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The influence of damming on landscape structure change in the vicinity of flooded areas: Case studies in Greece and the Czech Republic

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ABSTRACT

Many studies have recently been published on changes in land use/land cover (LU/LC), but only a few have been concerned with the impact of technical hydrological measures on LU/LC. This study evaluated physical landscape structure changes due to the realisation of important hydrological facilities (in 1959) in central Greece. The results were compared with the locality where the dam can be extended in the future (in the Czech Republic), (i.e. the potential flooded area is protected from the development of urban structures by a territorial limit). Changes were monitored in a zone that was 500 m from the border of the directly flooded area (Greece) and 500 m from the border of the potential directly flooded area (Czech Republic). The importance of the study relates to a comparison of landscape characteristics, which emerged following the analysis of aerial photos in two different time periods. The spatial landscape dynamics from 1945 until 1996 (Greece) and from 1950 to 2012 (Czech Republic) in the study area were monitored and changes were analysed, together with the effects that the dam/territorial limit might have had on structure of the surrounding landscape. All data were processed using Arc-map GIS by the Environmental Systems Research Institute (ESRI). The results showed that from early 1945s to 1996s, the landscape within the study area in Greece has undertaken a complicated evolution in landscape structure and composition. The human activities have significantly changed the distribution and quantities of each land cover types in surrounding of Plastiras reservoir. The decrease of Shannon's diversity index in Greece manifested intensive management and reconstruction of landscape by human beings, which means reduced landscape heterogeneity and landscape diversity, leading to the decrease of environmental benefits and ecological stability. The different and methodically new way that we analysed landscape changes forms the basis for analysing landscape functional changes in the future. This may help us to better evaluate historic effects of anthropogenic activities like dam or similar construction on landscape structure and its changes and predict possible changes, in case of new dams realization.

1. Introduction

One of the important tasks regarding mid- and long-term development and planning policies is the anticipation of potential environmental changes caused by natural or human processes and the production of a scenario for potential adaptation measures. An extremely significant measure involving hydrology is to slow the outflow and retain water in the landscape. These measures have been documented since the birth of the first civilisations (4000 BC in India) and water cisterns can even be found in the Bible (Lancaster, 2008). Certain methods of retaining water in the landscape, especially direct flooding, lead to serious damage of the given area, disturbance of natural components and complete structural and functional transformation of the landscape (Stohlgren et al., 1998; Pielke et al., 1999; McCully, 2001; Singhsatyajit, 2002; Schneider et al., 2004; Narisma and Pitman, 2006; Keken et al., 2011a; Zdrazil et al., 2011). Questions include where the limits to these changes are and whether the area under impact is the same as that under direct flooding or much wider.

There is no doubt that at the threshold of the twenty-first century, humanity is facing extensive climate change (Saloranta, 2001; Lenhard et al., 2006; Vasbinder et al., 2010; Mooney et al., 2013), which might result in a lack of water and water sources. Water availability is economically important, for example for industry (Manoha et al., 2008; Forster and Lilliestam, 2011), drinking-water production (Ramaker et al., 2005; Senhorst and

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Zwolsman, 2005), agriculture and fisheries (Bartholow, 1991; Ficke et al., 2007) and recreation (Webb et al., 2008). The basic reasons for the potential accumulation of surface water are: (i) the provision of a sufficient amount of drinking water to cover to people's needs; (ii) the provision of a sufficient amount of water for the development of, and supply to, industry and agriculture; (iii) the protection of territories against flooding resulting from climate change (Keken et al., 2011a; Zdrazil et al., 2011).

The water policy in the Czech Republic (in 2014) defined 65 localities, which are territorially protected against supra-regional development (e.g. highways, expressways, corridors of high speed trains, large industrial facilities etc.), where dams could be built with a long-term perspective between 2030 or 2050 to cover water needs, if a lack of water becomes a problem. Similar measures or scenarios might need to be developed throughout Europe. In the case of dams being constructed, many natural or urban areas might be affected or even destroyed; thus, the question concerns the scale and scope of the potential impact on landscape structures and whether the potential impact will be limited to the directly flooded area or whether it will affect a much broader area in terms of structural land-cover changes.

1.1. Landscape change

Landscape changes occur on different time scales; therefore, they differ in magnitude and extent, which can be considered as intrinsic factors of their development (Bičik et al., 1996; Lipsky, 2000; Gerard et al., 2010; Skalos et al., 2012, 2014). The analysis of land-cover change plays a key role in understanding a great variety of phenomena in several research fields (Olah and Boltižiar, 2009; Olah et al., 2009). Land can be transformed through several spatial processes, including attrition, perforation and fragmentation, resulting in increases in isolation and habitat loss (Forman, 1995; Forman and Collinge, 1995; Keken et al., 2011b,b; Kusta et al., 2014a,b).

1.2. Landscape metrics

Landscape metrics or spatial metrics are among the key factors of modern landscape ecological research (Cushman and McGarigal, 2008; Uuemaa et al., 2009). Landscape metrics have been used to compare ecological quality across landscapes (Ritters et al., 1995) and scales (Frohn, 1997), and to track changes in landscape patterns through time (Henebry and Goodin, 2002). Scale is an essential concept in both the natural and social sciences, and has been defined in several ways (Gibson et al., 1998; Van Gardingen et al., 1997; Peterson and Parker, 1998; Marceau, 1999; Withers and Meentemeyer, 1999; Jeneretee and Wu, 2000). The spatial metrics that have been used to quantify spatial patterning of land-cover (LC) patches and LC classes of the study area, can be defined as quantitative and aggregate measurements that show spatial heterogeneity at a specific scale and resolution (Luck and Wu, 2002; Herold et al., 2003). To determine the extent of landscape changes, land-cover categories must be carefully described and identified (Krettinger et al., 2001).

1.3. Effect of dam construction on the spatial-temporal change of land use and land cover

Although the social benefits gained from dams are huge, a wide range of risk always exists and include partial changes in LC.

Due to the reduced risk of floods, the downstream area of dams become safer places to settle and expand development, hence accelerating the "urban sprawl" (Shepherd, 2005; Seto et al., 2011). Many factors responsible for the changes in the post-dam era manifest themselves over time, since mainly anthropogenic alterations in the landscape around dams occur continuously. Furthermore, artificial reservoirs seriously influence the surrounding ecosystem directly; one main impact relies on the phenomenon of open water evaporation, which modifies the microclimate of the locality and additionally enhances moisture supply, which manifests itself as precipitation (Kunstmann and Knoche, 2011).

1.4. Driving forces and linkage socio-economic factors, land cover and its changes

Land use LU/LC changes are mainly caused by human activities and natural ecological processes (Petit and Lambin, 2002; Munteanu et al., 2014). Research into LU/LC changes is conducted in the field of tension between social and natural sciences and requires an interdisciplinary approach (Lambin et al., 1999).

1.5. General tasks of the study

This study focuses on the evaluation of landscape structure changes, due to the realization of important hydrological facilities (Greece) and compares the outputs with data from the Czech Republic, where dams might be constructed in the future (i.e. the potential flooded area is protected from the development of urban structures by territorial limits) and more specifically to:

- Evaluate those landscape structure changes
- Analyse the microstructure of landscape changes during the monitoring period
- Compare the development of landscape characteristics in both areas during the reporting time period
- Provide information for further decision-making concerning the possibility and probability of future important hydrological facility construction in the Kocov region in the Czech Republic
- Evaluate the level of nature and human impact on the landscape as a driving force.

2. Materials and methods

This study is presented from the perspective of landscape ecology. The principal issues will compare and contrast the interaction between human activities and semi-natural and natural areas. A conceptual framework for landscape analysis will be based on the assumptions that the physical appearance (image, character) of a landscape is a result of the interaction between human activity and nature. In this comparative analysis case study, this is an interaction between dam construction or a delimitation of the land limit for potential dam construction and natural landscape development.

2.1. Study areas

For this study, two places of interest were defined: a locality where a flooded area already exists (the dam was constructed within the monitored period; in Greece, Fig. 1) and a locality where a dam might exist in the future (in the Czech Republic, Fig. 1; i.e. the potential flooded area is protected from the development of urban structures by a territorial limit). The buffer zone for research into landscape change was within 500 m from the border of direct flooding (i.e. in Greece, landscape structure changes were examined between 1945 and 1996, due to dam construction within the monitored period and in the Czech Republic, landscape structure changes between 1950 and 2012 were examined within