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A qualitative method for the spatial and thematic downscaling of land-use change scenarios

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ABSTRACT

Assessing the potential impact of future land-cover changes on habitat quality requires projections with a fine spatial and thematic resolution. The former is usually addressed by downscaling methods, often at the expense of the latter. We present a new, rule-based method to downscale land-use change scenarios to the landscape level while keeping a large number of land-cover classes (CORINE level 3). The method relies on the interpretation of European scenario storylines, the observation of past land-use changes, high-resolution regional data and expert knowledge.

The results give a landscape-level transposition of the scenario storylines which reflects the local conditions. The method has a number of advantages, such as its potential application in dialogues with policy-makers and stakeholders. Possible further developments include automating the rule-based selection to overcome the current limitations of this method in terms of spatial extent.

1. Introduction

Land-use/-cover change has increased dramatically in recent decades due to rapid demographic and societal changes; this is expected to continue in many European regions (Busch, 2006; Lambin et al., 2001). Agricultural and urban lands are particularly susceptible to these changes and affect habitat quality for both flora and fauna. Increased urbanisation and peri-urban settlement results in fragmentation, which affects various ecosystem processes (Lambin et al., 2001). Assessing the impact of land-cover changes on ecosystem processes or habitat quality requires data with a fine spatial and thematic resolution (Conway, 2009). Spatial resolution is necessary to calculate the degree of fragmentation (patch size, connectivity) precisely (Fahrig, 2003; Reidsma et al., 2006) and to preserve the representation of land-use types with typically small patches, such as grasslands, which may be lost at coarser resolutions (Schmit et al., 2006). Using a finer resolution also reduces the errors inherent to mapping methods, such as representing continuous data in a raster (grid) format (Dendoncker et al., 2008). Without sufficient thematic resolution it is impossible to assess habitat quality correctly: "agricultural land" may include very different land-cover types, such as highly intensive monocultures or low intensity, species-rich pastures (de Chazal and Rounsevell, 2009). This level of precision is often available for recent land-cover changes (post-1990), for instance in the CORINE land-cover (CLC) datasets (Büttner et al., 2002). Even the finest CLC classification (level 3, 44 classes) is arguably not sufficient for some ecological applications, especially as the more "natural"

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land-cover types, such as forest or shrub, are not very well differentiated in CLC (Neumann et al., 2007; Waser and Schwarz, 2006). However, high thematic resolution is less common for older changes, which makes the calibration of land-use/-cover change models very difficult. One exception is the BIOPRESS transect data, which details CLC level 3 land-cover in 1950, 1990 and 2000 (Gerard et al., 2010; Köhler et al., 2006; Thomson et al., 2007).

Scenarios providing alternative images of how the future may unfold are a popular tool for exploring alternative plausible land-use futures (Ewert et al., 2005; Rounsevell et al., 2005, 2006; Rounsevell and Metzger, 2010; Verburg et al., 2006). Rounsevell et al. (2006) describe how the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) (Nakicenovic and Swart, 2000) can be interpreted to derive European land-use change scenarios. The same methodology was used to develop the ALARM scenarios (Settele et al., 2005), which we use in this study. At the European level, the ALARM scenarios show a continuation of current trends in land-use change, but with differing magnitudes between the scenarios (Reginster et al., 2010; Spangenberg et al., in press). Unfortunately, the 10′ spatial resolution (approximately 16 km × 16 km) of these projections is too coarse for studies relating to biodiversity or ecosystem services, for instance. A number of quantitative downscaling methods have been used to refine the spatial resolution of land-use change projections (Dendoncker et al., 2006, 2008; Verburg et al., 2008, 2006). However, automated quantitative downscaling has limitations, such as the inability to adjust to the local context and the lack of control over the results. With fewer than 10 land-use categories, the thematic resolution of many current land-use scenarios also remains too coarse. Some studies use a finer thematic resolution in their particular field of interest, e.g. agriculture, but group all other land-uses into a single "other" category (Chakir, 2009). As observed by Conway (2009), increasing the number of classes in land-use change models may in some cases be detrimental to model accuracy, especially where less frequent types of conversions are concerned. This may explain why so little attention has been paid to improving thematic resolution, despite its importance for ecological and other applications.

For planners and policy-makers, it is essential to understand how land-use change might affect biodiversity and other ecosystem services, so that these services can be preserved and potential synergies or conflicts identified (Verburg et al., 2009). In turn, planners and policy-makers can also inform research by bringing local knowledge into the interpretation of scenario storylines for their region. This interaction is often overlooked when developing models and decision-making tools for management purposes (Jakeman et al., 2006).

We describe here a rule-based downscaling method which provides plausible projections of land-cover change at the landscape level, with fine spatial and, more importantly, thematic resolution. By using a qualitative method, we circumvent the main problem with calibrating models for rare events, namely insufficient data. As it relies on visualising the data, this method enables us to check during the downscaling process that the results are representative of local conditions and has the potential to be used for policy dialogue. Finally, working at the local level allows the use of detailed data and ancillary knowledge, which are often not available for large-scale data.

2. Materials and methods

Projected land-use changes from the pan-European ALARM scenarios (Reginster et al., 2010; Spangenberg, 2007; Spangenberg et al., in press) were thematically disaggregated and spatially allocated in a three-step process. Firstly, we derived the relative changes in four aggregated land-use categories from the ALARM scenarios and converted them to absolute increases or decreases in number of 100 m × 100 m (1 ha) grid cells within seven transects from the BIOPRESS project (Gerard et al., 2010; Köhler et al., 2006; Thomson et al., 2007). Secondly, we disaggregated these changes to the more detailed CLC categories used in the transects, to obtain the number of 1 ha grid cells by which each land-cover category will increase or decrease under each scenario. Finally, we allocated these changes spatially within the transect using a combination of scenario-specific rules, regional information and expert judgement (by the author team at this stage). These three steps are detailed in Sections 2.2.–2.4.

2.1. *Land-cover data and scenarios*

We used land-cover data from seven transects in the United Kingdom (Fig. 1), taken from the BIOPRESS project (Gerard et al., 2010; Köhler et al., 2006; Thomson et al., 2007). The transects in that project were chosen to intersect with Natura 2000 sites and are 15 km × 2 km rectangles, though some have missing sections due to lack of coverage by the aerial photographs from which the data is derived. The data follows CLC level 3 (44 classes). Each transect consists of a mosaic of polygons representing contiguous areas with a common land-cover history.

For our purpose, the polygon data for each transect was converted to 100 m (1 ha) grids, one per time step (1950, 1990, 2000). These were then converted to point data, with the points in the centres of the grid cells. The associated attribute table contained the land-cover classes for the three past time steps, to which we added three fields for 2030, one per scenario. These were initially filled with the land-cover class for 2000.

The ALARM land-use change scenarios (Reginster et al., 2010; Spangenberg, 2007; Spangenberg et al., in press) give projections of the percentage cover per 10′ grid cell in 2030 for seven land-use categories, following the three storylines in Table 1. The land-use categories are: urban, cropland, grassland, permanent crops, biofuels, forests and land in succession (i.e. abandoned agricultural land). The construction of the ALARM scenarios involved three steps: (1) construction of three alternative scenario storylines (Table 1), (2) estimation of the aggregate totals of land-use change using a supply/demand model and (3) spatial allocation of these aggregate quantities using spatially explicit rules (Rounsevell et al., 2006). The methodology is described in detail by Reginster et al. (2010) and Spangenberg et al. (in press).