

## **A GIS-BASED MULTI-CRITERIA MODEL FOR THE SUSTAINABLE MANAGEMENT OF GRAZING IN NATURAL PROTECTED AREAS. AN APPLICATION IN THE *ASPROMONTE* NATIONAL PARK**

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### **Abstract**

The present research was aimed at defining a GIS-based multi-criteria model working as a Spatial Decision Support System (SDSS) for the sustainable planning of grazing resources in the Aspromonte National Park (Calabria, Italy). The method of evaluation adopted is characterised by a multi-criteria approach, allowing the realization of thematic maps of land suitability (LS) for grazing. LS was evaluated and classified according to different domestic animal species, on the basis of a characterization of the main land features influencing it, and of the quality and availability of forage (both in quantitative terms and depending on seasons). Subtractive masking, overlaying maps representing limitations and constraints for grazing, allow to single out, from among the suitable areas, those where grazing can be carried out. In order to support decisions in the planning and management process, the model was refined so as to select grazing areas of sufficient extension (equal or superior to a fixed value), resulting from the combination of contiguous land units with satisfactory suitability. The model can easily be updated and can effectively support a Grazing Management Plan. Although implemented and tested for application in a specific park, it can be extended to other Mediterranean regions where stock raising has great importance in the local economy.

**Key words:** GIS-based multicriteria model, Sustainable grazing management, Natural protected areas

### **Introduction**

Today, a crucial point for a successful and sustainable management of natural resources in protected areas deals with the correct integration of two different objectives: nature conservation and development of the local population. The latter should be based on the valorisation of the natural and cultural resources of the park and favour activities with high environmental compatibility. Most of the Italian National Parks cover mountainous areas where forestry coexists with animal farming and agriculture. In time, these last have created landscapes that society today aims to protect; nevertheless, some activities - grazing in particular - can create conflicts between the economic exploitation of resources and the conservation of the natural heritage if not correctly managed, thus resulting in an unbalanced system. A clear definition and classification of the suitability of the land for grazing is needed; this should be carried out on the basis of considerations relating both to the kind and availability of feeding resources and to the limitations deriving from potential conflicts with other land uses and conservation targets (i.e. conservation of biodiversity).

The planning of grazing activities, within the broader problem of land management, today requires a careful analysis of the specific suitability of the countryside. To manage agro-forestry resources according to the economic, environmental, and social dimensions of sustainability, Decision-Making (DM) approaches and procedures that examine trade-offs between often competing/conflicting objectives/alternatives should be implemented (MODICA et al., 2016). In this respect, land suitability evaluation (LSE) is a widespread methodology that supports environmental managers and planners in analysing the interactions between location, development actions, and environmental elements.

A GIS-based Multi-Criteria Decision Support model for the sustainable planning of grazing-areas in natural protected areas was proposed. The GIS-based multi-criteria evaluation approach allow the

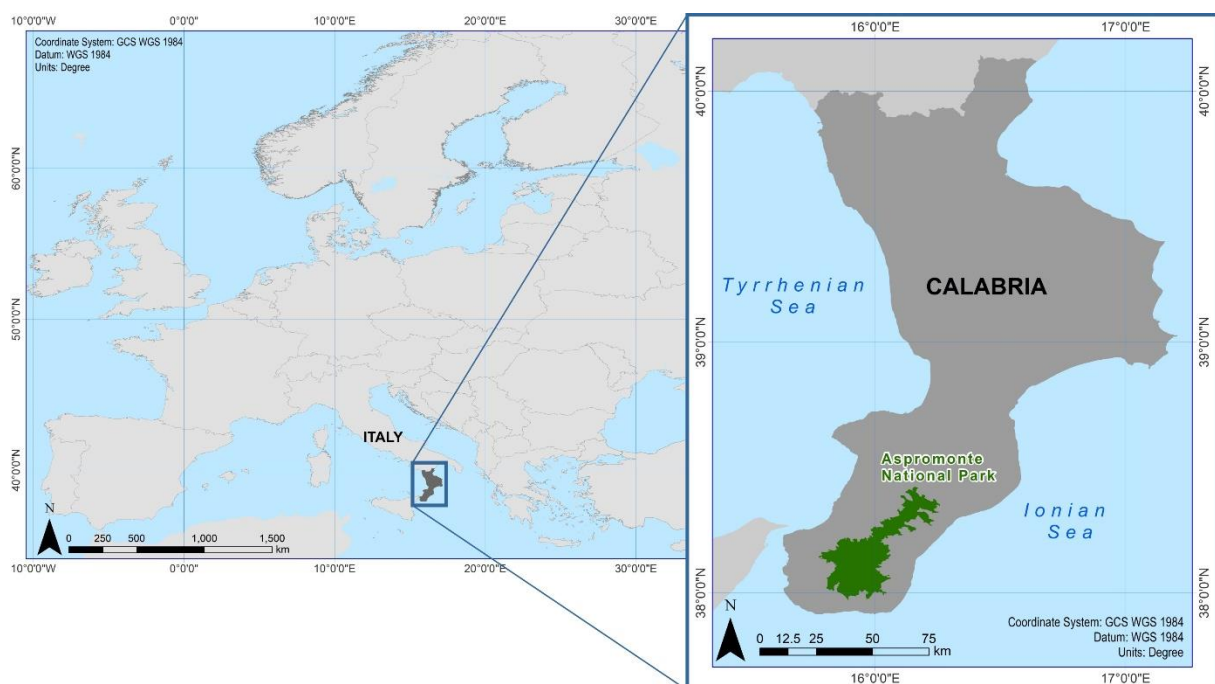
implementation of fewer decision rules thus reducing the number of factors used in land suitability analysis and making analysis easier for decision makers (DMs).

The work is orientated at the creation of an open model, which may be updated and adapted to the real needs of planning within a protected area.

## Materials and Methods

### Study Area

The Aspromonte National Park (Calabria, Southern Italy) covers an area of roughly 64.000 ha and comprises 37 municipalities. It was firstly instituted in 1989 (the sixth National Park instituted in Italy) while in 1994 its surface covered an area of about 76,000 ha. The current boundary was established in 2008. This territory is marginal and with a long pastoral tradition whose signs are still notably present in the landscape and local cultures. Here, cattle raising, although not easy inclined to technological innovation, represents a significant source of income for the local population and is mainly based on extensive farming. The domestic animals that graze in the park are mostly cattle, sheep and goats, many of which come from farms whose sheds are located outside of the park.



**Fig. 1.** Geographical location of the Aspromonte National Park (Calabria).

*Source: Own study.*

### Methods

The model implemented for the sustainable planning of grazing-areas is a GIS-based Multi-Criteria Decision Support System based on the FAO land use evaluation and land-Use planning procedures (FAO, 1976, 1993, 2007). It is organised in four consecutive phases each of them singled out in different steps (Fig. 2).

The evaluation of the aptitude of land for a specific use consists in the selection and successive analyses of those important features upon whose combination it is possible to base judgement on the degree of satisfying the requisites set by the considered use. Moreover, the explicit identification of constraints and opportunities for future land conservation and development is a specific goal of suitability analysis (STEINER et al., 2000).

Referring to the phase of the evaluation of the suitability for grazing, two steps are expected: the evaluation of productive suitability of the land, and based on the selected criteria; the effective usability of resources, based on the analysis of accessibility to the suitable areas and the availability of water. In many Mediterranean regions, this latter aspect has considerable importance above all in the spring-summer period, when the shortage of water is particularly felt.

Moreover, given that the behaviour of grazing animals and their alimentary needs cannot be considered as constant elements, the model defines the evaluation of suitability to pasture according to two

different behavioural classes that have been attributed to the domestic animals present in the park: class A (sheep and cattle); class B (goats). With the aim of taking account of the marked seasonality of the production of Mediterranean pastures, a further distinction, for each class, has been made on the basis of the grazing season (evaluations A1 and A2; B1 and B2) (Table 1).

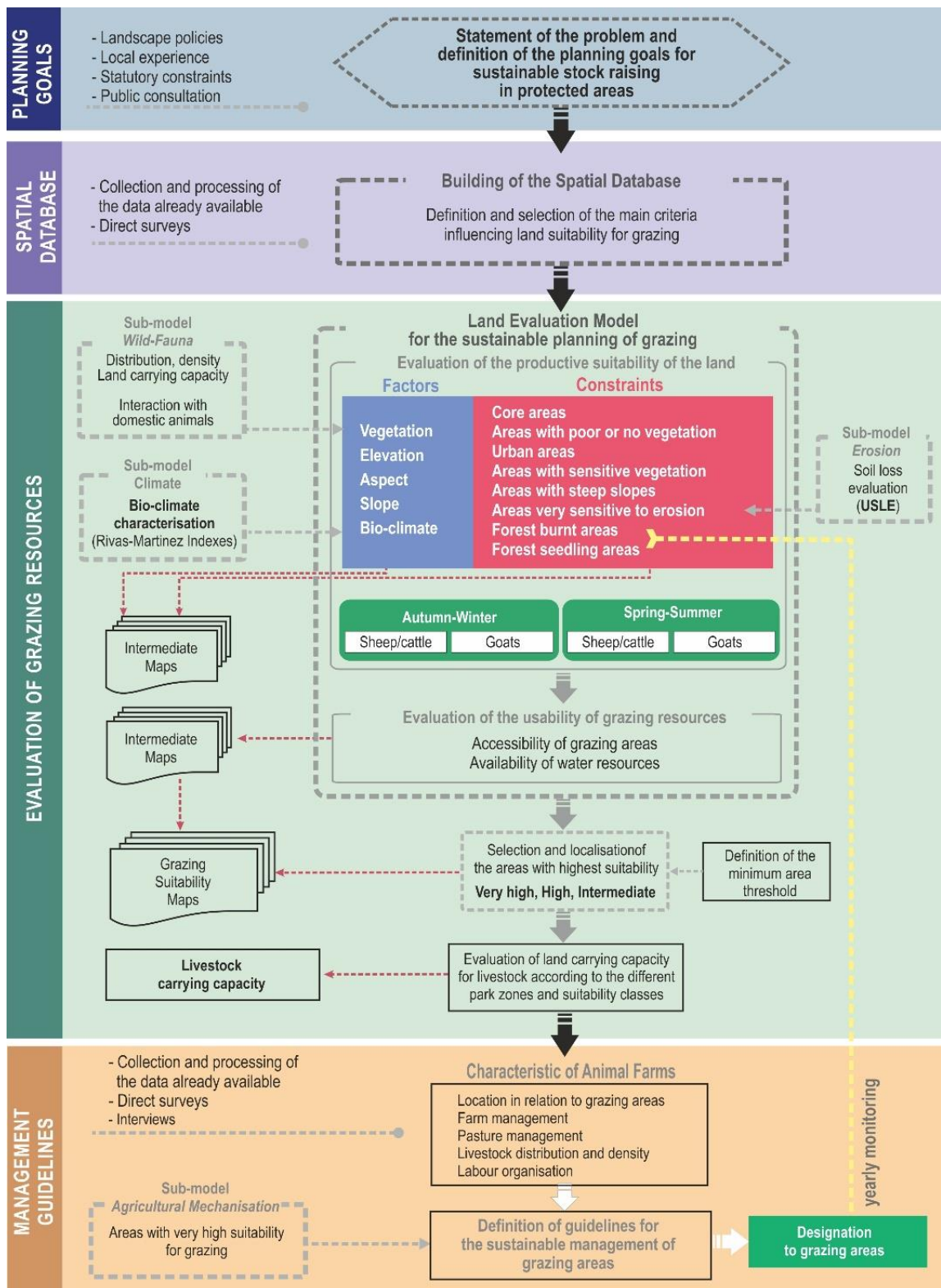


Fig. 2. Diagram showing the main stages of the model implemented for a sustainable planning of grazing areas.  
Source: Own study.

With the aim of answering the needs of planning, attempts were made to adjust the model so as to pinpoint those areas that have a higher or equal productive suitability to a pre-set value and only on these perform the evaluation of suitability to grazing. In addition, it was desirable to take into account the problems frequently determined by the fragmentary nature of distribution that often characterises Mediterranean vegetation, since the localized areas may be too limited to be destined for economically convenient pastureland.

According to other experiences (EASTMAN et al., 1995; JIANG, EASTMAN, 2000; MODICA et al., 2016), the selected criteria were processed as factors and constraints. Factors allow of measuring the vocation of an area for the considered use and represent the decisional variables, namely the elements to be sized for reaching the objectives of the planning process. In turn, they define a different degree of suitability of an area for that specific use.

The weight to be attributed to each factor has been obtained through the Analytic Hierarchy Process (AHP) procedure (SAATY, 1977, 1980). Despite relevant criticism highlighted by scholars, the AHP procedure remains widely applied in many research and operational fields (MODICA et al., 2015; VIZZARI, MODICA, 2013).

**Table1.** Different evaluations of the proposed grazing model.

Animal breeds		Grazing season	
Sheep and cattle	A	Autumn-winter	A1
		Spring-summer	A2
Goats	B	Autumn-winter	B1
		Spring-summer	B2

Source: Own study.

The method is based on the construction of a Pair-wise Comparison Matrix of the various factors, allowing to overcome the human difficulty in simultaneously judging the importance with regard to all the factors inserted in the model. Judgements are provided by experts and scaled according to the so-called ratio fundamental scale of the AHP (SAATY, 1977, 1980).

Constraints can have regulatory or physically nature and entail the exclusion of an area from the evaluation with respect to the considered use.

As aggregation procedure, the Weighted Linear Combination (WLC) followed by the constraints mask was chosen. In formula:

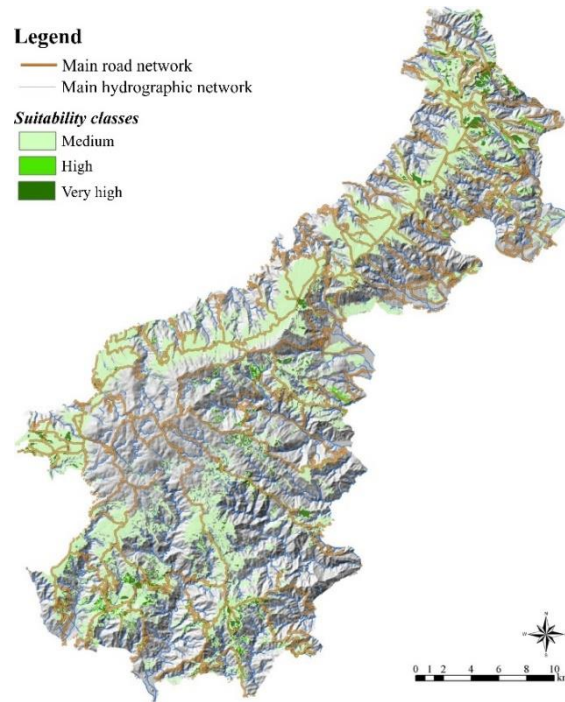
$$S_j = \left( \sum_{i=1}^n w_{ji} \cdot x_i \right) \cdot \prod_{k=1}^m c_{jk}$$

where:

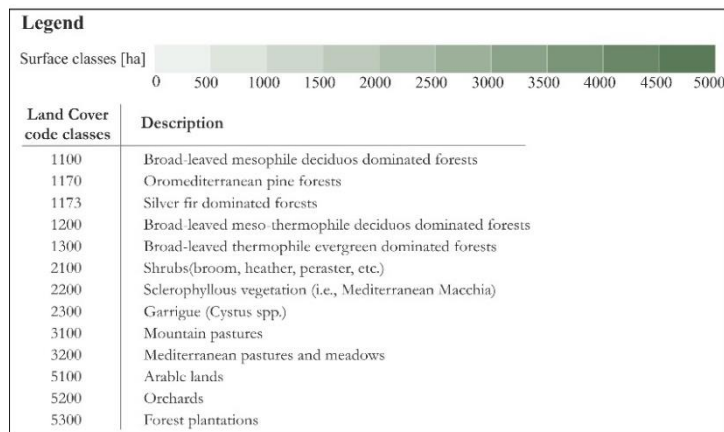
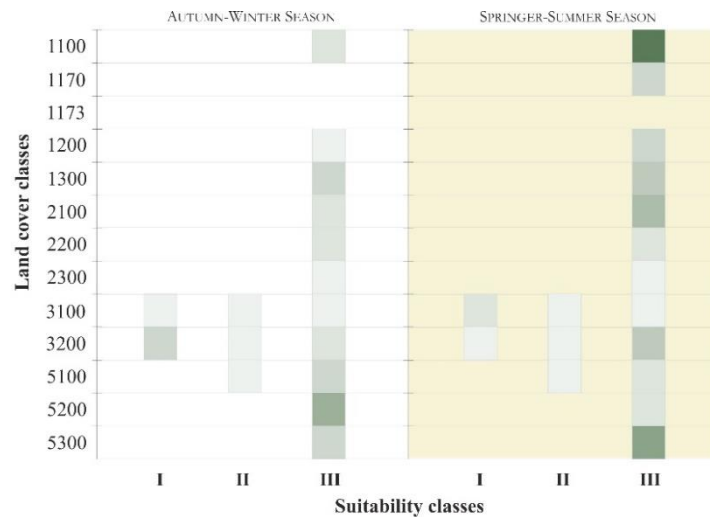
- $S_j$  expresses the suitability of the area (cell)  $j$ ;
- $w_i$  is the weight of the factor  $i$ -nth;
- $x_i$  is the factor  $i$ -nth inserted in the model;
- $c_{jk}$  are the  $k$  constraints present in the area (cell)  $j$ .

## Results

The obtained results of the WLC procedure was firstly reclassified in 6 suitability classes, then only those areas belonging to the highest suitability classes a with an extension of at least 10 ha were selected. Then, the usability of the grazing resources was obtained based on the analysis of Euclidean distance of the most suitable areas from the road network and the water resources. The final product consists of maps of land suitability for grazing, distinguished according to the categories of animals considered, on the basis of the specific behavioural characteristics and the grazing season. The result obtained represents the current picture of the areas potentially destined for domestic animal grazing. From this, it is possible above all to verify the grazing areas in terms of extension and spatial distribution, as well as the dispersion in the territory of the park of these areas and their vicinity to secondary roads.



**Fig. 3.** Map of best grazing areas for sheep and cattle, spring-summer seasons (case A2).  
 Source: Own study.



**Fig. 4.** Distribution of the most suitable grazing areas according to classes of 500 ha and to the different land cover types.  
 Source: Own study.

## Discussions and Conclusions

The work was directed above all towards creating an open model, that could be updated and adapted to the real needs of planning in the park and that, given the necessity of a multidisciplinary approach, could interact with data and studies concerning different scientific fields.

The validity and efficacy of the adaptive methods of planning much depend on the availability of up to date, reliable, homogeneous and publicly accessible data. In fact, not always, and not all the data and information needed for territorial analysis are available and have the desired characteristics. On one hand, this compels the need for the model to be flexible for an immediate application following a simplified modality. On the other hand, it stresses the pressing demand on the management bodies of the territory to set up data banks and land information systems, suitably structured and accessible, side by side with sufficiently detailed and up to date thematic maps.

With the application to the case study, it has been possible to check the effectiveness of the model with respect to the set objectives. It has allowed pinpointing the grazing areas on the basis of a transparent procedure in all the stages of evaluation, likewise permitting the repetition of the evaluation operations when these did not prove fully satisfactory at first. It is precisely this transparency and traceability of the evaluation processes, together with the availability and accessibility of territorial data, that constitute the initial condition for democratic and participatory planning, and thus for consultation and "negotiability" of the choices.

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