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Future land-use change scenarios for the Black Sea catchment

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ABSTRACT

Plausible future scenarios have been created for the Black Sea catchment, focussing on spatially explicit alternatives for land-use changes. Four qualitative storylines (HOT, ALONE, COOP and COOL) were first developed, based on interpretation of the respective global scenarios (A1, A2, B1 and B2) produced by the Intergovernmental Panel on Climate Change. Quantitative statistical downscaling techniques were then used to disaggregate the outputs of global scenarios at a regional level. The resulting land-use maps were spatially allocated at 1 km resolution in the Metronamica model, using a set of factors related to the identified drivers of change. The land-use change model was calibrated on historical trends of land-cover change (MODIS 2001 and 2008) translated into spatial allocation rules, and future land-use projections (IMAGE, 2001) were adopted. Suitability and constraint maps and population trends were used to regulate the modelling process. The calibrated model was validated by statistical procedures, visual evaluation and stakeholder involvement in order to ensure its plausibility and accuracy. This methodology bridged the gap between the global and regional scales. Four simulated future states were produced for the main land-use classes–forest, grassland, cropland and built-up areas, as well as scrublands, crops/natural vegetation and barren land–for 2025 and 2050. The results suggest that the features highlighted in these scenarios are guided by global trends, such as population rise and decreasing agriculture, but with different growth rates and a variety of spatial patterns, with regional variations resulting from local backgrounds and policy objectives. This study aims to provide future land-use data as a potential geographical tool to assist policy makers in addressing environmental emergencies such as water stress and pollution. In particular, the exploration of plausible futures can support future assessments to comply with the EU Water Framework Directive and Integrated Coastal Zone Management policies around the Black Sea.

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1. Introduction

With expected global environmental change as the main driver of uncertain futures, scenario exploration has become an essential tool used in regional policy support discussions, with results such as the IPCC scenarios on global climate change (Nakicenovic et al., 2000) and the Millennium Ecosystem Assessment scenarios (Carpenter et al., 2006). These global scenarios have been shown to be plausible by many follow-up regional analyses and new scientific evidence on global warming (Rahmstorf et al., 2007), regional climate patterns and ecosystem change. However, global scenarios have remained of limited applicability at local and regional levels due to the inadequacy of scale (Kumar et al., 2006) and data input limitations. There are inherent difficulties in understanding the impact of global change drivers at local level because of specific bio-physical and socio-political factors acting locally. Therefore, spatially explicit scenario development using well-understood local and regional factors is necessary for adequate policy support. Such scenario-building methodologies have been explored within the enviroGRIDS project for the Black Sea catchment (BSc) (Lehmann et al., 2013).

Scenario construction and analysis aims at exploring the range of uncertainties related to a future state of a system (Mahmoud et al., 2009) that cannot be well characterized by either probabilistic or deterministic predictions. In environmental science, this method builds on the systematic assimilation of multi-disciplinary quantitative and qualitative data. A first step consists of exploring what can be characterized to some degree by relations and predictions, and then identifying and describing what is left as uncertainty. This provides the added value of identifying unforeseeable points that may change the future state of the system. Environmental scenarios are integrated scenarios, as they need to combine a range of themes and subjects. Scenario themes are typically suggested by the cause and effect relationships between the most critical and most uncertain variables. The different themes are linked in a coherent narrative. Several unique storylines are typically proposed, each of which has its own likelihood of occurring. Environmental scenario construction and analysis has not yet developed into a standardized method of research. Several scenario families have been created in the past, e.g. the IPCC greenhouse gas emission scenarios (Nakicenovic et al., 2000), the Millennium Ecosystem Assessment scenarios (MEA, 2005a), the Global Environment Outlook (UNEP, 2012) and the Great Transition scenarios (Raskin et al., 2012). They all present quite different pictures and working methodologies; however, certain common elements can be identified. Recently a formal framework for scenario definition for environmental decision making was published by an international team (Mahmoud et al., 2009). They outline the following major points of scenarios that aim at characterizing future environmental factors and conditions. These consist of threats to natural ecosystems and socio-ecological systems, and have consequences for land-use. The key issues include:

- Water resources – water's importance for human survival, ecosystem management, economic activities, agriculture, power generation, etc.; the quantity and quality of water are equally important in assessing present and future demands for the resource;
- Land-use – issues related to food security, carbon cycling and land-management practices;
- Technology – technological changes that affect societal development, economic growth and environmental conservation.

The BSc includes parts of 24 countries in different bio-geographical and socio-political situations, and encompasses considerable ethnic, socio-economic, cultural, administrative and political diversity. Its climate varies from alpine through continental and arid steppe to humid temperate forest and warm Mediterranean. Rapid coastal development for tourism, industry and transport has accelerated over the last decade. Part of the BSc has also seen a considerable decline in economic activity and population following the collapse of socialist-planned economic systems. In all this diversity of factors and drivers of change, there is one common element – the Black Sea and its coastal influence. The objective of enviroGRIDS is to present large-scale climatic, demographic and land-use scenarios of change in the BSc, starting with key long-term processes of change on land, such as agricultural practices and urban/residential transformations. The modelling process explores examples of such situations using widely available global datasets, followed by presentations and discussions with local experts and refinement of the original results. The aim is to develop qualitative storylines derived from interpretation of the global scenarios and to downscale the globally modelled estimates to simulate disaggregated changes at administrative levels and at 1 km resolution to support evaluation of the impact of land-use change on water resource distribution.

2. Methods

The development of land-use change scenarios is a widely accepted method for anticipating future trends and supplying tools to enable policy and decision makers to develop sustainable strategies (Nakicenovic et al., 2000). Scenarios are plausible views of the future based on 'if and then' assertions – if the specified conditions are met, then future land-use and land cover will be realised in a particular way (Alcamo et al., 2000). The land-use scenarios were implemented in Metronamica (RIKS, 2011a), a Cellular Automaton (CA) modelling system.

The first step was to quantify the qualitative storylines by using IPCC descriptions, IMAGE data and partner input. The land-use classes to be used were selected and aggregated and their behaviour modelled to meet the software requirements. Next the key element of the dynamic CA model was defined. Its dynamic behaviour arises from a given land-use cell's response to its current suitability, zoning and accessibility parameters and the effect of neighbouring cells. The combined influence of these factors generates a transition potential, which is updated in each yearly time step. Finally, the model was calibrated and the suitability and neighbourhood rules