban areas (arising from population and economic change) are similar for each scenario, but the spatial patterns are very different. This reflects alternative assumptions about urban development processes. Forest land areas increase in all scenarios, although such changes will occur slowly and largely reflect assumed policy objectives. The scenarios also consider changes in protected areas (for conservation or recreation goals) and how these might provide a break on future land use change. The approach to estimate new protected areas is based in part on the use of models of species distribution and richness. All scenarios assume some increases in the area of bioenergy crops with some scenarios assuming a major development of this new land use.

Several technical and conceptual difficulties in developing future land use change scenarios are discussed. These include the problems of the subjective nature of qualitative interpretations, the land use change models used in scenario development, the problem of validating future change scenarios, the quality of the observed baseline, and statistical downscaling techniques.

Keywords: Land use scenarios; Special report on emission scenarios (IPCC SRES); Climate change; Spatial allocation rules; PELCOM land cover data set; Land use modelling

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1. Introduction

The need to develop future land use change scenarios stems from the important role that human activities play in environmental quality. From ecosystem functioning and biodiversity to water resources and greenhouse gas emissions, land use is central to the landscapes around us. Therefore, an understanding of how land use might evolve is required in order to estimate how people will modify their environment in the future. In Europe, the most important land uses are agriculture and forestry, which cover about 45% and 36% of the total land area, respectively (FAO, 2003). Both land classes have changed considerably during the last decades. While agricultural land areas have declined by about 13% between 1961 and 2000 (Rounsevell et al., 2003), the area used for forest growth has increased steadily and has almost compensated for the contraction in agricultural land use (Kankaanpää and Carter, 2004a). However, the changes in both land use types are not directly related (Kankaanpää and Carter, 2004a) and involve a set of other factors that require consideration. A range of models has been developed to better understand, assess and project changes in land use and land cover (Veldkamp and Lambin, 2001; Parker et al., 2003; Veldkamp and Verburg, 2004). However, in spite of progress in integrating biophysical and socio-economic drivers of land use change (Veldkamp and Verburg, 2004), prediction of future land use remains difficult. Scenario analysis provides an alternative tool to assist in explorations of the future.

The work presented here reports the development of quantitative, spatially explicit and alternative scenarios of future land use in Europe (EU15, Norway and Switzerland), which were constructed to support analyses of the vulnerability of ecosystem services in the context of the EC funded ATEAM project (advanced terrestrial ecosystem analysis and modelling). The scenarios were developed for a range of different land use classes that reflect the principal uses of land in Europe. As many of the land use modelling and assessment methodologies for individual land use types have been published elsewhere (see for example Ewert et al., 2005; Rounsevell et al., 2005; Kankaanpää and Carter, 2004a,b; Reginster and Rounsevell, in press), the purpose of this paper is to synthesise both the methodological aspects of the scenario development (including the competition between different land use types) and the key results. The intention is not to repeat the detailed methodological descriptions given elsewhere, but to provide short methodological summaries and specifically to focus on a joint comparison of projected changes in the different land use classes. The paper attempts to highlight issues concerning the technical and conceptual limitations to land use scenario development, and discusses how land use scenario analysis might be developed further. This includes some initial effort to downscale the projected land use changes to finer resolutions more applicable for local impact studies.

2. Methods

2.1. Overview of the approach

The methodology was based on an interpretation of the four marker storylines (A1FI, A2, B1 and B2) of the Intergovernmental Panel on Climate Change (IPCC), special report on emission scenarios (SRES) (Nakićenović et al., 2000). Each SRES storyline describes different, socio-economic development pathways in terms of demographic, social, economic, technological and environmental drivers. The scenario logic is based on a matrix approach. Within this matrix, the vertical axis represents a distinction between more economically (A) and more environmentally and equity (B) orientated futures. The horizontal axis represents the range between more globally (1) and more regionally orientated developments (2). From this starting point, the scenario development method followed three basic steps:

1. *Qualitative descriptions* of the range and role of different land use change drivers were interpreted from the SRES storylines and for the European region;
2. *Quantitative assessments* were made of the total area requirement (quantity) of each land use type, as a function of changes in the relevant drivers for each scenario;
3. *Spatial allocation rules* (specific to each scenario) were used to locate the land use quantities in geographic space across Europe.

The approach was implemented using a range of techniques that were specific to each land use type (urban, cropland, grassland, bioenergy crops, forest land and protected areas), including reviews of the literature, expert judgement and modelling. These techniques are detailed below. The baseline year was fixed at 2000 and the scenarios were constructed for three time slices (2020, 2050 and 2080) for a 10-min (latitude/longitude) grid. The baseline (i.e. the current geographic distribution of land use) was used as the starting point for the construction of the scenarios and was derived from the PELCOM 1 km resolution land cover data set (Mücher et al., 2000) combined with the REGIO statistical database at the NUTS2 level (Eurostat, 2000).

2.2. Interpretation of the SRES storylines for Europe

The SRES framework has the advantage of coupling changes in the physical environment (climate change) with concurrent changes in socio-economic factors. This is because the different assumed socio-economic development pathways are responsible for different levels of greenhouse gas emissions and thus, climate change (Mitchell et al., 2004). However, the SRES framework is global in extent and so, its use for Europe first requires a translation of the global driving forces to the European scale. This was undertaken at two levels: an interpretation of cross cutting drivers that are