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Spatial analysis of selected biodiversity features in protected areas: a case study in Tuscany region

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ABSTRACT

The development of strategies for biodiversity analysis is critical at several levels, particularly at the national one. The World Conference on Biological Diversity held in Rio de Janeiro in 1992, the European Natura 2000 network and the Environmental Conference of the Regions of Europe (EN.CO.RE) brought forward several measures aiming at the preservation of Biodiversity. Targets for biodiversity preservation include protected areas among others. Accordingly, the analysis of the degree of biodiversity of protected areas proves to be a valid tool to evaluate the effectiveness of those measures.

The present manuscript analyses the degree of some relevant features of biodiversity in the Region of Tuscany, through the implementation of multidimensional indicators in a Spatial MultiCriteria Analysis. After a state of the art of biodiversity definition, four indicators have been used for the analysis. A raster map in which pixels have higher or lower values of biodiversity was produced in order to investigate which of these values might be located in protected areas. Protected areas with high value of biodiversity confirmed that the adopted environmental policies are positively related to the conservation of biodiversity. The result of the analysis, corroborated through auto-correlational statistical analysis, has highlighted the important role of protected areas in maintaining a certain degree of biodiversity.

1. Introduction

The concept of biodiversity encompasses a set of meanings, which currently converge toward the concept of conservation of species including animals, plants, and their habitats. Article 2 of the International Convention on Biological Diversity defines "Biological diversity" as "*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*".[1] The United Nations Food and Agriculture Organization (FAO) considers that the concept of Biodiversity "*includes the variety and variability of ecosystems, animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain human life as well as the key functions of ecosystems*".[2] The World Wildlife Fund (WWF) defines Biodiversity as "*the HUGE variety of other animals and plants on our planet, together with the places where found*".[3] The United Nations Environment Programme[4] (UNEP) gives a clear-detailed biodiversity definition: "*The term 'biodiversity' is indeed commonly used to describe the number, variety and variability of living organisms. This very broad usage, includes many parameter and is essentially a synonym of 'Life on Earth'*". UNEP identifies three levels of biodiversity.

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[1] Available online http://www.cbd.int/convention/articles/default.shtml?a=cbd-02 [last accessed January 20, 2016]

[2] Available online http://www.fao.org/biodiversity/en/[last accessed January 20, 2016]

[3] Available online http://wwf.panda.org/about_our_earth/biodiversity/[last accessed January 20, 2016]

[4] Available online http://old.unep-wcmc.org/what-is-biodiversity_50.html [last accessed January 20, 2016]

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1. Genetic diversity comprises all the different genes contained in all the living species, including individual plants, animals, fungi, and microorganisms.
2. Species diversity includes all the different species, as well as the differences within and between different species.
3. Ecosystem diversity encompasses all the different habitats, biological communities and ecological processes, as well as variations within individual ecosystems.

It is important to consider, however that biodiversity comprehends a number of sensitive issues that are directly connected to human development. For instance, urban development is at the centre of multiple spatial planning studies aiming at controlling and regulating growth to avoid the phenomenon of urban sprawl. In this case, biodiversity, being part of natural areas and habitats threatened by human activities, should be included in the decision-making processes.

The literature is rich with models for the analysis of biodiversity. This is approached from different points of view: in 2001 three prominent conservation journals published approximately 547 papers on the subject (Fazey et al., 2005). Dormann et al. (2008) performed a multimodel prediction to evaluate the effects of climate, land-use intensity, and landscape structure on species richness in some groups of organisms. Gotelli et al. (2009) used mechanistic models that simulate speciation, dispersal, and extinction of species in a heterogeneous landscape. Pelissier and Couteron (2007) used a multivariate linear model in order to quantify the relationship between observed species' diversity and one (or a set of) external explanatory variable(s) depicting accessible information about the species' environment.

Protected areas (PA) follow special measures for environmental preservation that are correlated to biodiversity. The emerging need for biodiversity analysis can be explained by "a shift from source-oriented to effect-oriented policy that can be recognized in environmental and nature conservation policy since the 1980's"... In the case of effect-oriented policy, the quality of the (eco) system is the starting point for the elaboration of policy and measures" (Turnhout et al., 2007). At the same time analysis of biodiversity in protected areas (mainly represented by National, Regional, Provincial parks and Natural reserves) has always been considered an important area of discussion. Based on the World Conference on Biological Diversity held in Rio de Janeiro in 1992, and in line with most of the important actions such as the "European Natura 2000" network or the Environmental Conference of the Regions of Europe (EN.CO.RE), several protected areas and measures aimed at the preservation of biodiversity were instituted in Italy. These areas/measures are:

- Sites of Community Importance (SCI) and Sites of Regional Importance (SRI)
- Protected wetlands under the "Ramsar Convention",[5]
- National Strategy for Biodiversity (active since 2010, and which development is part of Italy's commitments since the ratification of the Rio de Janeiro '92 Convention through the Act no. 124 of 14 February 1994). This act was implemented in Tuscany through the Regional Energy and Environmental Plan (Paer 2013–2015).[6]

The ways to measure biodiversity is an area of discussion particularly relevant at the science/policy interface (Turnhout et al., 2007). The Convention on Biological Diversity (CBD), mandated Biodiversity Indicators Partnership (BIP), promotes the development of indicators in support of the CBD and related conventions, national and regional governments, and a range of other sectors. Indicators initiated under the partnership are linked to the goals of the Strategic Plan for Biodiversity 2011–2020 and include habitat extent, protected areas and species' extinction.[7]

The present work analyses the degree of biodiversity of specific areas' characteristics in the region of Tuscany, using specific indicators, implemented through a Geographic Information System (GIS). The aim of this paper is to highlight the areas having a high value of biodiversity, and indicate which of these areas are located within protected areas: protected areas with high value of biodiversity confirm that the adopted environmental policies are positively related to the maintenance of biodiversity; on the contrary protected areas with low value of biodiversity indicates the failure of environmental policies in preserving biodiversity. The interesting aspect of this paper is the analysis of the spatial correlation between values of features relevant to biodiversity and protected areas. This is implemented by using a geographical dataset with high resolution. A spatial MultiCriteria Analysis is used for the development of a raster map in which the pixels (75 m of resolution) have higher or lower values of biodiversity depending on the selected indicators (refer to Section 3). The adopted methodology represents also a tool to support territorial planning. It will assist stakeholders to better identify and verify the effects of the national or local environmental policies and may be easily replicated in other contexts.

This paper is organized as follows: in Section 2, methodology is described; in Section 3, the indicators are selected; in Section 4, case study is introduced; in Section 5, the model is implemented; in Section 6 discussion of the results is provided; Section 7, is dedicated to conclusions and future recommendations.

2. Definition of the model

The Spatial MultiCriteria Analysis (MCA) is a MultiCriteria decision techniques applied in Geographic Information Systems (GIS), which permits the processing of a large number of data through MCA rules.

The MCA developed in the USA during the second half of the 70s, is classified as a decision support tool for decision makers or groups of decision makers (i.e., citizens, public or private bodies, investors, politicians, etc.) involved in a planning process. MCA is based on mathematical procedures that can identify the best (ideal) choice for a given a set of alternatives, criteria, indicators, targets, and attributes related to a specific problem (target study). With reference to statement, (Watson and Buende, 1987) "*The reality in relation to which a decision maker must make a decision is a construction of the individual. Therefore, when we worry about what action to take, what is important in guiding the choice are our own mental models of the world* ", the main purpose of the MCA is to provide a decision support tool, and to select through calculations, based on variables that consider human behaviour, which are the best possible solutions for a given problem. Spatial MCA relies upon the potential of GIS to solve MultiCriteria models in order to support decision-making in spatial planning processes (Malczewski 2006a,b), and to get results that are easy to interpret.

The MCA evaluation method was first combined to Geographic Information Systems around 1990 (Janssen and Rietveld, 1990; Carver, 1991; Malczewski, 1999; Thill, 1999). Spatial MCA includes a set of procedures for combining criterion maps (spatial dimension) and preferences with respect to the relative importance

[5] Convention on Wetlands of International Importance, especially as Waterfowl Habitat

[6] Available online Tuscany region official website [last accessed January 20, 2016]

[7] Available online https://www.cbd.int/sp/[last accessed January 20, 2016]