



Multi-criteria decision analysis for land suitability mapping in a rural area of Southern Italy



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ABSTRACT

Selection of suitable areas for territorial planning is a complex process and needs many diverse indications on the basis of which a decision may be assumed. This paper focuses on the integration of Geographical Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) to evaluate the potential of a rural coastal area, located in northern Puglia (Southern Italy), to improve its sustainable development through the restoration of manor farms. Comparing the results obtained using the Weighted Linear Combination (WLC) and the Ordered Weighted Averaging (OWA) procedures, suitable sites where the restoration could be implemented were identified. In order to consider the stakeholders' judgments and to reach a shared decision in selecting the preferred alternatives, the Analytical Hierarchy Process (AHP) approach was used for prioritization, due to its relative ease in handling multiple criteria and compensating both qualitative and quantitative data. The results highlight how the spatial distribution of suitable areas is closely linked to the risk assumed and, consequently, to the capability of the methods in varying both risk and tradeoff parameters. Particularly, the OWA procedure shows higher potentialities in performing, with greater detail, the territorial evaluation and generating a wide range of decision strategies. The methodologies described and their application procedures can be extended to similar territorial contexts, in issues in which a notable number of territorial factors should be taken into account.

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1. Introduction

In recent years, territorial planning experiences have increasingly focused on aspects related to environmental preservation, protection from natural disasters (safety of population), rural land transformations and sustainable development (Edwards and Lurdés, 1996; Alphonse, 1997; Bernetti and Fagarazzi, 2002; Lütz and Bastian, 2002; Geneletti, 2004; Trisorio Liuzzi et al., 2006; Marsden and Sonnino, 2008; Neri and Sánchez, 2010; Tortora et al., 2015). As regards the Puglia region, regional planning problems are being definitely underestimated (Regione Puglia, 2006) in terms of governance of both municipal and extra-municipal areas. Inadequate programming is more evident in the coastal areas, where overexploitation of resources and anthropic pressure are the main causes of degradation (Picuno et al., 2011).

In the coastal area of *Piana di Macchia* (Monte Sant'Angelo municipality), major physical-environmental aspects are strictly intertwined with anthropic ones, thus generating intricate problems the solution of which is neither easy nor univocal. Indeed,

various interests – olive-growing based agricultural activities, conversion and re-industrialization of a large industrial area (ex-petrochemical pole), tourism-accommodation facilities, and protection of natural and environmental resources – co-exist in this area and might conflict with each other.

So, for appropriate land use policies, the main objective to be pursued is to identify management priorities and support decision-making while providing comprehensive information.

Land suitability mapping, based on geographical information systems (GIS), is one of the most useful applications for spatial planning and management (Malczewski, 2004, 2006). In association with multi-criteria decision analysis (MCDA), GIS can be defined as a process that integrates and transforms geographic data (input map criteria) and value judgments (decision makers' preferences and uncertainties) to obtain an overall assessment for choosing between alternative actions (objectives), hypotheses and locations (Eastman et al., 1993; Malczewski, 2004; Boroushaki and Malczewski, 2008).

De Araújo and Macedo, 2001 used GIS techniques and multi-criteria analysis in geologic modelling for mineral favourability mapping in Brazil. A multi-criteria approach for the identification of waste disposal areas was followed by Calijuri et al. (2004) in order to

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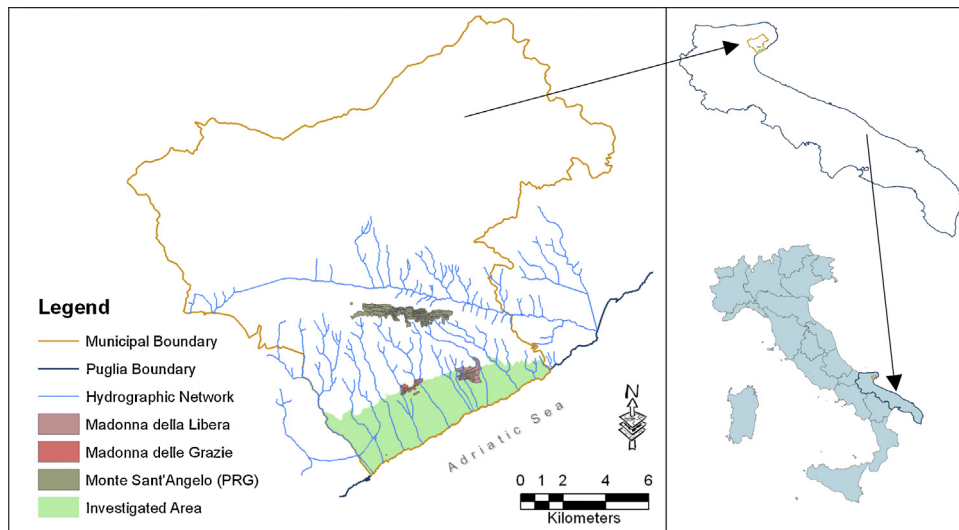


Fig. 1. Geographic position of the municipality of Monte Sant'Angelo and its coastal area.

minimize the harmful effects from rock processing that cause pollution to surface and groundwater resources. Dal Sasso et al. (2012) identified quarry reuse alternatives with the application of a two-step methodology, comprising a multi-criteria analysis related to a site-specific level and territorial indicators checking over the wide area.

Image processing of current and historical maps is carried out, in many papers (Capobianco et al., 2004; Haase et al., 2007; Tortora et al., 2015), in order to analyze landscape changes and to approach environmental issues.

The growing interest in combining GIS capability with MCDA processes is due to the GIS potential of handling (managing, processing, upgrading and storing) large amounts of complex geo-referred data from different sources at multi-spatial, multi-temporal and multi-scale levels, obtaining a time-efficient analysis.

Lastly, another potential advantage of a GIS-based approach for siting arises from the fact that it not only reduces the cost of site selection but also provides a digital database for long-term monitoring of the area (Moeinaddini et al., 2010).

Along with the increase of GIS technology, some MCDA methods have evolved as a fundamental tool to assist decision makers in either ranking a set of alternatives for problem solving or making a choice among these while considering the conflicting criteria. The integration of GIS-MCDA procedures has, in fact, considerably advanced the map overlay approaches (McHarg, 1969) to site suitability analysis, with the result of transforming spatial and alphanumeric data into a best decision (Sumathi et al., 2008). The decision rules can be classified into *multiobjective* and *multiattribute* decision making methods (Malczewski, 2004). In the multiobjective methods the alternatives are to be generated, taking into account the factors and the constraints imposed. *Factors* are commonly measured by a numerical scale that is continuous (slopes, distances, altitudes, climatic factors) or discontinuous (land use, physical or administrative boundaries). They can enhance or reduce the land suitability to the target objective. *Constraints* are instead real impediments, if any, to achieve a specific objective planning (hydro-geological constraint, minimum safe distances, exposure, etc.).

Multiattribute techniques assume that the number of alternatives (plans) is given explicitly (Malczewski, 1999). Multicriteria procedures are carried out to check land allocation decisions or the suitability of a unique predetermined objective (land policies, territorial guidelines).

This work uses a multi-disciplinary approach to generate a suitability composite map, with the aid of GIS-MCDA techniques, emphasizing the effects of environmental, socio-economic and territorial management features. It is aimed at identifying, in a coastal territory of northern Puglia, the sites where structural measures could be performed to support the socio-economic development, based on a rural tourism that can integrate the agricultural, natural and architectural resources.

The analysis refers to the area of Piana di Macchia, Monte Sant'Angelo, where many manor farms are present, that could be restored and used with a view to targeted agro-environmental tourism. The identification of the areas that appear to be more suitable is affected by the limited financial resources and, consequently, by the need to select the sites in a rational way. To reach the above mentioned aim different analysis approaches were used and compared: Boolean overlay, Weighted Linear Combination (WLC) and Ordered Weighted Averaging (OWA).

2. Materials and methods

2.1. Site description

2.1.1. Study area

The site investigated is the coastal strip of the municipal territory of Monte Sant'Angelo, which is located on the south-eastern hillside of the Gargano promontory and falls within the province of Foggia (Fig. 1). This well-known agricultural area in the Puglia region features a remarkable concentration of valuable historical and cultural sites, combined with a very interesting natural landscape.

The analyzed territory, named *Piana di Macchia*, is a flat area, sub-triangular in shape, with a surface of 21.85 km² and 11 km long. To the west it borders the Pulsano stream, which represents the boundary with the municipality of Manfredonia, to the east the rocky promontory of Puntarola, in close proximity to the boundary with the municipality of Mattinata and to the north the rocky cliff, on which the town rises 843 m a.s.l.

The area enjoys a typically Mediterranean climate, with mild and scarcely rainy winters and hot and dry summers.

The geology of the area consists of alluvial flood plain deposits of the Quaternary period that form a 100 m thick blanket. Such low permeability deposits are formed by sub-rounded pebbles and are almost always buried in a matrix of residual soils easily washed

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