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# Landscape Typology in the Mediterranean context: A tool for habitat restoration

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## Abstract

Despite the wide use of Landscape Character Assessment (LCA) as a tool for landscape planning in NW Europe, there are few examples of its application in the Mediterranean. This paper reports on the results from the development of a typology for LCA in a study area of northern Sardinia, Italy to provide a spatial framework for the analysis of current patterns of cork oak distribution and future restoration of this habitat. Landscape units were derived from a visual interpretation of map data stored within a GIS describing the physical and cultural characteristics of the study area. The units were subsequently grouped into Landscape Types according to the similarity of shared attributes using Two Way Indicator Species Analysis (TWINSPAN). The preliminary results showed that the methodology classified distinct Landscape Types but, based on field observations, there is a need for further refinement of the classification. The distribution and properties of two main cork oak habitats types was examined within the identified Landscape Types namely woodlands and wood pastures using Patch Analyst. The results show very clearly a correspondence between the distribution of cork oak pastures and cork oak woodland and landscape types. This forms the basis of the development of strategies for the maintenance, restoration and recreation of these habitat types within the study area, ultimately for the whole island of Sardinia. Future work is required to improve the landscape characterisation , particularly with respect to cultural factors, and to determine the validity of the landscape spatial framework for the analysis of cork oak distribution as part of a programme of habitat restoration and re-creation.

## Introduction

Landscape is an expression of the complex interrelationship between nature and culture over time and provides the basis for the integrated and sustainable management of natural resources. The need to protect valuable natural and cultural landscapes has been previously recognised by the IUCN and UNESCO (Pinto-Correia *et al.* 2002) and has been introduced into the European Policy and Research agenda with the Pan European Biodiversity and Landscape Strategy (1996) and the European Landscape Convention (Council of Europe 2000).

There is increasing recognition that the spatial structure of landscape elements is a factor of critical significance in determining biodiversity (Gergel & Turner 2001) and achieving sustainable development (Wrbka *et al.* 2002). This is also highlighted by recent European legislation (Council of Europe 2000) which now considers the conservation status of the wider countryside, including both its biological and landscape diversity. The rapid changes of the 20th century and growing concern about their impact on the quality of the countryside has led to a renewed interest in, firstly, the inventory of land cover and land use and, secondly, mapping and understanding landscapes.

Mediterranean landscapes have been shaped by a high degree of natural disturbance (Archibold, 1995; Allen, 2001) and the early impact of humans which continues to the present (Allen 2003). This has not only resulted in a high diversity of landscapes but also a gradient of human impacts from severe to light and a range of potential threat. There are still relict relatively undisturbed natural landscapes where agriculture is constrained due to physiography/topography (Rossi and Vos 1993 and traditional, primarily subsistence agricultural landscapes (Pinto-Correia, 2000; Green and Vos 2001) that are of high conservation value (e.g. Correia and Freitas

2002; Selmi and Boulinier 2003). By contrast, there are also extensive areas of stressed landscapes comprising large-scale agriculture with an increasingly intensive land use (Rackham and Moody 1996).

In recent years these landscapes have seen more changes including intensification or extensification of agricultural systems, urbanisation, tourism, pollution and the introduction of alien species (Di Castri, 1981; Cowling *et al.*, 1996; Archibold, 1995). The intensity of these impacts is dictated by socio-economic factors such as population growth and rural depopulation, agricultural subsidies, forestry, agricultural products and tourism (Naveh 1998). Some of these impacts are affecting traditional wooded landscapes of Southern Europe, for example the agro-silvopastoral landscapes of cork oak in Sardinia. These diverse and heterogeneous landscapes have great ecological, cultural and socio-economic value (Commission of the European Communities, 1997).

The measurement of the impact of land use change, and other forms of development on the biota of the Mediterranean, needs to be assessed within an appropriate spatial framework that captures underlying differences in the physical and cultural environment. One such framework is 'landscape character' (Swanwick & Land Use Consultants, 2002), currently being developed and applied in England for a range of applications including the setting of targets for habitat restoration and species recovery.

Landscape character assessment is an hierarchical spatial framework that incorporates both the physical and cultural dimensions of landscape. This framework is established, usually as part of a GIS database, within which it is possible, for example, to derive measurement of change, indices of sustainability and ecological quality and to develop options for future landscapes within specific landscape types. The development of landscape character assessment/mapping has been facilitated by the use of GIS as a decision support tool. This technology provides significantly increased opportunities for more detailed environmental resource inventory and analysis in space and time and shows considerable promise for nature conservation (Gergel and Turner 2001).

At the start of the 21st century, Landscape Character Assessment (LCA) is maturing as the primary tool for classifying, describing and evaluating landscapes to support decision making about the future direction of the countryside. LCA draws on data from existing published sources, field survey information and the input of stakeholders to identify and describe areas of common character. Landscape character assessment can operate at multiple scales, from regional, to national (Swanwick and Land Use Consultants 2002) and European level (Washer and Jongman 2003) and can be employed for both socio-economic (Schmitz *et al.* 2003) and conservation purposes (Lesley 2001).

The concurrent development of Geographical Information Systems (GIS) technology has facilitated the storage, retrieval, analysis and display of map-based data that is central to Landscape Character Assessment. An approach that exhibits potential for biodiversity assessment is Landscape Character Mapping. The rationale behind landscape character mapping is that particular combinations of physical and cultural factors occurring in different areas result in similar landscapes. The approach is based on a series of natural (i.e. landform, geology, soils) and cultural factors (i.e. land use, settlement pattern) that are used to describe the variability in the landscape at various spatial scales depending on the research scope.

Landscape assessment in Europe has a long history and has been applied at national (Griffiths *et al.* 2004) but also at European level (Meuus 1995; Washer and Jongman 2003). Despite its wide use in NW Europe as a tool for landscape planning, landscape typology has found limited application in the Mediterranean. Exceptions include Portugal (Pinto-Correia, *et al.* 2002), Spain (Mata and Sanz 2003) and Italy (Ministry of Environment 2003).

In the light of the above the aim of this paper is to test the validity of landscape character mapping as an appropriate spatial framework for ecological monitoring in the Mediterranean.

The specific objectives are to:

- identify distinct Landscape Types within a pilot area in Sardinia
- determine the habitat potential of each Landscape Type for supporting cork oak.

Cork oak habitats in Sardinia cork cover a total surface area of c.200,000 ha, including woodlands and wooded pastures (Boni, 1994). These habitats have had historically a major role in the socio-ecomomic development of the island (Ruju 2002) and are invaluable in terms of nature conservation. Currently some of these habitats in Sardinia are protected under Regional Parks or Natura 2000 sites but are at the same time increasingly under pressure (Vogiatzakis *et al.* 2005).

## Materials and Methods

### *Study area*

The study area is located at North Sardinia (Figure 1). The size is c.50 x 50 km with an elevation range from sea level to 1300m. It stretches west-east from Sassari to Olbia. It extends to the mountain massif Monti Limbara in the north and Monti di Alà in the south and includes the lake of Coghinas. The geology is diverse ranging from recent Quaternary alluvial deposits to Hercynian intrusive rocks. Rock outcrops dominate and soils are generally thin. There is a diverse range of landscape types, which in turn result in diversity of habitat types. These include various types of even and uneven mixed forests and wooded pastures where *Quercus suber* can be the


Figure 1. Sardinia and the study area.

dominant tree or as a mixture with, for example, *Quercus ilex* and *Olea europea*. The area includes two Natura 2000 sites *Monte Limbara* (16308 ha), and *Campo di Ozieri e Pianure Comprese tra Tula e Oschiri* (31611ha) and a part of *Catena del Margine e Goceano* (36563 ha).

**Datasets**

*Elevation, Geology and Soils*

The elevation map of the study was derived from a Digital Terrain Model of Sardinia with a pixel size of 90 x 90m (SRTM DEM). The vector geology map consists of data extracted from the 1: 200 000 geological map of Sardinia (RAS 1996) while the vector map of the soils was digitised from the Soil Map of Sardinia (Aru *et al.*, 1990). For both maps data were stored in polygon format and associated databases. Soils were simplified according to differences in soil drainage and soil fertility resulting in five classes (Table 1). Moreover, the complexity of the area's geology needed to be simplified into meaningful categories for landscape character assessment (Table 1).

*Land Cover and Settlement Pattern*

Land cover, the expression of natural and man made vegetation in the study area was taken from the CORINE land cover map of Sardinia (Marini *et al.* 1993). The CORINE land cover map was used to derive the first cultural layer. The land cover classes in the study area were amalgamated in order to reflect the principal broad categories (post 1950): agricultural areas, agro-forestry areas, forested areas and urban areas. An additional cultural layer on settlement patterns in the study area was extracted from the AIMA aerial photographs (1:10 000 scale) with ancillary information from the 1: 50 000 topographic maps of IGMI. This layer provided information on the nature of settlements (urban, rural) as well as the spatial pattern of the settlements (clustered, nucleated etc). As a result five categories were employed as shown in Table 1. All the maps used in this study form a co-registered spatial database to the Gauss Boaga projection system.

*Landscape Character Mapping*

Landscape character mapping is hierarchical, based upon the successive sub-division of the mapped attributes. The landscape was divided first into physiographic units from contour and geological data. The resulting units were then further sub-divided by soil type and finally by cultural patterns to derive the building blocks of the system, the Landscape Description Unit (LDU). Figure 2 illustrates the general approach and shows how the physical and cultural attributes were successively combined to derive the LDUs. These units were subsequently amalgamated into Landscape Types with similar physical and cultural attributes using TWINSPAN analysis (Hill 1979). The classification was carried out using the PC-ORD for Windows program, version 4 (McCune & Mefford, 1999). The analysis used presence/absence data for 26 variables (Table 1) with the following initial parameters: the maximum number of indicators per division was 2, the maximum level of division was 4 and the minimum group size for division was 10. The classification was stopped at the third level of division, resulting in eight groups containing a sufficient number of units to characterize existing landscape types. The results of the classification were then mapped into a GIS to produce a map of Landscape Types (Figure 3).

*Fieldwork*

Extensive fieldwork was carried out in July 2004 in the study area in order to evaluate the results of the developed typology and produced map. Validation plots were sampled in proportion to the area occupied by each landscape type. 43 sampling points were collected and their characteristics

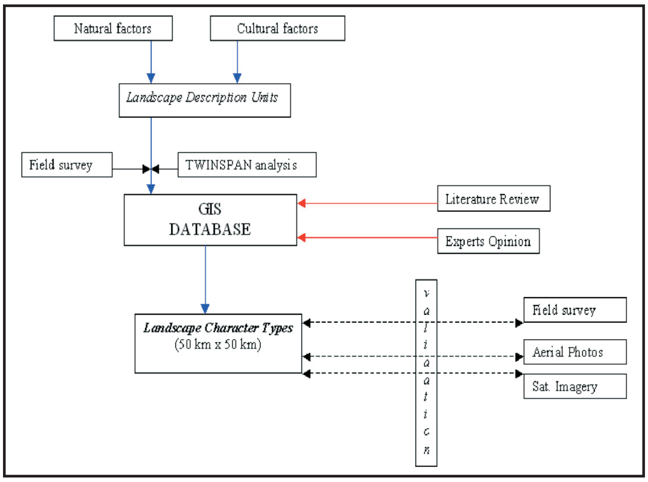


Figure 2. Flow diagram of the methodology employed.

Table 1. Physical and Cultural Attributes used for Landscape Character Mapping

| Landform | Geology | Soils | Land Cover | Settlement Pattern |
|---|---|---|---|---|
| Steep upland terrain | Quaternary deposits | Overdrained infertile soils | Woodland | Absence of Settlement |
| Rolling hills | Pliocene-Pleistocene alkaline sub-alkaline deposits | Deep well drained soils | Agriculture | Nucleated |
| Steep hills | Tertiary Marine Sedimentary Deposits | Deep poorly drained soils | Agrosilvopastoral | Clustered |
| Valley bottoms | Tertiary Continental Sedimentary Deposits | Shallow soils | Urban areas | Dispersed |
| | Oligocene-Miocene calcalkaline volcanic deposits | Mixed soils | | Industrial or Urban Fabric |
| | Carbonatic and Dolomitic shelf Deposits | | | |
| | Late Hercynian intrusive complex | | | |
| | Metamorphic complex | | | |

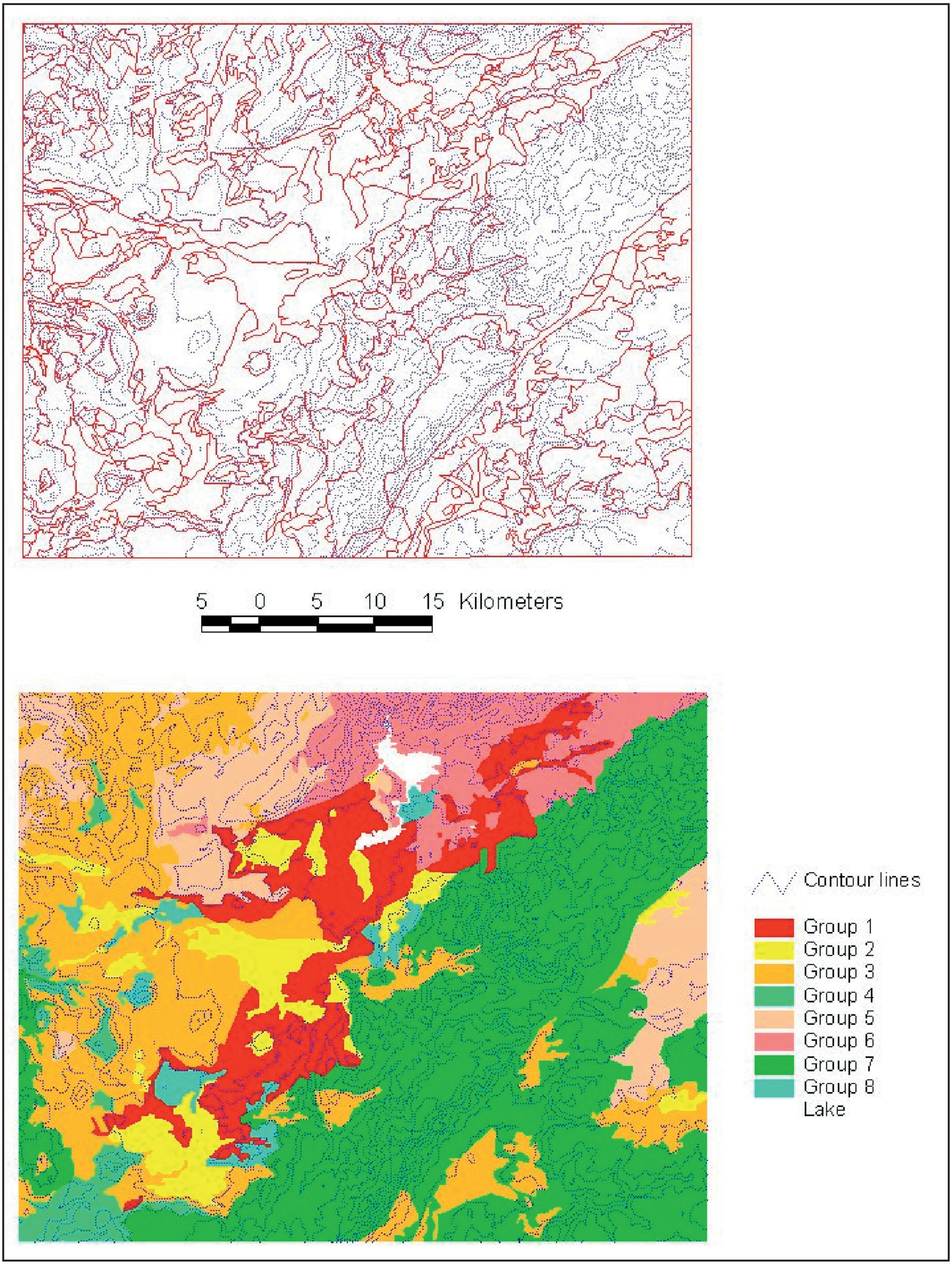


Figure 3. From Land Description Units (LDUs) to Landscape Types.

according to the existing maps were recorded. Their geographical position was determined using a GPS. Other on-site observations included principal land cover, geology and any visible impacts (e.g. fire, overgrazing).

*Habitat Analysis*

In order to investigate the relationship between landscape type and the distribution of cork oak habitat types, their extent within the mapped Landscape Character Types was analysed. For this purpose the Forest Map of Sardinia was used (Barneschi 1988), an important source of information for the distribution of cork oak on the island. The vegetation map includes a detailed typology for the various vegetation formations/habitats where Quercus suber is present. Therefore, for simplicity, all cork oak habitats were re-classified into two main classes: cork oak woodland and cork oak wood pasture. The total area, the number of patches and the mean patch size of these two broad habitat types within each Landscape Character Type were then calculated using patch analyst within ArcView GIS (Table 3).

## Results

### *Classification*

The end product of the subdivision of these attributes was a map of 236 homogeneous landscape units (LDUs) as shown in Figure 3. These were then classified using TWINSPAN analysis resulting in eight groups containing a sufficient number of units to characterize existing landscape types:

- Group 1: These landscape units occupying valleys of the study area, on continental sedimentary deposits or calcalkaline volcanic deposits (Oligocene and Miocene) predominantly mixed soils where agriculture is the main cover type with a variety of settlement patterns.
- Group 2: These units are found on valleys mainly on alkaline sub-alkaline or Quaternary deposits mainly shallow soils, with intense agriculture activity and nucleated settlement pattern.
- Group 3: Units on rolling hills mainly on Tertiary sedimentary deposits or Oligocene and Miocene calcalkaline volcanic deposits. Soils are shallow, agriculture is the main landcover type and settlements appear in clusters.
- Group 4: Also found on rolling hills on alkaline sub-alkaline deposits (Pliocene-Pleistocene). The soils are mostly shallow covered by woodlands or agriculture while settlements are absent.
- Group 5: Units on rolling hills on calcalkaline volcanic deposits (Oligocene and Miocene), with mixed soils, predominantly agrosilvopastoral activity and dispersed or absent settlements.
- Group 6: Found on steep hills or valleys these units appear mainly on late Hercynian intrusive complex and some on tertiary continental sedimentary deposits. The soils are mixed the landcover is either woodlands or agroforestry while settlements are absent.
- Group 7: These units on upland terrain, on calcalkaline volcanic deposits (Oligocene Miocene) or late hercynian intrusive complex have shallow soils, and are characterised by woodlands and the absence of settlements.
- Group 8: Units on valleys overlaying alkaline sub-alkaline deposits (Pliocene-Pleistocene) or calcalkaline volcanic deposits (Oligocene-Miocene). The soils are shallow while

Table 2 Short description of the Landscape Types in the study area

| Landscape Type | Short description | TWINSPAN Groups |
|---|---|---|
| 1 | Agricultural non-populated landscapes | 1+3 |
| 2 | agricultural populated landscapes | 2 |
| 3 | Non-populated mosaic landscape of woodlands and agriculture | 4 |
| 4 | Agrosilvopastoral landscapes non-populated on alkaline deposits | 5 |
| 5 | Non-populated lowland wooded landscapes on intrusive rocks | 6a |
| 6 | Non-populated agroforestry landscapes on sedimentary deposits | 6b |
| 7 | Non-populated upland wooded landscapes on intrusive rocks | 7 |
| 8 | Non-populated lowland wooded landscapes on alkaline deposits | 8 |

Table 3 Examined habitat size attributes within Landscape Types

| | Woodlands | | | Wood Pastures | | |
|---|---|---|---|---|---|---|
| Landscape Type (LT) | % area within LT | Mean patch size (ha) within LT | No of patches within LT | % area within LT | Mean patch size within LT | No of patches within LT |
| 1 | 57 | 260 | 405 | 12 | 155 | 143 |
| 2 | 90 | 171 | 88 | 22 | 72 | 51 |
| 3 | 7 | 35 | 15 | 0 | 0 | 0 |
| 4 | 58 | 99 | 156 | 22 | 51 | 116 |
| 5 | 84 | 54 | 153 | 0 | 0 | 0 |
| 6 | 112* | 67 | 68 | 29 | 46 | 182 |
| 7 | 30 | 110 | 269 | 14 | 51 | 272 |
| 8 | 103* | 107 | 50 | 35 | 107 | 17 |

*over 100% indicates the presence of patches which extends beyond the border of the landscape type. See text for discussion woodland is the predominant cover type and settlements are absent.

However, work in the field showed that groups 1 and 3 as identified by TWINSPAN refer to the same landscape character therefore were amalgamated into one type. Moreover, group 6 as derived from TWINSPAN was split into two landscape types displaying distinct differences in land cover and physiography. This resulted in 8 Landscape Types (Table 2).

*Habitats and landscape types*

Although cork oak woodland and wood pasture habitats in Landscape Type 1 occupy a relatively small area (Table 3) they have the largest mean habitat size compared to the other groups and the largest number of patches. There is no cork oak wood pasture and only a small area of cork oak woodland in Landscape Types 3 and 5. Woodland mean patch size is also the smallest for these landscape types group. Of all the types identified cork oak woodlands occupy the largest area in Landscape Types 6 and 8. In these two groups the presence of patches that extend beyond their boundaries which were counted by the software as wholly belonging to them resulted in extremely high percentage value (Table 3). In Landscape Type 7 the number of patches for the two habitat types are almost equal whereas n Landscape Type 8 the mean patch size is the same for both woodlands and wood pastures. Landscape Types 6 and 8 are the ones where the percentage of cork oak wood pastures is relatively high if compared to other landscape types 29% and 35% respectively (Table 3).

These results show very clearly a correspondence between the distribution of cork oak pastures and cork oak woodland and landscape types. This forms the basis of the development of strategies for the maintenance, restoration and recreation of these habitat types within the study area, ultimately for the whole island of Sardinia.

**Discussion**

The landscape character approach has the potential to be used for ecological monitoring in the Mediterranean but also other regions in the world where human impact has been very high. So far the only study on the landscapes of Sardinia (Aru *et al.* 1991) resulted in a fairly descriptive typology of a regional scale mainly based on rock types with limited information on morphology and land cover and little emphasis placed on cultural elements. However, in Sardinia, as everywhere in the Mediterranean Basin, the long presence of human has been of vital importance in shaping the landscape. This is also evident for the existing cork oak habitats in Sardinia which reflect differences in physical (e.g. geology) and cultural (e.g. land-use) factors.

In this case study the preliminary results showed that the methodology employed classified the range of landscape types characterising the study area. For example, Landscape Type 7 corresponds to the wooded landscapes on the intrusive rocks of Monti di Ala while Landscape Type 1 corresponds to the agricultural landscapes on the plain between Oschiri and Ozieri. However, some of the proposed groups as derived from TWINSPAN, for example group 6 were too broad and therefore needed further subdivision in order to be assigned to ecologically meaningful Landscape Types (Table 2).

Landscape classifications are descriptive and intentionally subjective. Statistical procedures are commonly employed to determine the rules to decide between classes in order to produce repeatable results with minimal personal bias. For example clustering techniques have been applied at the global level for developing coastal typologies (LOICZ 1998) while TWINSPAN and its predecessor, Indicator Species Analysis, has been widely used for environmental and landscape classification at various scales (Bunce *et al.* 1996; Bunce 2001). The discrepancies related to some landscape types identified in this study may be due to the use of TWINSPAN for the classification. Important decisions on the rules of the analysis and the groups' identification are subjective and rely on the user's knowledge and experience (Kent and Coker 1992). The key problems with this approach are misclassified LDUs which arise from the TWINSPAN method. There is no means within the method to correct these errors, without manually overriding the results of the classification. This is a weakness of the LDU Type classification and shows that further work is required to develop a robust classification of the LDUs. In this study the division between Groups 1 and 3 was artificial since work in the field demonstrated that these two types were similar. Therefore these two groups were treated as one (Table 2).

The LDU map (Figure 2) shows units of relatively uniform physical and cultural characteristics as interpreted from available regional datasets. Although this allows for consistent mapping, it is acknowledged that the resolution of the base map data may be insufficient to capture the full range of physical and cultural differences that characterise the Sardinian landscape. For example, the soil data is only available at 1:250 000 scale. This is insufficiently detailed for accurate mapping of variations in soil type at Level 2. Confusion arose due to the inclusion in the classification of areas where soils are "mixed" i.e. where, according to the map, the type incorporated two very different types, Cambisol and Leptisol into the same unit.

Although the mapping utilises layers of digital data within a GIS environment, the boundaries between units are interpreted visually. The lack of detail in the soil data combined with the uncertainty associated with mapping cultural features invariably means that boundaries are estimated with varying degrees of certainty. There is a need to develop data structures, beyond the simple polygon model currently employed that can describe this level of uncertainty, while still forming a usable spatial framework for landscape planning.

Although the importance of historical mapping is widely acknowledged for landscape character assessment the lack of detail is a common obstacle to these studies (e.g. Griffiths et al 2004; Washer and Jongman 2003). In this study it proved possible to map land cover and settlement pattern but, as Pungetti (1996) highlighted, other profound cultural features of the Sardinian landscape are also linked with land use patterns including, enclosed lands (the chiudende), the Nuraghi systems, the caves, the monasterial properties, big estates and medieval settlements. Some of these were linked with the exploitation of the cork oak and are also found in the study area. However, despite being clearly visible in the landscape many of these features, for example the chiudente patterns, are not easily distinguished from satellite imagery or aerial photographs. Climate is one of the common datasets used in landscape classification it is usually employed over large geographic areas (Wascher and Jongman 2003). However, the inclusion of climate at this level of study was not considered appropriate since the area was small and therefore climate did not display great variations.

Following the trend in other parts of southern Europe in the last fifty years cork oak habitats in Sardinia, have undergone major changes, mainly due to human factors (Vogiatzakis *et al.* 2005). These are related to agricultural practices (Vacca 2000; D'Angelo *et al.* 2001), grazing practices (Ruiu *et al.* 1995; Pampiro *et al.* 1991) and recently the impact of defoliator attacks (Sechi *et al.* 2002). Therefore developing tools for habitat restoration at a landscape scale is of utmost importance. An important aim of the project was to determine the habitat potential of each Landscape Type. In particular, a distinction was made between the character of a landscape unit and its current condition. Character refers to the physical and cultural attributes that characterize a landscape unit – differences, for example, in soil, geology, landform and land use. By contrast, condition, refers to the extent to which the typical ecological attributes of a landscape unit are present. Thus, where a landscape type is typified by extensive cork oak wood pasture in large patches, connected by stonewalls but much of that character has been eroded by agricultural intensification the unit is said to be in poor ecological condition.

Similar approaches have been successfully employed in the UK for Wales and the Chilterns (Griffiths *et al.* 2004; Lee et al 2001). This kind of analysis enables us evaluate this potential of a landscape type for a specific habitat, either for retention of the habitat restoration of former habitats and re-creation of new habitats. For example in Landscape Type 1 the woodlands should be retained since from the analysis it emerges that they have high mean patch size and large number of patches. In Landscape Type 7 where there is a smaller number of patches and a relative small patch size (Table 3) buffering and connection maybe more appropriate. It is more likely that there is a gradient of condition within each character type, from poor to optimal for a particular habitat, but this would require future work looking into difference within the units (LDUs) of each Landscape Type.

These indications have to be interpreted cautiously since the habitat data are derived from the Carta Forestale which is not up to date. Moreover, some discrepancies may arise during patch analysis mainly due to large usually patches extending beyond one Landscape Type and therefore measured twice. There is a need to focus on specific habitats rather than generic groups according to regional needs/policies. For example one of the habitat types, woodland in groups "Sugherete a gruppi" have a great importance for habitat restoration towards cork oak woodland because they represent past nuclei of this woodland and therefore are suitable and at the same time relatively easy to convert to cork oak woodland. This detail will allow accounting for a target habitat's condition which is an important aspect for restoration purposes, and which currently in this study is unaccounted for. However, this will need an updated inventory (or detailed mapping) of these habitats. The indications derived herein have to be interpreted cautiously since the habitat data are derived from the Carta Forestale which is not up to date. Nevertheless this approach provides an insight in the past and an indication of processes that influence habitat restoration in the future. Despite its limitations it is anticipated that this type of analysis will assist with formulating policies to protect those habitats that remain and identify suitable sites for re-creation of habitats that have been lost.

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