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Rural landscape planning through spatial modelling and image processing of historical maps

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ABSTRACT

Rural land has been affected over the years by profound, complex and difficult to understand transformations due to natural events, human intervention and changes in natural cycles. Nowadays, the analysis of rural land as well as the environment and landscape is made easier and more complete through the use of powerful and reliable tools; many changes can be considered to be models of territorial development that may prove useful in the appropriate planning of interventions in a rural area. In this paper the land use changes in a rural area located in Southern Italy were analysed by comparing some historical cartographic supports produced by the Italian Geographic Military Institute at different periods over about 160 years with modern maps, in order to evaluate the morphological and vegetation variations of agro-forestry land. The results in terms of landscape modification of the study area show significant changes: the agricultural and forestry land has been affected by deep transformations. Land use and morphological changes at four time steps were conducted through the implementation of digital terrain models, which were enriched by draping land cover pictures over them; these finally enabled an evaluation in a scenic way of the morphological and vegetation variations of the agro-forestry landscape, allowing a virtual jump back to periods when digital aerial photography was not yet possible. Multitemporal analysis with the support of GIS techniques has great potential for assessing and monitoring landscape diversity and typical changes of vegetation and for planning sound interventions in landscape structures.

Introduction

Human activities have imposed a transformation on extra-urban land that may lead to the modification of the frail equilibrium of whole ecosystems. Sound planning strategies should therefore be pursued, employing a multidisciplinary approach that takes into account geographical, environmental and landscape factors as variables interacting among themselves and with social and economic aspects (Tortora et al., 2006). Over recent years different systems have been developed with the aim of providing support to policy makers in the field of agricultural development (Van Delden et al., 2010). According to this scenario, an accurate analysis of the performed variations and the global monitoring of all ecosystems is necessary to propose suitable environmental protection politics (Picuno et al., 2011). The visualization of spatial information in the form of maps is critical to facilitating decision making in environmental management (Iosifescu-Enescu et al., 2010).

Moreover, the technical and spatial analysis methodologies that have been recently developed could ensure both the proper management and planning of land, especially if tailored to environmental protection and to efficient control of the agricultural and forestry resources. Suitable models for policy impact assessment (Brown and Brabyn, 2012) should help harmonize the EU agricultural policies and socio-economic processes at different levels and in different sectors (i.e. local zoning regulations, infrastructure planning and interaction between these sectors) as well as external factors such as climate change and socio-economic drivers (Van Delden et al., 2010). Landscapes are spatially diverse, leading to the unequal distribution of landscape services over an area. An evaluation of the policy effects should therefore be spatially explicit as policies are likely to have a location-specific effect on the provision of landscape services (Willemen et al., 2010). An *ex ante* evaluation of the consequences of spatial planning and policy on the supply of landscape services can support effective decision making (Bockstael et al., 1995; Verburg et al., 2009).

The analysis of the historical landscape and the influential driving factors of landscape development may provide an essential basis for tackling current environmental questions in spatial planning (Haase et al., 2007). The landscape should be understood

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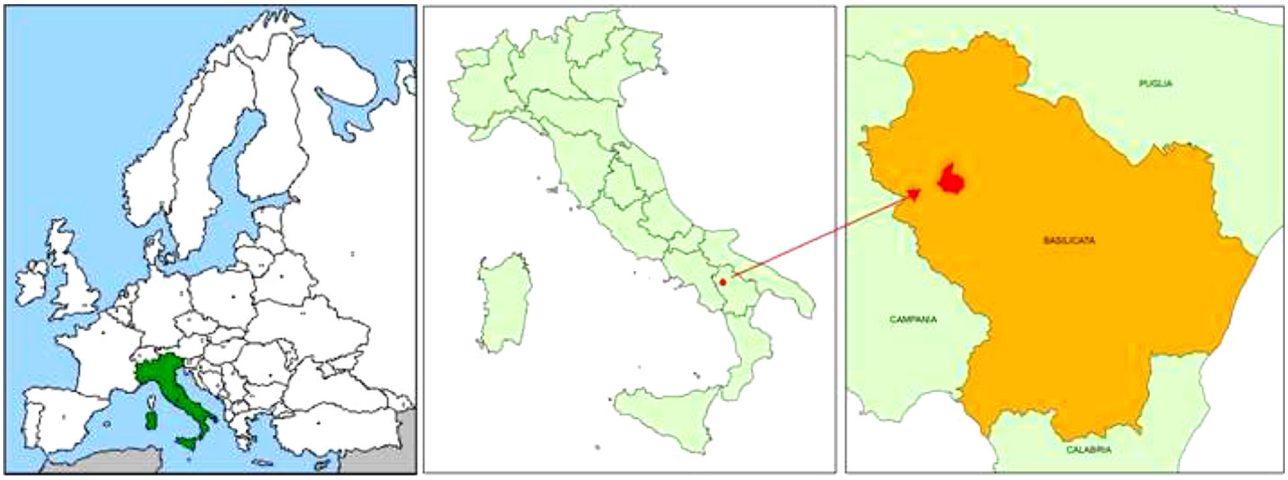

Fig. 1. Map of the study area within the Basilicata region.

as a dynamic and open system where biophysical, social and economic factors interact to define the current structure. The knowledge of historical landscape development ought therefore to be a starting point for long-term landscape monitoring (Neubert and Walz, 2002). In most landscapes, large-scale patterns of geological, topographical and morphological alteration are overlaid by smaller-scale variations in microclimate and disturbance patterns. Landscape processes are nested in a spatio-temporal hierarchy, from large-scale, slow processes like geological change, to smaller-scale, rapid processes like plant competition and succession (Gillson, 2009).

In order to evaluate the processes involved, suitable information about the landscape, the land-use structure and the environment are required. The results of investigating historical developments primarily consist of quantitative, statistical information on land-use change (Pelorosso et al., 2009), which can, for instance, be used for the continuous monitoring of comparable metrics and indices in time series (Geri et al., 2010). The spatio-temporal dynamics of traditional rural mountain landscapes reflect the land use evolution over the centuries resulting from the longstanding interaction between people and the environment, and recent changes due to the impact of population migrations and policies influencing land use (Cullotta and Barbera, 2011). That interaction between man and environment led to the development of traditional landscapes whose characteristics are closely linked to many features of the local geography, climate, water availability, soils and the historical occupation of a region (Pôças et al., 2011). A time series can be used to predict future general trends in the case of assumed constant political and economic frameworks. Scenarios that are generated to make projections of future land-use changes or to identify land-use patterns with certain optimal characteristics are based on narrative story lines that consistently describe the relationships between the driving forces of environmental changes and their evolution (Lambin et al., 2003). In order to generate these future scenarios, the dynamics of urban land use patterns can be "simulated" taking into account the initial state of the system, the participating factors in land-use dynamics, and the rules that produce the dynamics that drive the evolution of actual cities (Barredo et al., 2003).

Regional and local investigations of landscape change (Schneeberger et al., 2007) enable land-use trends and developments to be differentiated by region and hence support analysis of the causes of the changes (Haase et al., 2007). A multitemporal analysis of land, with the support of GIS and historical documents, is very important for monitoring landscape diversity (Yeh and Huang, 2009) and for investigating changes in vegetation and landscape structure (Leyk et al., 2006).

Vegetation plays an important role in human life and economic activity. The economic role of vegetation is dependent on its ecological function, which is of particular importance like determines the top priority of taking them into account in the system of rational nature management. The role of vegetation is directly associated with its specific purpose in addressing the required social and production tasks. It is appropriate to identify the particular roles of vegetation within these groups according to vegetation-specific nature management practices such as conservation, protection and resource management (Belov and Sokolova, 2009). In addition to vegetation, there are other elements that have a correlation with the landscape, such as buildings, which should be appropriately considered in data processing (Picuno, 2012). There is often a difficult relationship between rural buildings and the landscape (Jeong et al., 2012). European landscape planning policy has particular building codes that protect local cultural identity and promote landscape quality (Council of the European Union, 2001).

To understand the territorial and landscape changes that have occurred over the years, especially in Europe, it is important to recognize the limits of expert approaches and to integrate them with the use of various tools (participatory GIS, semi-directed meetings, photo-elicitation, cognitive mapping, etc.), which allow individual evaluations to be established (Domon, 2011). Geographical Information Systems (GIS) are excellent tools for landscape modelling, for knowing about changes of vegetation and conducting three-dimensional analyses. They allow an easy digitalization of geographical information and coverage structure, and they facilitate graphical representation (Hernández et al., 2004). The morphological and vegetation variations of agro-forestry in the landscape may be evaluated through the implementation of a digital terrain model (DTM), over which the land cover picture is draped; further elements can be successively introduced in a rural landscape and may be included with the aim of understanding the changes occurring in the landscape. Spatial data combined with GIS-based modelling and interpretation using detailed digital elevation models (DEMs) and orthophotos are very useful tools as well. Spatial information is, as a rule, visualized using photographic and thematic maps (Batson, 1990; Gehrke et al., 2006). While photographic maps claim to be an accurate reproduction of the original settings, thematic maps portray their content in an abstract form, while the topology of spatial units is maintained (Olbrich et al., 2002). Here, GIS was used to integrate and manage different kinds of data and to create high quality maps that incorporated many