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The application of a Multicriteria Spatial Decision Support System (MCSDSS) for the assessment of biodiversity conservation in the Province of Varese (Italy)

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ABSTRACT

Spatial Decision Support Systems (SDSSs) are rapidly gaining traction for planning and policy-making, thanks to their significant new capabilities in the use of spatial or geospatial information.

The present paper illustrates the development of a basic MCSDSS (Multicriteria Spatial Decision Support System) that integrates spatial information techniques such as GIS (Geographic Information System) and Multicriteria Analysis (MCA). Many spatial problems are complex and require the use of integrated analysis and models. In the work a methodological framework for such integration is provided, highlighting the advantages and characteristics of GIS and MCA coupling and paying attention to the issues of transparency and applicability. The method is illustrated with reference to a case study in the Province of Varese (Italy). The purpose of the research is to generate a suitability map of the study region, concerning the characterization of biodiversity conservation, to be used as a decision variable in spatial planning. Different criteria are considered in the analysis and the results are obtained in the form of maps and analyzed through IDRISI Andes software. In particular, by using the resulting suitability map as a means of analysis, it is possible to identify, for the sake of biodiversity conservation, some critical areas needing mitigation measures. In addition, areas with high biodiversity conservation values can be highlighted and monitoring procedures can therefore be planned. The study concludes with some lessons learned during the development of the MCSDSS and highlights that the applied methodology is an effective tool in providing decision support for spatial planning.

Introduction

Territorial transformations projects and, more generally, spatial plans are subject to evaluation and their consequences must be considered and managed. In this context, different and conflicting objectives have to be taken into account, referring to social, cultural and symbolic interferences, that can be addressed through quality assessment, vague use values and imprecise temporal horizons (Roscelli, 2005). This leads to consider urban and territorial transformations processes as "weak" or unstructured problems since they are characterized by multiple actors, many and often conflicting values and views and a wealth of possible outcomes and high uncertainty (Prigogine, 1997; Simon, 1969).

Speaking about spatial planning, a very important issue refers to nature conservation and biodiversity. The importance of the topic is stressed above all in the European Directive on the Strategic Environmental Assessment of plans and programmes (European Directive 42/2001) where biodiversity is defined as one of the key topics to address (Geneletti, 2008).

The world's biodiversity encompasses all living organisms (animals, plants, fungi, and microbial groups inclusive of genetic diversity and ecosystem/landscape diversity) in their interactive state contributing to multitude of services of relevance to sustain the ecological integrity for the benefit of the humankind. An overview on the status of biodiversity profiles at local to regional scale suggests that it is at its highest state of vulnerability, due to increased exploitative anthropogenic activities and climate change induced losses (Gatson and Spicer, 1998; Kumaraswamy and Udayakumar, 2011). Thus there is a need for biodiversity conservation in order to sustain the ecological integrity and enhance livelihood support system as identified in the millennium development goals.

Biodiversity conservation is closely related to other global environmental changes and globalization issues, such as climate change, land use and land cover change, and sustainable development (Gude et al., 2007; Liu et al., 2011). In such a context

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biodiversity conservation can be viewed as a complex planning problem, involving environmental, socio-economic and operational aspects.

Mention should be made to the fact that biodiversity issues are usually poorly considered outside protected area (Beunen, 2006; Geneletti, 2006) and therefore there is a need for exploring methods to support biodiversity conservation assessment. In order to improve the consideration of biodiversity issues in spatial planning, the present paper proposes the adoption of a particular Spatial Decision Support System (SDSS), the so-called Multicriteria Spatial Decision Support System (MCSDSS), that is based on the combined use of Multicriteria Analysis (MCA) (Figueira et al., 2005; Roy and Bouyssou, 1995) and Geographic Information System (GIS).

The increasing development in geographical information technologies has helped the construction of GIS-based Spatial Decision Support Systems (SDSS), thereby enabling multi-purpose planning. Tools that incorporate information from different research areas can greatly assist the policy development of today's complex and interconnected issues, resulting in more informed decision-making. Generally speaking, SDSS can be defined as an interactive computer-based system designed to support a user or a group of users in achieving a higher effectiveness of decision-making while solving a semistructured spatial decision problem (Malczewski, 1999). An SDSS has the advantage over a non-spatial DSS of being able to store and manipulate complex spatial data structures, to conduct analyses within the domain of spatial analysis, and provide spatially-explicit output (i.e. maps) and other reporting tools. An SDSS thus represents an ideal tool to support long-term integrated planning for sustainable development.

The work considers the development of a MCSDSS for the assessment of biodiversity conservation in the Varese Municipality (Italy). The application has been performed by means of the IDRISI software.

The objective of the paper is thus to outline the suitability of the area under examination to undergo a process of territorial transformation, based on the conditions of biodiversity conservation, trying to explore links and trade-offs among economic, environmental and operational aspects. After the Introduction section, the paper is organized as follows: Spatial Decision Support Systems section briefly illustrates the SDSS state-of-the-art and methodological background, Case Study Characterization section presents the study case under analysis, Model Development section describes the application of the MCSDSS model to the study case, Results and Discussion section contains the results and their discussion and Conclusion and Future Developments section illustrates the conclusions derived from this research.

Spatial Decision Support Systems

State of the art

Decision Support Systems (DSS) are defined as model-based sets of procedures for processing data and judgments to assist a manager in his decision-making. In other words, DSS are interactive computer-based systems that support Decision Makers (DMs) to solve problems and make decisions. In the context of DSS, for a long period researchers ignored the importance of the graphical analysis of spatial information. One of the first experiences concerning the use of maps in decision-making processes refers to the work of McHarg (1969), where the basic concepts that would be later developed in Geographic Information Systems (GIS, Charlton and Ellis, 1991) are set forth. GIS provide an important way of enabling DMs to make better decisions by conducting spatial analysis and displaying spatial information.

Whereas DSS and GIS can work independently to solve some simple problems, many complex situations demand the two systems to be integrated in order to provide better solutions (Li et al., 2004). In this sense, it can be stated that the development of SDSS has been associated with the need to expand the GIS system capabilities for tackling complex, not well-defined, spatial decision problems (Densham and Goodchild, 1989). The concept of SDSS evolved in the mid 1980s (Armstrong et al., 1986), and by the end of the decade many works concerning SDSSs were available (Densham, 1991; Goodchild, 1993; Densham and Armstrong, 1987; Armstrong, 1993). Over the course of the 1990s there has been considerable growth in the research, development, and applications of SDSS and in recent years these common decision support functions have been expanded to include optimization (Aerts et al., 2003; Church et al., 2004), simulation (Wu, 1998), expert systems (Leung, 1997), Multicriteria evaluation methods (Feick and Hall, 2004; Malczewski et al., 1997; Malczewski, 1999; Thill, 1999), on-line analysis of geographical data (Bedord et al., 2001), and visual-analytical data exploration (Andrienko et al., 2003) with the aim of generating, evaluating, and quantifying trade-offs among decision alternatives. The field has now grown to the point that it is made up of many threads with different, but related names, such as collaborative SDSS, group SDSS, environmental DSS and SDSS based on spatial knowledge and on expert systems (Malczewski, 2006a,b).

With specific reference to GIS-based multicriteria decision analysis, the full range of techniques and applications has been recently discussed in a very interesting study developed by J. Malczewski (2006a). From 2000 the number of studies has been increasing and several applications can be found in different fields. Multicriteria Spatial Decision Support Systems (MCSDSS) are commonly applied to land suitability analysis (Malczewski, 2004) and mention can be made of some very recent researches in the sphere of urban and environmental planning (Chen et al., 2001; Geneletti and Abdullah, 2009; Huser et al., 2009), environment/ecology (Draganm et al., 2003; Geneletti, 2007; Hala and Hegazy, 2009; Zucca et al., 2007), and transport (Keshkamat et al., 2008).

MCSDSS methodology

As already mentioned, spatial decision problems involve a large set of alternative options and multiple, conflicting and incommensurate evaluation criteria (Malczewski, 2006a,b). Alternatives are often evaluated by a number of individuals (DMs, stakeholders, interest groups), that are characterized by preferences with respect to the importance of criteria. Following this reasoning, many spatial decision problems can be addressed by means of GIS-based Multicriteria analysis or Multicriteria Spatial Decision Support Systems (MCSDSS). These two different areas of research (GIS and MCA) can benefit from each other: GIS techniques have an important role in analyzing decision problems, while MCA provides a full range of methods for structuring decision problems and for designing, evaluating and prioritizing alternative decisions (Malczewski, 2006a,b); moreover, GIS is able to manage and process spatial information, and the flexibility of MCA can combine factual information (e.g., soil type, slope, infrastructures) with value-based information (e.g., expert's opinion, quality standards, participatory surveys) (Janssen et al., 2005; Mahmoud and Garcia, 2000). According to Simon's model (Simon, 1969) the decision-making process can be divided into three main stages, namely intelligence, design and choice. Intelligence refers to the structuring of the problem, during which the objectives and values to pursue are explored. One or more criteria, or attributes, are then selected to describe the degree of achievement of each objective (Keeney, 1992). The design involves data collection and processing, as well as the development of the multicriteria value structure (the relationships between