



THE "CARTA DELLA NATURA" MAPPING PROJECT IN THE SUPRAMONTE AREA (CENTRAL-EAST SARDINIA)

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ABSTRACT - Since 1991, the Italian framework law on protected areas, has been calling for the editing of a national Nature Map, an instrument for the assessment of the state of the environment in Italy. The methodology applied in Sardinia is comparable with those applied in the other regions of Italy, with the necessary modifications, generalizations and integrations. Satellite imagery represents the fundamental informative layer to provide a synoptic view of the whole territory. In a second proceeding step, supervised classification is thematically enhanced by using logical niche models of species and habitats derived from assessed relationships between species-habitats known distributions patterns and available predictors, i.e. GIS thematic layers. This has resulted in the production of a habitat map with 24 habitat and land use classes. The environmental assessment procedure delivered four maps, the ecological value, the environmental sensitivity, the anthropic pressure and the land vulnerability (fragility). A reduction from 70 to 24 habitat/land use types, is coherent with the aims of the projects and planned deliverables. These 24 classes have been detected with semi-automatic procedures and with a high level of reliability. It is a reasonable compromise between thematic resolution and the possibility to record a synoptic view of the whole land in an acceptable lap of time. Various stakeholders will benefit from knowing the current condition of habitats distribution. Described deliverables are powerful tools for monitoring at regional level future land-use and habitat changes on a solid quantitative basis, for environmental conservation and habitat management.

KEY WORDS - Nature Map (Carta della Natura), Sardinia, CORINE Biotopes, Remote sensing, Ecological assessment.

INTRODUCTION

Since 1991, the Italian framework law on protected areas, i.e. the Law 6th December 1991, no. 394, has been calling for the editing of a national "Carta della Natura" (Nature Map), i.e. a map document on the national environmental resources and, therefore, an instrument for the assessment of the state of the environment in Italy. The Nature Map is presently under development in Italy. It will provide an analysis of all the main natural features in the whole country (not only in protected areas) and will help in identify vulnerable areas and threats to biodiversity

conservation. On the basis of that legal commitment, the governmental agency APAT (Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici) located in Rome, Italy, has established a national network, with regional focal points responsible for the remote-sensing/Geographical Information System/mapping project. From the original legislation provision of a simple map, the project has necessarily moved toward a more updated and useful concept of cartography as an integrated science merging different geomatic tools and techniques. The Regional Government of Sardinia, more precisely the Department for Nature Conservation (see acknowledg-

ments section for more detailed information) has appointed the University of Sassari, notably the Department of Botany and Plant Ecology, to lead the development of the GIS/mapping project in Sardinia. A few previous studies have dealt with the applications of geomatic tools to the territory of Sardinia for habitat/vegetation or land-use mapping, but they were generally concentrated to local areas (Brundu *et al.*, 1998; Brundu and Camarda, 2005) or to the whole territory of the islands at a medium to low scale. Therefore this is the first project that will apply the same methodology over the whole regional territory, with a resolution of 1:50,000 and, for some local areas, even more detailed. The methodology applied and the main results achieved in the first test area (central-east Sardinia) are herewith described.

MATERIAL AND METHODS

The study area, rectangular shaped and sized 21.5 x 17.0 km, is located in central-east Sardinia (central UTM ED50 coordinates, 32 T 530000, 4448700, Figure 1 left-side). It covers the limestone mountain area called "Supramontes" and the surrounding land in the districts of Urzulei, Orgosolo, Dorgali and Oliena, over a land surface of about 310 km².

This sub region has been accurately studied in the past by several Authors (e.g. Camarda, 1977; Arrigoni *et al.*, 1990; Arrigoni and Di Tommaso, 1991; Arrigoni, 1996). It's a very peculiar mountain system with important biodiversity and landscape values, hosting one of the best preserved climatic *Quercus ilex* L. forest in the Mediterranean basin. As a matter of fact it is under legislation protection by the institution of a National Park and of a few Sites of European Interest (Dir. 93/42/EEC).

The methodology applied to the Sardinian study area is comparable with those applied in the other regions of the Italian territory (APAT, 2003; 2004; Amadei *et al.*, 2004), with the necessary modifications, generalizations and integrations, to fit with the regional peculiarities in terms of vegetation typologies and land use classes. The project legend for habitat classification follows the CORINE Biotopes

Manual (Commission of the European Communities, 1991), *i.e.* the original project for the description of sites of importance for nature conservation in Europe. One-to-one conversions between CORINE classification and other Europe wide projects (e.g. EUNIS, see Pinborg 1998) are generally feasible.

Satellite imagery (Landsat Thematic Mapper data, acquired during 2000) represents the fundamental informative layer to provide a synoptic view of the whole territory at a single to few given dates. Landsat imagery has several advantages for regional-scale studies. First, with more than 30 years of Earth imaging, it offers the longest-running time series of systematically collected remote sensing data (Cohen and Goward, 2004; Röder *et al.*, 2005). Second, the spatial resolution facilitates characterization of land cover and cover change associated with the grain of land management. (Cohen and Goward, 2004).

The classification methodology (*i.e.* supervised classification, maximum likelihood) basically uses spectral features of the data (after radiometric and geometric correction) and 600 ground control check areas, acquired by GPS positioning in the field (*i.e.* approximately one each 0.5 square kilometres). The ground control areas has been selected with a surface usually larger than 2 hectares, as more uniform as possible, representative of the main habitat types, and, whenever possible, floristic field surveys have been recorded in representative plots inside the control areas. A further assessment of ground truth data reliability has been performed using digital colour orthophotographs (1:10,000 scale, Volo Italia IT 2000, taken during the "Terraitaly 1998-99" flight, CGR Parma, Italy). Nevertheless, before applying supervised algorithms, the selected reference image is classified using an unsupervised clustering (ISODATA) algorithm in order to facilitate the choice of the training areas for the supervised classification.

Finally, in a second proceeding step, classification is thematically enhanced by using logical niche models of species and habitats derived from assessed relationships between species-habitats known

distributions patterns and available predictors, *i.e.* GIS thematic layers such as digital terrain model (DTM) and derived layers (slope, aspect), soil types, geology and land-use. The model is implemented in the spatial modeller environment of ERDAS Imagine (2003) and the thematic layers are combined by means of consecutive conditional statements. Nevertheless, for small habitat not detectable due to thematic, radiometric or geometrical resolution of the available data set, the precise border of the habitat – as polygon feature - (recorded in the field using GPS or digitized/verified on digital orthophotographs) was used to implement the full model. This is especially the case of small linear-shaped habitats such as peculiar form of riparian vegetation, and vegetation of limestone “falesias” (with a very high degree of sloppiness).

The third operational step concerns the procedures for map validation and map editing. The precision of the habitat map derived by the first two steps has been verified in the field, and using the aerial orthophotographs. Therefore the necessary corrections and integrations have been applied to the model. Map editing can be described as routine operations for generalisation of the map, according to the project scale, such as filtering toward a defined resolution, smoothing polygon borders, removing “noise” polygons (with surface less than 0.5 hectares) that are not useful for the general interpretation of the study area (usually applied after conversion of all

the data-set into raster format).

The final fourth step is the assessment procedure that is performed on each mapped habitat through a number of independent indicators. Validity and robustness of the model is guaranteed by the choice of indicators on which there seems to be a general agreement on the most updated scientific literature. The ecological value, the environmental sensitivity, the anthropic pressure and the land vulnerability (fragility) have been assessed for the study area according to APAT methodology (APAT 2003, 2004).

Data processing has been performed using Erdas Imagine 8.6 and ESRI ArcGis 9.2 software on windows platform (Fig. 1).

RESULTS

Seventy main vegetation typologies are present in the study area and are detectable by field survey using floristic and physiognomic descriptors (Camarda, pers. obs.). These 70 typologies, with the unavoidable required generalisation, might be enclosed in 50 habitats (biotopes) according to the CORINE Biotopes legend. As a matter of fact, there is a clear need to simplify the local diversity patchiness according to the project scale (1:50,000), and to adapt the CORINE biotopes legend to the local situation and to the general standards applied for the whole Italian territory by APAT. Twenty-three over fifty are habitat types of European interest (according to Annex

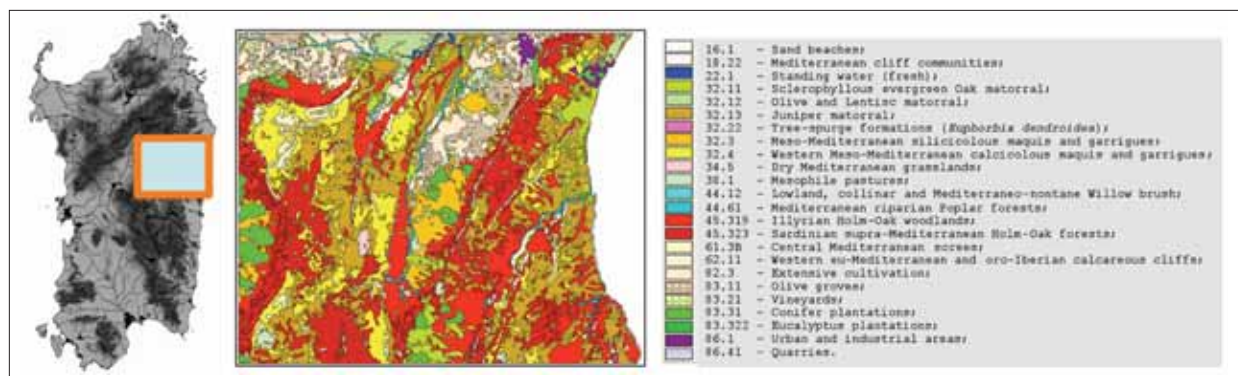


FIGURE 1. On the left, location of the study area in the central-east Sardinia. On the right, the habitat map for the study area and the legend with the mapped habitats.

I of the Directive 92/43/EEC, as amended by the following legislation). A sub-set of the Annex I habitat types are defined as being “priority” because they are considered to be particularly vulnerable and are mainly, or exclusively, found within the European Union (Article 1d). The importance of these priority habitat types is emphasised at several places in the Directive (Articles 4 and 5 and Annex III), not only in terms of the selection of sites, but also in the measures required for site protection (Article 6) and surveillance (Article 11).

Finally, the geomatic methodology applied in the study area, notably the image supervised classification as enhanced by modelling, on ERDAS/ArcGIS platform, has resulted in the production of a habitat map with 24 habitat and land use types (Figure 1 and 2).

The most abundant habitat types in the study area are *Q. ilex* forest types (45.319 and 45.323 CORINE codes), covering a total surface of about 10,500 ha (about 36% of the study area), in particular the thermo-Mediterranean and supra-Mediterranean *Q.*

ilex forest, i.e. *Pistacio-Quercetum ilicis* s.l. and *Aceri-monspessulani-Quercetum ilicis* (Figure 2 and Figure 3) that are known to characterize this mountain area of Sardinia (Arrigoni *et al.*, 1990; Arrigoni and Di Tommaso, 1991; Arrigoni, 1996). Due to the availability of digital data, with number and size of detected polygons inside one mapping category, software tools such as patch analyst (ArcView extension) give the possibility to evaluate landscape metrics indicators such as fragmentation. The two habitat types for *Q. ilex* forest are composed by 505 polygons. They have a very similar spectral behavior (also in multi-temporal Landsat TM imagery, see Brundu and Camarda, 2005) with only slight differences at Landsat TM bands 1, 4 and 6 (Figure 3), which are not suitable for a precise discrimination that has therefore been possible only after using an adequate niche model, DTM based (elevation, aspect).

A second very important and abundant habitat type in the study area is *Juniperus phoenicea* and *J. oxycedrus* matorral (32.13 code), covering 20% of the mapped area with 341 polygons. This is followed by garigues and shrublands on limestone areas (32.4)

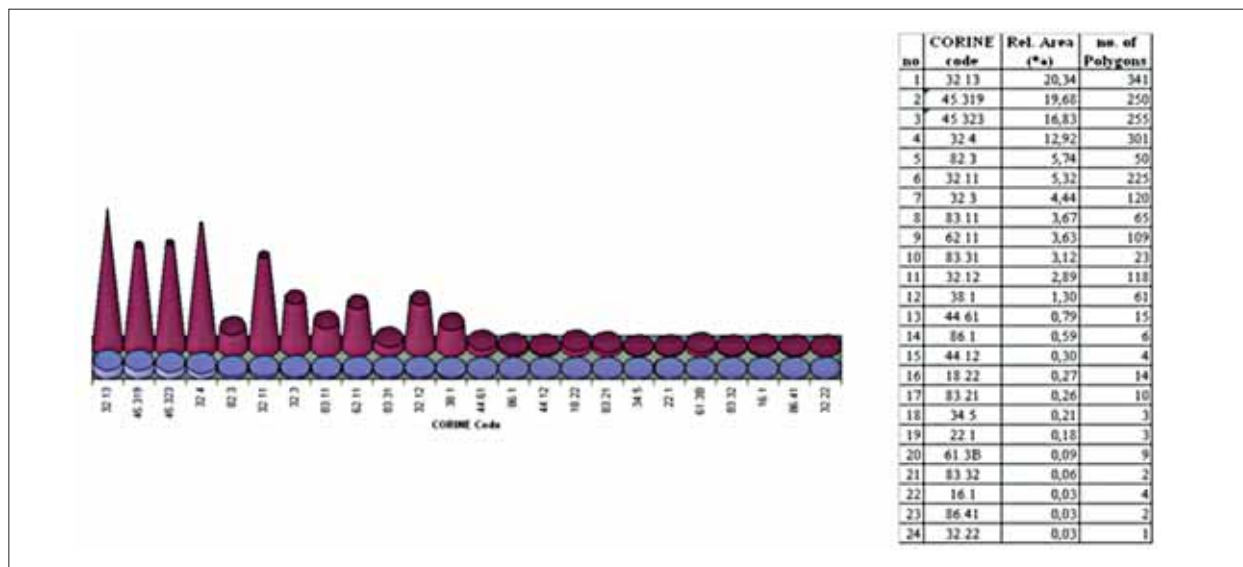


FIGURE 2. Relative abundance of the 24 habitat/land use types detected in the Sardinian study area. The graph shows in blue the percentage cover of each typology and in purple the number of polygons detected for each typology. Data are also presented in the table on the right.

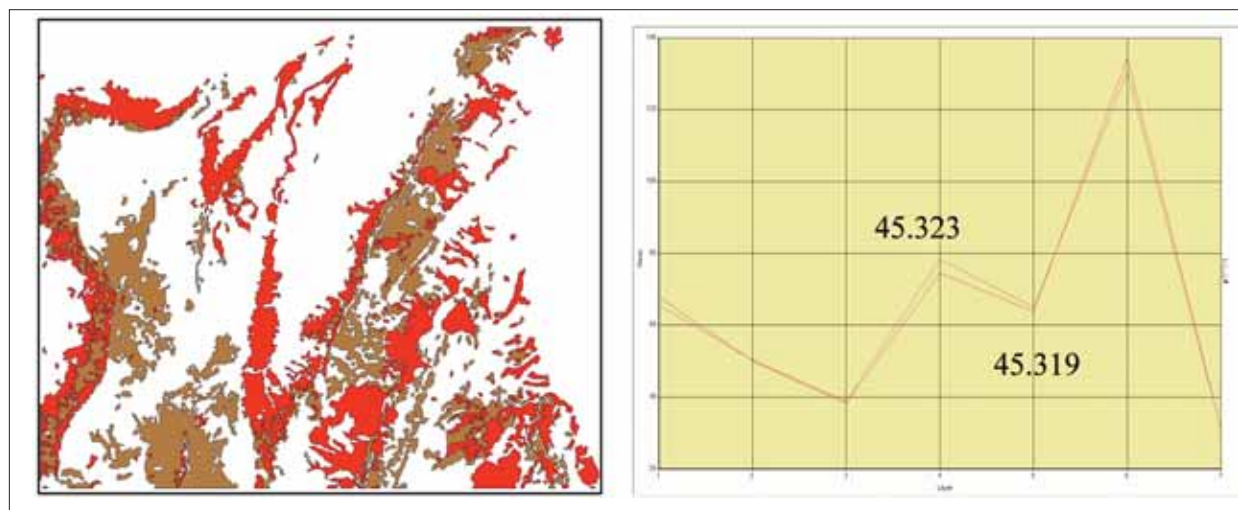


FIGURE 3. On the left, the map with the distribution of the two main types of *Q. ilex* forest (*Pistacio-Quercetum ilicis* s.l. – in red - and *Acri-monspensulani-Quercetum ilici* – in light brown). On the right the Landsat TM spectral signature of the training areas for the two *Q. ilex* forest types (CORINE Biotopes codes are reported).

covering the 13% of the land (301 polygons), enclosing, as already remarked, different vegetation types, such as garigues with *Santolina insularis* (Genn. ex Fiori) Arrigoni and dwarf shrubs, garigues with *Ephedra major* Host., garigues with *Genista corsica* (Loisel.) DC and *Thymus catharinae* Camarda, but here-with treated as a whole.

Additionally, during the field surveys in the study area, 82 remarkable species have been recorded, as being endemic, rare or phytogeographically relevant.

The environmental assessment procedure described in the methods section, delivered four original thematic maps for the study area, *i.e.* the ecological value, the environmental sensitivity, the anthropic pressure and the land vulnerability (fragility) (Figure 4).

DISCUSSION AND CONCLUSIONS

The application of the described methodology required a simplified description of the natural actual vegetation, which is, nevertheless a drawback implicit in any modeling procedure applied to environmental systems. There are clear project constraints. Using a European level vegetation legend (CORINE

Biotopes) imply, from one hand, the possibility of useful and meaningful comparison between different geographical regions, but, from the other, unavoidable sharp generalizations. Radiometric (spectral), geometric and temporal resolution of Landsat TM imagery, and of the available GIS thematic layers for modeling, are other important constraints that necessarily imply a generalized interpretation of the vegetation mosaic. Nevertheless a reduction from 70 to 24 habitat/land use types is coherent with the aims of the projects and planned deliverables. It must also be remarked that these 24 typologies have been detected with semi-automatic procedures and with a remarkable level of reliability. This methodology, after being tested on the study area as herewith described, is being extended to the whole island (24,000 km²), expecting to complete the mapping of the whole territory of Sardinia by 2008. It is a reasonable compromise between study thematic resolution and the possibility to record a synoptic view of the whole land in an acceptable lap of time. Various stakeholders, and first of all – the Regional environmental Authority - will benefit from knowing the current condition of habitats distribution and covering. The Nature Map, the GIS informative layers, and the eval-

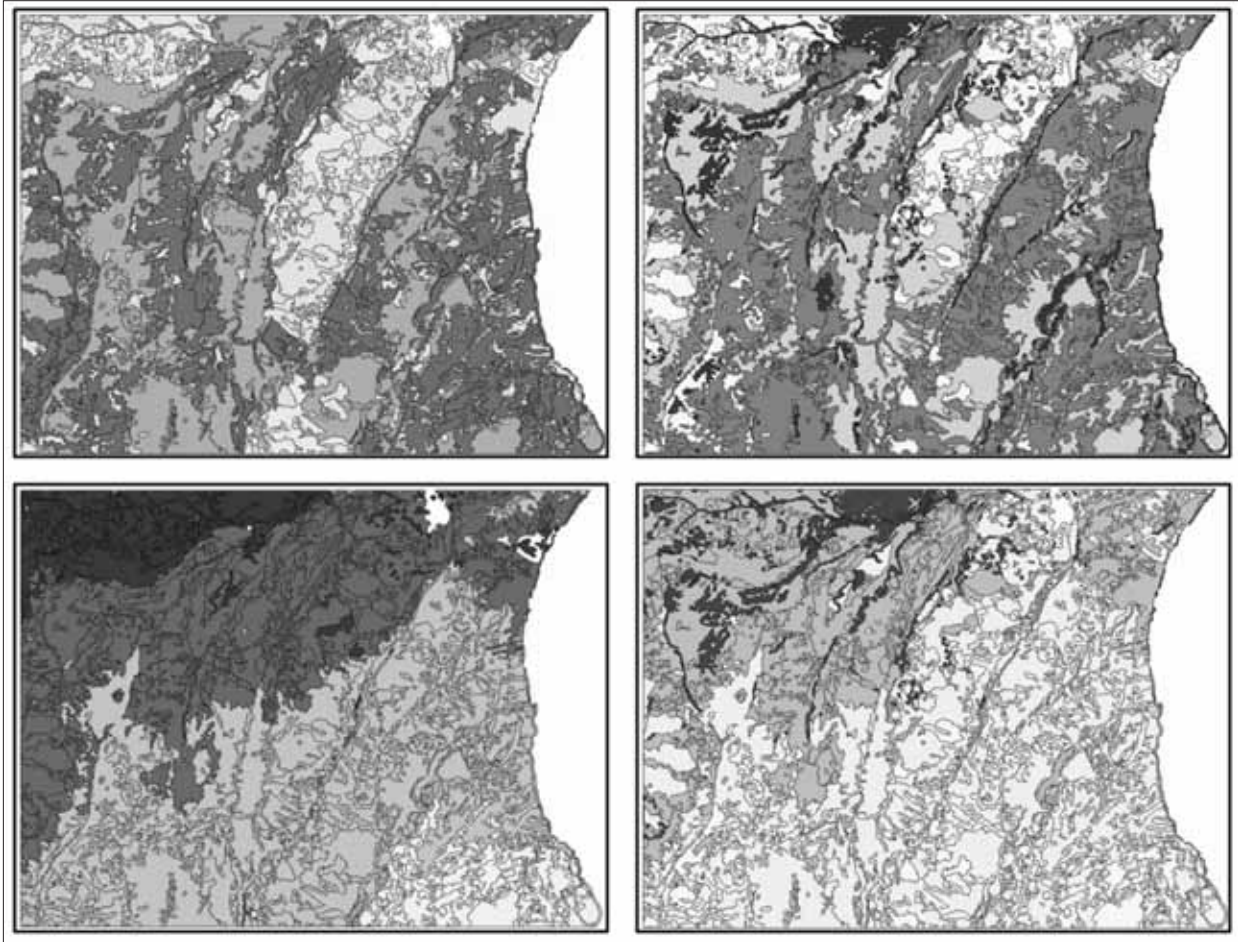


FIGURE 4. Clock-wise from right-top corner, ecological value, environmental sensitivity, anthropic pressure and land vulnerability (fragility) maps for the Sardinian study area.

uation maps are powerful tools for monitoring at regional level future land-use and habitat changes on a solid quantitative basis, for environmental conservation and habitat management.

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RIASSUNTO

Il presente studio descrive la metodologia di realizzazione ed i primi risultati del progetto "Carta della Natura" in un'area di circa 310 kmq nella Sardegna centro-orientale. Per la realizzazione di tale carta è

stata applicata la metodologia APAT, con le necessarie modifiche ed integrazioni, che si basa, in primo luogo sull'elaborazione di immagini tele-rilevate a partire dall'individuazione delle firme spettrali caratteristiche di ciascun habitat. La classificazione "supervised" è stata perfezionata utilizzando modelli di nicchia. Oltre alla carta degli habitat, nella quale sono stati cartografate 24 tipologie di Habitat/land use, sono state realizzate 4 carte tematiche derivate relative a: valenza ecologica, fragilità, sensibilità ecologica e pressione antropica. Attualmente è in fase di realizzazione la cartografia della natura dell'intero territorio regionale.

Le carte prodotte, oltre a fornire importanti informazioni sulle tipologie di habitat presenti, sulla loro distribuzione e sul loro stato di conservazione, in assenza di una carta regionale della vegetazione reale, rappresentano un importante strumento per la programmazione la gestione del territorio ed il monitoraggio in campo ambientale.

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