Progress in Physical Geography 30, 2 (2006) pp. 175–200

Mediterranean ecosystems: problems and tools for conservation

I.N. Vogiatzakis,[1]* A.M. Mannion[2] and G.H. Griffiths[2]

[1]Centre for Agri-Environmental Research, School of Agriculture, Policy and Development, The University of Reading, Earley Gate, Reading RG6 6AR, UK
[2]Department of Geography, The University of Reading, Whiteknights, Reading RG6 6AB, UK

Abstract: Mediterranean ecosystems rival tropical ecosystems in terms of plant biodiversity. The Mediterranean Basin (MB) itself hosts 25 000 plant species, half of which are endemic. This rich biodiversity and the complex biogeographical and political issues make conservation a difficult task in the region. Species, habitat, ecosystem and landscape approaches have been used to identify conservation targets at various scales: ie, European, national, regional and local. Conservation decisions require adequate information at the species, community and habitat level. Nevertheless and despite recent improvements/efforts, this information is still incomplete, fragmented and varies from one country to another. This paper reviews the biogeographic data, the problems arising from current conservation efforts and methods for the conservation assessment and prioritization using GIS. GIS has an important role to play for managing spatial and attribute information on the ecosystems of the MB and to facilitate interactions with existing databases. Where limited information is available it can be used for prediction when directly or indirectly linked to externally built models. As well as being a predictive tool today GIS incorporate spatial techniques which can improve the level of information such as fuzzy logic, geostatistics, or provide insight about landscape changes such as 3D visualization. Where there are limited resources it can assist with identifying sites of conservation priority or the resolution of environmental conflicts (scenario building). Although not a panacea, GIS is an invaluable tool for improving the understanding of Mediterranean ecosystems and their dynamics and for practical management in a region that is under increasing pressure from human impact.

Key words: conservation, GIS, Mediterranean Basin, modelling, spatial analysis.

I Introduction

Mediterranean-type ecosystems occur between 31 and 40 north and south of the equator (Figure 1). They are so defined because of climatic characteristics, notably warm wet winters and hot dry summers. Their disjunct distribution of these ecosystems in every continent apart from Asia reflects exposure to oceanic influences. Although there is much heterogeneity

*Author for correspondence. Email: i.n.vogiatzakis@reading.ac.uk

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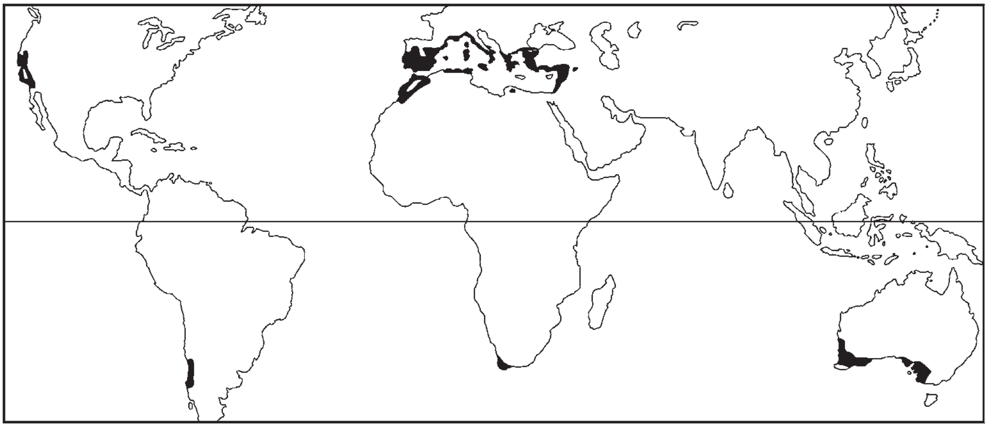

Figure 1 Mediterranean type-ecosystems of the world

between these regions, especially in relation to geology, soils, floristic and faunistic composition, there remains considerable uniformity.

Biogeographically all such regions are characterized by woody shrubs with sclerophyllous leaves and all have high biodiversity. Mediterranean-type ecosystems occupy only 1.2% of the Earth's surface (di Castri, 1981) but they contain a disproportionate number of plant species; Cowling *et al.* (1996) estimate that they house *c.* 48 000 species, representing *c.* 20% of the World's vascular plants (see also Heywood and Watson, 1995; Groombridge and Jenkins, 2002). These ecosystems second are thus second only to tropical rain forests as biodiversity 'hot spots'. Moreover, all Mediterranean-type ecosystems have a high proportion of endemic species (Table 1). These 'hot spots' are a product of internal environmental heterogeneity: dissected mountainous landscapes, a high degree of natural disturbance (see details in Archibold, 1995; Allen, 2001) and naturally occurring fire (see papers in Moreno and Oechel, 1995; Pignatti *et al.*, 2002). Furthermore all Mediterranean-type ecosystems are susceptible to degradation and species loss due to human activity. This includes deforestation, the expansion of

Table 1 Some biogeographical characteristics of Mediterranean-type ecosystems

	Area 10^6 km^2	Native flora (vascular plants)	% Endemic	Threatened taxa	% Threatened	% Conservation area
California	0.32	4300	35	718	16.70	1.6
Chile	0.14	2100	23	?	?	2.6
Mediterranean Basin	2.30	23 300	50	4251	18.24	3.1
South Africa	0.09	8550	68	1300	15.20	14.4
Southwest Australia	0.31	8000	75	1451	18.10	6.5
Total area	2.95					

Source: based on data in Calow (1998).

pastoral agriculture, the loss of arable agriculture from some regions, disturbance of natural fire regimes, mining, urbanization, tourism, pollution and the introduction of alien species, and difficulties of agreeing and implementing conservation strategies because of complex land ownership and control (di Castri, 1981; Cowling *et al*., 1996; Archibold, 1995).

The intensity of these impacts is dictated by socio-economic factors such as population growth or rural depopulation, the governmental control of agriculture through subsidies, or the need to generate income through forestry, agricultural products and tourism. Such impacts are well documented. For example, Trinder-Smith *et al*. (1996) and Richardson *et al*. (1996) detail threats to plant diversity in South Africa's Cape Peninsula. Here, people-environment interactions have intensified since European settlement in 1652 since when *c*. 37% of the area became agricultural or urban land. Moreover, Richardson *et al*. (1996) report that *c*. 10.1% of the remaining land area houses dense stands of alien species while 32.9% is highly invaded. Similarly, Southwest Australia has been altered substantially following European settlement in the early 1800s (Hobbs, 1998), as agricultural systems based on wheat production were established. Of some 12 000 vascular plant species, 52 may have already become extinct with 232 threatened (Hobbs and Mooney, 1998) and fragmentation is a problem for conservation (Saunders *et al*., 1991).

In Chile and California, European settlement, beginning in 1542 and 1840 respectively, brought urbanization, agriculture and alien invasions. Both regions are characterized by many alien plant species that have become naturalized; there are more than 1000 in California and more than 600 in Chile (Sax, 2002). In California rapid economic development in the last 20 years has caused rural depopulation and consequent ecosystem development characterized by high fire frequency. This is not so in the Mediterranean-type communities of Chile, and it may account for the success and naturalization of alien species and that fire that does not favour native mattoral species (Rundel, 1998). This situation is considered by Sax and Brown (2000) as the 'paradox of invasion'. Moreover, Chile's Mediterranean region has experienced considerable afforestation than any other and forestry plantations of non-native *Pinus radiata* and *Eucalyptus globulus* now occupy 20% of the region (Aronson *et al*., 1998). As in Chile, California's Mediterranean region has undergone enormous land use since 1800s. Some habitats, notably wetlands, grasslands and marshes, have been reduced to less than 10% of their natural extent and areas of intensive agriculture have lost most of their natural habitats (Walter and Gillet, 1998).

In relation to the future of Mediterranean-type ecosystems, climatic change is all-important, though there are difficulties in predicting change and its ecological significance. Wide topographical variation and associated diversity of habitats make the estimation of future climatic characteristics precarious, as in the prediction of species and community response. However, at the regional scale general circulation models (GCMs) indicate that evergreen forests will migrate north and diminish in extent in, for example, the Mediterranean Basin itself as they are replaced at its southern margins by shrublands and grasslands. This scenario is reinforced by the International Panel on Climate Change (IPCC, 2001; Cheddadi *et al*., 2001) and is a response to increased temperatures, lengthier drought conditions and enhanced evapotranspiration. Species and communities in high mountain regions are likely to be especially vulnerable to change, and many may disappear (Mooney *et al*., 2001). Fire frequency may also increase, to favour shrub rather than tree growth (Mouillot *et al*., 2002). There is the added complication of the impact of invasive species under altered climate conditions (Mooney *et al*., 2001).

The rapidly intensifying human activity in Mediterranean-type lands is a serious problem for conservation. Despite acknowledgement of the ecosystem services rendered by the biodiversity of these ecosystems, their role as gene banks, and their wealth-generating capacities as tourism destinations, a relatively small land area within these Mediterranean regions has been designated as official conservation zones. Table 1 shows that South Africa leads the way in relation to the area conserved. However, conservation efforts face many problems which arise from the absence of adequate data or absence of a coordinated database to inform conservation. Moreover, it is not always obvious what should be conserved or how conservation should be managed. To resolve such questions ecologists, conservationists and planners are considering new available tools such as Geographical Information Systems (GIS) to improve data quality and availability and for conservation planning. GIS not only enable the management of spatial and attribute data from various sources but they can be used to:

- inform the decision-making process using scenario building;
- provide rapid landscape or biodiversity assessments where information is available, eg, the identification of high conservation priority areas;
- predict species and habitat distribution from limited field data, thus saving time and money and accelerating the conservation process.

II The Mediterranean Basin

The extent of Mediterranean-type ecosystems is greatest in the Mediterranean Basin; *c*. 73% of the total area of such ecosystems occur here and it houses some 50% of the vascular plants (Table 1). The location of the basin has proved particularly advantageous for the development of high biodiversity as floral and faunal elements have merged at the junction of three continents. The rises and falls of sea level during the last three million years must also have contributed to the repeated integration and isolation of ecosystem components. The relative climatic uniformity throughout the basin, with a summer drought and winter rainfall, is also a critical ecological factor. Moreover, much of the region comprises faulted and folded limestone young orogenic systems which present a variety of habitats of elevations ranges from sea level to alpine. Fire is another significant factor in the dynamics of ecosystems in the Mediterranean Basin. Elevated temperatures during the summer drought and the accumulation of dry biomass effectively accelerates nutrient recycling (see Pyne, 2001). Fire has become an important management technique and has probably been employed since prehistoric times (Moreno *et al.*, 1998; Pyne, 2001).

The environmental history of the Mediterranean region has been presented by Allen (2003) who shows that the last three million years have been characterized by shifts in vegetation communities. Open communities were replaced by shrublands or forest during interglacial climatic amelioration following long, cold stages when global ice cover was extensive. The ecosystems of the Mediterranean Basin have experienced a long and intense history of human influence. Early hominids (eg, *Homo erectus*) migrated out of Africa through Mediterranean lands into Europe and Asia. Thereafter, modern humans (*Homo sapiens sapiens*) colonized the Mediterranean Basin (Mannion, 1999; 2002) *c*. 10 000 years ago. This was a turning point in cultural and environmental history. Humans domesticated certain plants and animals, such as wheat, barley, sheep, cattle and goats, and the ecosystems were subject to modification. This pressure has not since relented: civilizations have waxed and waned but the food- and wealth-generating capacity of the Mediterranean Basin has been exploited with increased intensity. There is debate regarding the relative significance of climatic and anthropogenic factors influencing the character of the Mediterranean region's ecosystems; should such ecosystems be considered as degraded or as landscapes adapted to disturbance (Allen, 2003)? The latter view is beginning to prevail but nevertheless human activity, especially agriculture, has played a major role in shaping Mediterranean landscapes for at least the last 7000 years. Today agriculture remains a major pressure; in many Mediterranean countries, it is manipulated via the European Union's (EU) Common Agricultural Policy (CAP).

Further anthropogenic pressures have been described by Naveh and Lieberman (1994) as the cause of 'neo-technological landscape degradation'. In addition, the forces of population growth and industrialization have stimulated considerable land-use change, especially agricultural intensification, with associated impacts including soil erosion, eutrophication and industrial and power-plant construction (Naveh, 1998).

Tourism is also an ongoing cause of environmental change. Since the 1960s especially, the Mediterranean has experienced ever-increasing tourist numbers and consequently coastal regions especially have been transformed. Tourism will increase substantially in coming decades, to *c*. 220×10^6 in 2025 tourists (UNEP, 1988; quoted in Naveh, 1998). Similarly, human population is likely to expand. Today there are *c*. 140×10^6 people with a predicted rise to 200×10^6 by 2025, especially in urban centres. Such changes will not be uniform. The richer countries of the western and northern Mediterranean have near zero rates of population increase, while many eastern and southern Mediterranean countries have positive growth rates ranging from 3.3% per year in Jordan to 0.3% in Greece (World Resources Institute, 1999).

Even within a given nation population concentrations will alter; there is already rural depopulation in many parts of the Mediterranean Basin. This causes land abandonment in southern France and Corsica (Etienne *et al.*, 1998). The loss of 'genres de vie' in areas like the centre of Corsica, the hinterland of Montpellier, the Plain of Crau in the Lamergue and Provence's coastal forests reflect the cultural significance of rural depopulation. The decline in pastoralism in Corsica, for example, has resulted in postpasture successions which begin with grassland and progress through shrubland to dense forest (Said, 2002). Such temporal dynamics must be considered in nature reserve designation and management. Further need for management is illustrated by Ruecker *et al*. (1998) who have investigated soil erosion rates on terraces formerly used for agriculture in the Meastrazqo of Castellon, Spain. Newly abandoned arable lands experience rates of erosion of *c*. 2.2 t $ha^{-1}yr^{-1}$; on land abandoned *c*. 10–20 years ago where shrub vegetation has become established, the rate of erosion falls to 0.6 t $ha^{-1}yr^{-1}$ but where grassland is maintained for cattle grazing soil erosion is almost nil. Rural depopulation, and associated problems of landscape management, are beginning to appear in the eastern and southern Mediterranean basin as agricultural change, the intensification of tourism and industrialization occur. This has been highlighted by Loumou and Giourga (2003) who highlight the plight of traditional olive groves on low-fertility slopes and terraces. This once popular multi-purpose crop is being abandoned in favour of pasture, and competition from commercial olive groves and oil-seed crops is exacerbating the problem. Conservation here is no less of a priority than in other Mediterranean ecosystems, though the approach to it will differ.

Despite such long-term pressures the Mediterranean Basin has a high biodiversity and a high percentage of endemic species (Table 1). The entire Mediterranean Basin may house as many as 25 000 higher plants with *c*. 50% being endemic (Quezel, 1985). The dominant physiognomic units of vegetation are shrublands; these are variously described (Table 2). Since 1970 there have been several conservation initiatives to address environmental degradation (Table 3). Attention has focused on coastal/marine ecosystems and wetlands. The former have been especially adversely affected by tourism. Despite such initiatives, Naveh (1998) claims that most natural coastal sand-dune habitats have disappeared. Cencini (1998) also highlights the degraded state of the Po delta, Italy,

Table 2 Definitions of Mediterranean plant formations

Region	Definition
Mediterranean Basin	Maquis: a dense, mainly evergreen shrub community 1–3 m high. Garrigue: open heath communities, often with low-growing spiny and aromatic shrubs.
South Africa	Fynbos: evergreen heath communities typical of the Cape Flora; maybe mountainous or coastal fynbos.
Southwestern Australia	Mallee: heath communities of small eucalypts with a ground flora of grasses and herbs.
Chile	Matorral: evergreen shrub communities 1–3 m in height.
California	Chaparral: evergreen shrub communities 1–4 m in height.

Source: based on Archibold (1995).

Table 3 A summary of nature conservation policy and legislation in the Mediterranean

Title	Aim
MAP, 1975 (Mediterranean Action Plan)	To assist the Mediterranean governments to assess and control marine pollution, to formulate their national environmental policies.
METAP (Mediterranean Technical Assistance Programme)	Second phase of European Programme for the Mediterranean to reverse present environmental degradation
MEDPAN	To strengthen links between managers of protected areas.
MedSPA (Mediterranean Specially Protected Areas)	To protect the Mediterranean environment, including protection of biotopes.
MedWet	To conserve Mediterranean wetlands.
Barcelona Convention, 1976	To protect the Mediterranean Sea against pollution.
Nicosia Charter, 1990	To provide closer cooperation on sustainable development in the Euro Mediterranean region including nature conservation.
Alghero Convention, 1995	Coastal and marine biodiversity in the Mediterranean.
Venice Declaration, 1996	Declaration on Mediterranean wetlands.
Mediterranean Wetlands Strategy, 1996	

Source: based on data from ECNC (2004).

where fresh- and saltwater lagoons and sandbanks have been damaged by urbanization and economic activity. Similarly wetlands have been lost at an alarming rate for many reasons. In the Camargue, for example, some 30×10^3 ha of wetlands have disappeared since 1940, mainly due to agriculture (Tamisier and Grillas, 1994). The rapidity with which anthropogenic impact is occurring and the threat of global warming (see Lavorel *et al.*, 1998; Lavorel, 1999) means that provision for conservation is vital. There is a pressing need to identify areas of conservation priority and to establish effective legal and management structures.

III Nature conservation and information availability in the Mediterranean Basin (MB)

The conservation value of the MB is recognized worldwide (see Olson and Dinnerstein, 1998; Mittermeier *et al.*, 1998; Myers *et al.*, 2000). Within the MB there have being several hotspots of plant diversity identified (eg, Davis *et al.*, 1994; Medail and Quezél, 1999) in their majority uplands or islands. Conservation has a long history in the MB, beginning particularly with a tradition of botanic gardens founded in the fifteenth and sixteenth centuries (Heywood, 1990; du Puy and Jackson, 1995). Their early role in conservation was, however, incidental and only in the last 20 years has it become a primary mission (IUCN, 1989). Moreover, Maunder *et al.* (2001) researching the effectiveness of European botanic gardens found that the collections do not fully reflect the priorities as defined by the Bern Convention (Council of Europe, 1992).

Conservation efforts/decisions in the MB require adequate information on its biodiversity. However, it has often been noted (eg, Medail and Quezél, 1997) that estimating the biodiversity of the MB is difficult. Biogeographers have argued for more than a century about the boundaries of the circum-Mediterranean region (Quezél, 1985) using a range of criteria for delineation (Figure 2). Moreover, political boundaries on which national biodiversity assessments are based on do not correspond to biogeographical boundaries (Figure 3). Often they include elements not belonging to the Mediterranean realm, as for example the national floras of Portugal or Turkey (see Quezél, 1985). The opposite is also true with assessments based on the biogeographical rather than national boundaries as for example the *Flora of Turkey* (Davis, 1965 *et sequel*) and the *Flora Iberica* (Castroviejo *et al.*, 1986–2001).

An invaluable source of information on plant taxonomy and distribution in the MB is the Med-Checklist (Greuter *et al.*, 1984; 1986; 1989). At the national scale the detail of information on plant species varies between countries (Table 4). For example, Spain, Italy and Turkey have completed their national floras 'inventory' while Greece and Portugal are in the process of doing so. Moreover, new species have been described in recent years (eg, Guner *et al.*, 2000; Baccheta *et al.*, 2000; Rios and Crespo, 2001) while introductions remain an acute problem in the area (eg, Villa *et al.*, 2001). Consequently the adequacy of species information for conservation has been questioned (Greuter, 1994; Blondel and Aronson, 1999). The Euro + Med project (EUROMED, 2003) will resolve some of these problems by providing an up-to-date database and information

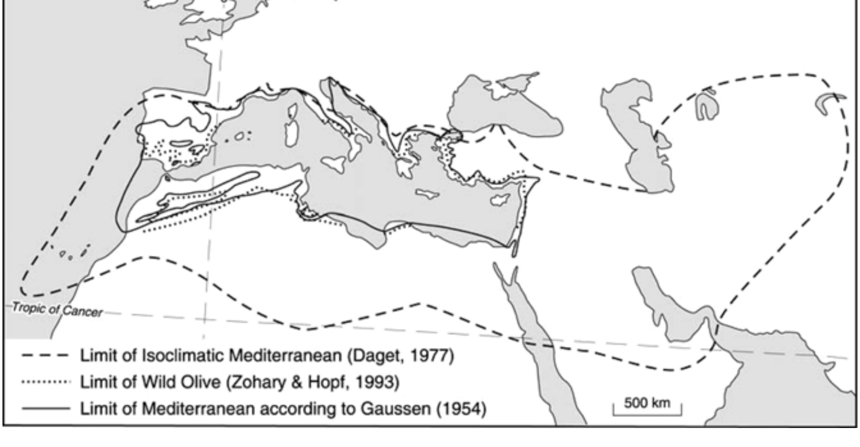

Figure 2 Delineation of the Mediterranean area based on three different criteria

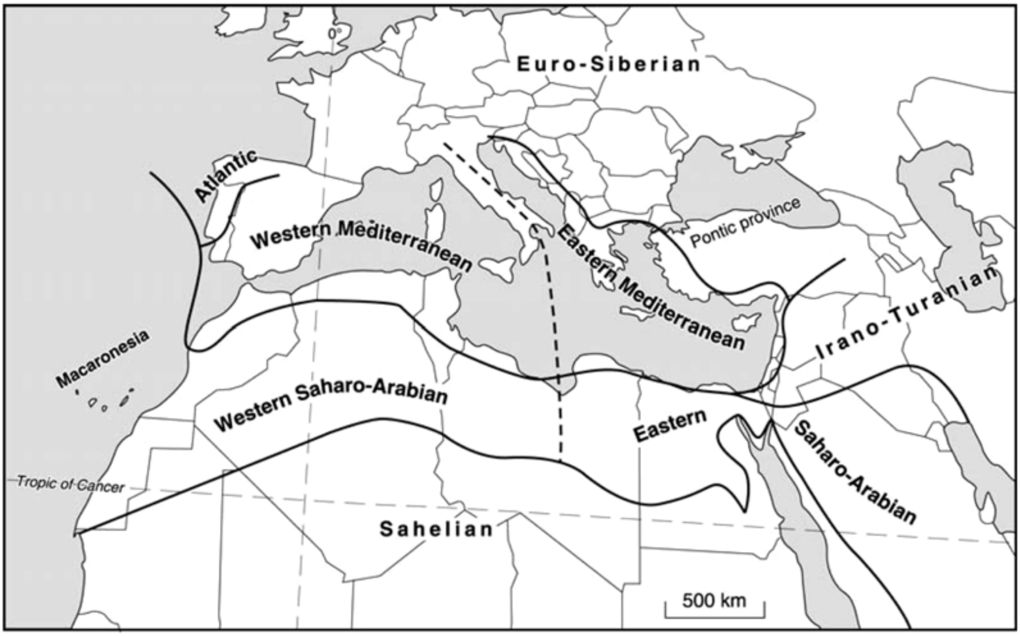

Figure 3 Biogeographical realms in the Mediterranean area
Source: (adapted from Blondel and Aronson, 1999).

system for the vascular plants of Europe and the Mediterranean region.

Both species and ecosystem-based approaches have been employed to conservation issues in the MB. A range of analyses at national level (Garcia-Barros *et al.*, 2002) and regional level (Legakis and Kypriotakis, 1994; Troumbis and Dimitrakopoulos, 1998) and European level (Palmer and Smart, 2000) have been based on individual species that are rare or endangered or habitats characterized by high species richness and/or endemism. This approach is usually hindered across the MB by the lack of information, particularly on mountain areas (Dimopoulos *et al.*, 1997; Bergmeier, 2002; Vogiatzakis *et al.*, 2003a). The long-term maintenance of genetic diversity is a requirement for the survival of the organisms protected (Groombridge and Jenkins, 2002). Since the MB is the centre of origin of many crops, the conservation of genetic diversity has attracted research at national (eg, Negri *et al.*, 2000; Porfiri *et al.*, 2001; Maxted, 2003) but also at international level (eg, Heywood and Skoula, 1999; IPGRI, 2003).

Species reintroduction in the MB is limited and the examples discussed by Blondel and Aronson (1999) reveal problems related to the cost incurred if carried out on scientific grounds and the prevalence of economic or political criteria for conservation over scientific reasons. Moreover, in an example from Crete, Greece, the introduction of the Cretan ibex in the islet of Dia proved to be at the expense of the endangered plant species *Centaurea idaea* (Rackham and Moody, 1996).

The ecosystem-based approach for conservation has been advocated in the MB because it ensures the protection of species genetic diversity and the ecological processes essential to species survival (Greuter, 1979; Ruiz de la Torre, 1985; Blondel and Aronson, 1999). The designation of Natural Protected Areas in the MB has contributed to

Table 4 Globally threatened groups of species and protected areas in the Mediterranean Basin

Country	Mammals	Birds	Plant species	Area (000)	No. of protected areas	Area protected (000)
Albania	3	3	0	2740	25	2.8
Algeria	13	6	2	238 174	18	2.5
Bosnia-Herzegovina	10	3	1	5100	5	0.5
Croatia	9	4	0	5592	26	6.7
Egypt	13	7	2	99 545	12	0.8
France	18	5	2	55 010	132	11.7
Greece	13	7	2	12 890	24	2.2
Israel	14	12	0	2062	15	14.9
Italy	14	5	3	29 406	169	7.3
Jordan	10	8	0	8893	9	3.4
Lebanon	5	7	0	1023	1	0.4
Libya	8	1	1	175 954	6	0.1
Macedonia FYR	11	3	0	2543	16	7.1
Malta	2	1	0	316		
Morocco	16	9	2	44 630	7	0.7
Portugal	17	7	15	9150	24	6.5
Slovenia	9	1	0	2012	14	5.7
Spain	24	7	14	49 944	217	8.4
Syria	4	8	0	18 378		
Tunisia	11	5	0	15 536	6	0.3
Turkey	17	11	3	76 963	49	1.4
Yugoslavia Fed. Rep.	12	5	1	10 200	27	3.2

Source: based on www.redlist.org and www.wri.org. Gaps reflect lack of information.

conservation efforts, though much variation exists between the Mediterranean countries in terms of the areas occupied by Mediterranean-type scrub communities, the numbers of species present, the numbers of endemic species and the area conserved (Tables 4 and 5). These data reflect the uneven approach to conservation that characterizes Mediterranean nations.

A gap analysis to determine the level of protection of European forests (WCMC, 2000) suggested that Mediterranean broadleaved sclerophyllous forests and scrub are among the forest types with low protection (<2%). Such gaps will be addressed by the Natura 2000 network implementation (Council of Europe, 1992), though only the Mediterranean countries in the European Union (EU) will be affected (Table 6). To be retained in the EU list, sites must be designated before 2004 but progress towards completing the network has been slow. Countries such as Italy and France have been condemned in the past by the EU Court of Justice for failing to designate all their most suitable territories as SPAs. Moreover, significant information gaps for Spanish SPAs remain (European Commission, 2003).

At the European level recent legislation (eg, Pan European Biological and Landscape Diversity Strategy) now considers the conservation status of the wider countryside, including both its biological and landscape diversity. Mediterranean landscapes have frequently become fragmented due to human activities in the past as a result of fire and grazing (see

Table 5 The state of floristic information in the Mediterranean countries

Country	No. of plant species	No. of endemics	% of endemism	Flora	Red data book*
Albania	2965	24	0.8	Flora e Shqiperise	320
Algeria	3100	250	8.1	Flore de l'Afrique du Nord	
Bosnia-Herzegovina				Analitiske Flora Jugoslavije	Yes
Croatia	4283	280	6.5	Flora Croatica	401
Cyprus	1620	130		Flora of Cyprus	
Egypt	2066	70	3.4	Flora of Egypt	Yes
France	4500	133	3.0	Flore de France	Yes
Greece	4900	742	15.1	Flora Hellenica	263
Israel	2200	165	7.5	Flora Palestina Flora of Syria, Palestine and Sinai	
Italy	5463	712	13.0	Flora d'Italia	Yes
Jordan	2200	145	6.0	Flora Palestina	
Lebanon	2600	311	12.0	Nouvelle flore du Liban et de la Syrie	
Libya	1800	134	7.4	Flora of Libya	
Macedonia FYR				Flora na SR Makedonia	
Malta	914	16	1.7	Flora of the Maltese Islands	398
Morocco	3600	150	17.4	Flore du Sahara	
Portugal	2500		6.0	Flora Iberica Flora de Portugal	200
Slovenia	3175			Mala Flora Slovenije	Yes
Spain				Flora Iberica	Yes
Syria	3100	395	12.7	Flora of Syria, Palestine and Sinai	
Tunisia	2150	39	2.1	Flore de l'Afrique du Nord	
Turkey	8472	2711	32.0	Flora of Turkey and the East Aegean Islands	Yes
Yugoslavia Fed. Rep.	5000	320	6.4	Flora de la Republique socialiste de Serbie	Yes

Source: based on data in www.euromed.org.uk and http://www.unep-wcmc.org/. Gaps reflect lack of information.
*The number of species in red data books is given where known.

review in Rundel *et al.*, 1998) and at present due to demands on land, agriculture, forestry, recreation and conservation (Lacaze, 2000). Fragmentation comprises more than one process that affects species and their interactions as well as ecosystem processes (Moilanen and Hanski, 1998). Thus the conservation of biodiversity cannot be achieved by concentrating efforts solely on habitats and species within protected areas (Pino *et al.*, 2000). There are three distinct roles that landscape plays in the conservation of biological diversity in the MB. It provides habitat at smaller spatial scales (eg, Ferreras, 2001; Virgos *et al.*, 2002), it influences the effectiveness of reserve areas (eg, Wolff *et al.*, 2002) and controls connectivity in the landscape, including movement of organisms

Table 6 Natura 2000 network implementation progress in the Euro-Mediterranean countries

	No. of sites proposed	Total protected area (km^2)	% of national territory	Complete and computerized site maps	Complete and computerized Natura 2000 forms	Assessment of national list
Greece	236	27 461	20.9	Yes but	Yes but not validated	Substantial but still incomplete
Spain	1276	118 496	23.5	Yes but not validated	Yes but not validated	Substantial but still incomplete
France	1174	40 632	7.4	No	Yes but not validated	Substantial but still incomplete
Italy	2369	41 266	13.7	Yes but	Yes but not validated	Substantial but still incomplete
Portugal	94	16 500	17.9	Yes but not validated	Yes but not validated	Substantial but still incomplete

Source: European Environment Agency (2003).

between reserves (see Ferreras, 2001; Brotons and Herrando, 2001; Santos *et al.*, 2002; Rodriguez and Delibes, 2003). In particular, traditional agricultural landscapes in the MB are of particularly high conservation value for the flora (eg, Correia and Freitas, 2002) and fauna (eg, Selmi and Boulinier, 2003). The idea for a holistic approach for the conservation of the great natural and cultural assets of the region's landscape was advanced by Naveh (1993; 1995) who proposed a 'Book on Mediterranean threatened landscapes'. This is yet to be written but preliminary results came out as a special issue of *Landscape and Urban Planning* (volume 24, 1993), and were taken further by Green and Vos (2001). According to these studies the following cultural landscapes are threatened in the MB:

- relict natural landscapes which consist of relicts of relatively undisturbed ecosystems where agriculture is limited due to physiography/topography (Rossi and Vos, 1993);
- vanishing traditional landscapes which were originally oriented towards subsistence agriculture, as for example the montados and dehesas in Portugal and Spain (Pinto-Correia, 2000);
- stressed landscapes which comprise large-scale agricultural landscapes with an increasingly intensive land use as in western Crete (Rackham and Moody, 1996).

Despite this range of conservation efforts, their efficiency for the long-term management and protection of Mediterranean biodiversity in the light of future climatic changes has been questioned (Allen, 2003). Thus there remains a strong interest in the identification of potential effects of rapid, anthropogenic climate change on the biota of the MB.

IV GIS and nature conservation

1 Storing spatial and attribute data

The first step towards ensuring the long-term persistence of the elements that comprise the ecosystems in the MB is to establish a baseline of biological information required for their effective management. Following the shift in geography from conventional to digital maps and the advent of GIS, ecologists 'discovered' a powerful tool for storing ecological data and analysing ecological processes (Johnston, 1998; Wadsworth and Treweek, 1999). GIS, together with parallel developments in spatial data processing disciplines (eg, photogrammetry, remote sensing), is able to handle a wide range of information from many sources and at different levels of resolution (Longley *et al.*, 2001; Bernhardsen, 2002).

GIS is a invaluable tool for achieving conservation goals in the MB since it can assist with the management of this information and integrate/interact with databases on species distribution and ecology such as MEDUSA, EUROMED, or the data of *Flora Europaea* (Tutin *et al.*, 1964–1980) and *Atlas Florae Europaea* (Jalas and Suominen, 1972–1996) now available in digital format. Moreover, GIS can be used to identify and explore correlations among biotic and abiotic elements of the Mediterranean landscape and contribute to nature conservation and resource planning. This is, for example, one of its principal uses in the SynBioSys project, an initiative of the European Vegetation Survey for the evaluation and management of biodiversity among plant species, vegetation types and landscapes at a European scale (SynBioSys, 2003).

An important source of GIS data, where there is no mapped information on environmental data, is remote sensing (Donoghue, 2002). The interpretation of satellite images from a variety of sensors is based on the analysis of spectral signatures of different surface features on the earth's surface and has a plethora of applications at various scales (Donoghue, 2000). The basic features and suitability of satellite imagery as a source of data for mapping have been discussed in Alexander and Millington (2000), Skidmore, (2001), Millington *et al*. (2002) and Scott *et al.* (2002b). The advantages and shortcomings of remote sensing in the study of Mediterranean ecosystems have been well documented by Shoshany (2000). The most frequent uses in the MB include vegetation mapping (Maselli *et al.*, 2000; Garaux-Garson and Lacaze, 2003), and fire fuel mapping (for example, Lopez *et al.*, 2002; Riaño *et al.*, 2002; Koutsias and Karteris, 2003) but also postfire dynamics (Diaz-Delgado *et al.*, 2002) and environmental protection applications (eg, Kwalie *et al.*, 2002). New developments in the field, ie, high resolution satellite systems such as IKONOS with nominal resolutions between 1 and 5 m, will substantially improve the capability for information extraction and provide new insights for monitoring and conservation. Although limited, reports on the use of IKONOS in the MB for agricultural (Colombo *et al.*, 2003) as well as semi-natural vegetation mapping (Chirici *et al.*, 2003) agree on its potential while highlighting the need for further investigation on its applicability.

European Community led projects such as MEDALUS (Brandt and Thornes, 1996), CORINE (CORINE, 1993), Natura 2000 (Council of Europe, 1992) and the European Forest Inventory (see Päivinen *et al.*, 2001) have used GIS coupled with remote sensing in order to make an inventory and monitor terrestrial/environmental processes of the member states. These programmes serve as a guide to environmental policy and legislation in the Euro-Mediterranean countries and form the European Nature Information System (EUNIS) (European Environment Agency, 2003). EUNIS provides access to publicly available data in a consolidated database for species, habitats and sites of Europe. In particular the EUNIS habitat types classification is a pan-European system to facilitate the harmonized description and collection of data across Europe through the use of criteria for habitat identification (European Environment Agency, 2003).

GIS has also been used for land evaluation (d'Angelo *et al.*, 2000; Ozcan *et al.*, 2003) for land-use change in mountainous regions (Taillefumier, 2003; Poyatoas *et al.*, 2003) as well as landscape analysis (Del Barrio *et al.*, 1997). The ability of GIS to integrate data from different sources recorded at different resolutions is one of the reasons why it has been advocated by prominent Mediterranean ecologists such as Naveh (1995), who suggested that the combination of GIS with 'Red Lists' will provide the means for effective conservation of endangered Mediterranean landscapes. Increasingly GIS has been advocated for a range of applications such as resolving the environmental threats to the Rif mountains in Morocco (Moore *et al.*, 1998) and for the management of the coastal zones in Turkey (Berberoglu, 2003; Berberoglu *et al.*, 2004).

2 Modelling and prediction

Undoubtedly, one of the most powerful and useful GIS abilities is prediction. Currently, there is a paradigm shift in ecology from descriptive to predictive approaches (eg, Hobbs and Moore, 1999) and GIS has a role to play, particularly in ecologically sensitive areas like the MB. This is highlighted by the limited information at the species level (Pausas, 1999; Allen, 2003) as well as at the community level (eg, Bergmeier, 2002; Vogiatzakis *et al.*, 2003a). GIS techniques can be used to predict species or community distribution patterns based on limited field data. This approach, which is called inductive or empirical modelling (Austin, 1998), has spawned a range of techniques for predictive vegetation and habitat mapping (cf. Franklin, 1995; Guisan and Zimmerman, 2000; Scott *et al.*, 2002a).

As a result there has been a significant uptake of these techniques for ecological research in the MB. For example, Kadmon and Danin (1999) examined the relations between the distribution of herbaceous and woody species from the flora of Israel and the variation (25–900 mm) in mean annual rainfall by integrating multivariate techniques and GIS. Pausas and Carreras (1999) used overlay techniques within a GIS to examine the relationship between 58 vegetation units and four terrain parameters in the eastern Pyrenees. Moreover, in a study by Carmel *et al.* (2001) logistic and linear regression were used to develop an empirical model of vegetation dynamics for an area in the Galilee mountains, Northern Israel, using topography, disturbance maps (such as grazing logging and fire) and vegetation properties.

Rouget *et al.* (2001a) used recursive partitioning and GIS analyses to relate the database of 10 600 field plots from the Forestry Inventory of Catalonia, Spain, with abiotic and biotic characteristics of each plot in order to explore the determinants of distribution, abundance and regeneration of six *Pinus* species (*P. halepensis, P. nigra, P. pinaster, P. pinea, P. sylvestris* and *P. uncinata*) that occur naturally in the area. Vogiatzakis and Griffiths (2006) used three variables, namely altitude, slope and geomorphology, within a GIS to predict the distribution of plant communities in the alti-Mediterranean zone of the Lefka Ori massif in Crete. Predictive mapping techniques can also be used for identifying suitable sites for re-establishment of endangered plant species in the MB. This approach has been employed in other Mediterranean-type ecosystems where GIS was used to assess suitability sites and guide ground survey activities for the re-establishment of *Euphorbia clivicola* R.A. Dyer in South Africa (Pfab and Witkowski, 1997).

With invasive species increasingly becoming a problem in the Mediterranean Basin in general (see di Castri *et al.*, 1990) and in islands in particular (see Delanoë *et al.*, 1996; Cassar and Stevens, 2002) prediction is also required to investigate the likelihood of an ecosystem or area to be invaded. GIS can be used to investigate the distribution of invasive species and their impact on plant diversity in a way that has been applied already in other Mediterranean-type ecosystems. For example, in the Cape peninsula of South Africa, Higgins *et al.* (1999) used logistic regression within a GIS to predict the probability of six invasive species occurring, as a function of topographic and other environmental factors such as flammability and soil moisture. A GIS-based approach was also employed by Rouget *et al.* (2001b) to assess the role of environmental factors and natural and anthropogenic disturbance in relation to invasion history and to predict invasion dynamics of four alien pine species in a highly fragmented semi-arid shrubland in South Africa. Currently in Europe a project called EPIDEMIE is under way (CEH, 2003) which aims to assess the risk and hazards of plant invasions as well as the susceptibility of Mediterranean island ecosystems to invasions where modelling using GIS is envisaged.

Predicting invasion by exotic competitors, however, is only one of the consequences of landscape fragmentation for which GIS can be used. The predictive abilities of GIS can be employed in the MB to investigate the effects of fragmentation on movement and dispersal of organisms and rates of gene flow. GIS allow the development of spatially explicit models that incorporate environmental data and population data which can assist the improvement of techniques such as Population Viability analysis (Heywood and Iriondo, 2003). This can be used to assess and monitor the biological status of the rare or threatened species. There are numerous examples where GIS had been used to predict the impacts of landscape fragmentation on habitat suitability and consequently on species distribution (see Lurz *et al.*, 2001; Seoane *et al.*, 2003). For example, GIS has been used to derive parameters for a statistical model as in the case of the wolf-habitat relationship in the northern Apennines, Italy (Ciucci *et al.*, 2003). More often, however, GIS is the main means for the construction of a spatial model as demonstrated by a study in Central Spain where Osborne *et al.* (2001) used logistic regression models within a GIS to assess the effect of habitat fragmentation among other parameters on the distribution of great bustards.

A major research theme in landscape ecology is the derivation of landscape metrics/indices to quantify various aspects of landscape patterns and describe ecological processes (see MacGarigal *et al.*, 2002). Once these processes have been quantified, their effects on species distributions and ecological functions at a range of spatial scales can be explained. The role of GIS in these studies is to provide the input, the grid-based maps, for the indices and to carry out the spatial analysis to explore relationships between processes and patterns. However, this type of research has received little attention in the MB with the exception of a study from Spain (Saura, 2004) that examined the effect of spatial resolution on six common fragmentation indices used in the Spanish National Forest Inventory. Future issues to be addressed should include the quantification of ecological processes such as fragmentation and the relationship between habitat proportion and patch size/isolation via simulated landscapes.

Modelling within a GIS can also be employed to investigate the potential effects of rapid anthropogenic climate change on species and community distribution (Enquist, 2002; Dirnboeck *et al.*, 2003) as well as nature reserves (Scott *et al.*, 2002a; Dockerty and Lovett, 2003). In the MB most of these modelling studies on the effects of climate change on vegetation is limited either geographically (see Parry, 2000; Box and Choi, 2000) or confined to individual species (eg, Huntley *et al.*, 1995). The only study that accounts for general changes in the MB, although not GIS-based, is the one by Cheddadi *et al.* (2001). Nevertheless a complete picture of the effects of climatic change on the ecosystems of the MB is not available.

Another role that the GIS can fulfil is integration with other ecological modelling techniques as has been reviewed in Johnston (1998) and van Etten (1998). The use of ecological modelling has enhanced the understanding of ecological processes in the Mediterranean and there have been a range of modelling studies ranging from vegetation dynamics (eg, Pausas, 1999; 2003; Lloret *et al.*, 2003) to species life cycles (eg, Peñuelas *et al.*, 2002), using different methods (Escudero *et al.*, 2003; Marin *et al.*, 2003) and at different spatial scales (eg, Thuiller *et al.*, 2003). Today these simulation techniques can be linked with GIS to give spatially explicit results and investigate patterns of ecological processes (see review in Scott *et al.*, 2002a). Although these attempts are still limited in the MB there is work currently under way to expand the vegetation simulation model FATE (Lloret *et al.*, 2003) for fire prediction to a new version that will integrate some GIS facilities/operations (Pausas, personal communication).

The complexity of nature and in particular the variation of species interactions and their responses to the environment make predictive models a difficult task. The conceptual issues, methods and limitations of these models have been thoroughly reviewed by Franklin (1995), Guisan and Zimmermann (2000) and Scott *et al.* (2002a). Some of these issues in the Mediterranean context have been discussed by Vogiatzakis *et al.* (2003b). An important point when modelling in particular within the GIS is that the factors to be used have to be measurable and mappable. For example, it is widely accepted that understanding current species and vegetation patterns in the MB requires an understanding of past human activities (eg, Pausas, 1999; Allen, 2001). This has been argued for the distribution of *Quercus coccifera* in Spain (Pausas, 1999) and *Quercus suber* in Sardinia (Vogiatzakis and Careddu, 2003). Therefore, it has been suggested that the inclusion of disturbance history when mapping actual or potential vegetation is necessary (Franklin, 1995; Pausas, 1999). Where a long series of records is available disturbance factors has been included in the modelling process (eg, Carmel *et al.*, 2001). However, it is generally admitted that this type of information is rarely available for incorporation into a GIS (Norton and Nix, 1991).

Although the construction of a good model requires reliable and sufficient information (see Pausas, 1999), the lack of information is usually a driving force for the development of predictive models. Where information are not available to provide map layers for inclusion into GIS, other tools of spatial analysis such as geostatistics (Webster and Oliver, 2001) can be employed. The use of geostatistics in combination with GIS has been advocated by Burrough (2001) and has been facilitated by the current availability of geostatistical routines/extensions within commercial GIS software such as Idrisi and ArcGIS. Although primarily used in the MB in soil science (eg, Kollias *et al.*, 1999; Castrignano *et al.*, 2000; Theocharopoulos *et al.*, 2003) there are many applications in vegetation and land-use studies.

In Italy, for example, Tasser and Tappeiner (2002) used GIS and geostatistics to investigate the impact of land use on vegetation in the Passeier Valley of South Tyrol, while in a study area in Tuscany Maselli *et al.* (2001) used kriging to estimate forest composition and structure in order to supplement information derived from Landsat TM imagery. Maestre and Cortina (2002) used geostatistics among other techniques to investigate the spatial pattern of soil properties and vegetation and their relationship in a semi-arid *Stipa tenacissima L.* steppe in SE Spain.

In addition to geostatistics most GIS packages have also inbuilt routines capable of dealing with fuzzy sets (Burrough and McDonnell, 1998). Fuzzy methodology has become an invaluable tool when dealing with spatial uncertainty in ecology (see review by Hunsaker *et al.*, 2001). This is a critical issue for spatial analysis and modelling since both GIS and remote sensing create approximate representations of geographical objects (Goodchild, 1994; Foody, 2002). Most of the examples where fuzzy methodology has been employed come from remote sensing applications, for example Maselli *et al.* (2000; 2001), with few exceptions (eg, Carranza *et al.*, 1998). The use of fuzzy sets in a GIS approach has few applications in the MB although Vogiatzakis *et al.* (2003b) have used it for mapping transitional areas in the Lefka Ori massif of Crete.

3 Identifying conservation priorities

Although a significant number of protected areas have been designated in the Mediterranean region, there are still gaps, indicated by recent studies on the protection level for European forests (Quezél *et al.*, 1999; WCMC, 2000). As a result it has been argued (see Scarascia-Mugnozza *et al.*, 2000) that we need to develop new tools based on GIS and simulation models to address gaps in conservation. Techniques like 'gap analysis', a concept relying on GIS techniques, provides a means of rapidly reviewing the distribution and conservation status of several components of biodiversity (Jennings, 2000).

This has already being applied at the European level looking at the current state of protection of European forests (WCMC, 2000). Similar approaches can be employed in the MB in order to identify gaps that may be filled through the establishment of new reserves or changes in land-management practices, or to determine the extent to which a focal species or habitats of European importance is adequately protected by the proposed Natura 2000 sites. For example, Berberoglu *et al.* (2004) used GIS to relate land-cover maps derived from imagery interpretation with the spatial distribution of plant and birds as recorded in census data to inform conservation policy in the Çukurova Delta, Turkey. In another study, Sfenthourakis and Legakis (2001) used GIS to identify biodiversity hot spots of endemic terrestrial invertebrates in southern Greece based on known distribution patterns of 424 species.

Increasingly simple scoring procedures to rate the conservation significance of areas, ie, iterative algorithms, are being used in practical applications aimed at conservation implementation on the ground (Pressey and Cowling, 2001). These principles have been used either in combination with a GIS (eg, Freitag *et al.*, 1998; Woodhouse *et al.*, 2000) or they have been built within a GIS as in the case of WORLDMAP. WORLDMAP (NHM, 2003) is a GIS programme designed for exploring geographical patterns in diversity, rarity and conservation priorities from large biological data sets. Since it is primarily targeting biological analysis it has features not yet available in commercial GIS software. Another example of a customized GIS software is DIVA-GIS by the International Plant Genetic Resources Institute (IPGRI) which was developed specifically for use with genebank data such as that available through national or international genebank documentation systems (IPGRI, 2003). Moreover, it allows identification of areas with complementary levels of diversity and extracts climate data for points of interest. This software could be used to suggest conservation priorities in the MB region.

The lack of resources that many countries face in the Mediterranean, particularly in the south and east, dictates that a realistic conservation plan should involve some form of prioritization among the possible conservation targets. A wide range of criteria has been used in nature conservation for that purpose (Heywood and Watson, 1995) that vary worldwide due to differences in biogeography, human population densities and scale of biological surveys (Spellerberg, 1992). Methods such as Multiple Criteria Evaluation (MCE) can combine the information of several criteria into a single index of evaluation as for example in a case study for the syntaxa in Greece (Dimopoulos *et al.*, 2000). Similar decision-making schemes can be supported within a GIS software and therefore allow the testing of different conservation options and scenarios based on a spatial database (Store and Kangas, 2001). A successful use of MCE in a GIS environment was a case study in Crete by Boteva *et al.* (2004). In this study five criteria were used in a Weighted Linear Combination scheme in order to assess and map the conservation value of areas within a Natura 2000 site in NW Crete. Moreover, Kitsiou *et al.* (2002) developed a methodology for the multidimensional evaluation and ranking of coastal areas in the island of Rhodes, Greece using a set of socio-economic and environmental criteria and based on the combination of multiple criteria choice methods and GIS. Similar methodologies may be employed in other Mediterranean areas/countries.

Perhaps one of the best examples that demonstrates the multiple uses of GIS in plant conservation programmes is the study by Draper *et al.* (2003). In this study GIS plays an important role in the conservation strategy of the Lisbon University Botanic Garden and has been used for comparison of ecological patterns, selection of protected areas, impact analysis of invasive species and as a tool for designing and implementing seed collection.

4 Landscape planning and management

Apart from evaluating the structural and functional changes of landscapes (eg, van Eetvelde and Antrop, 2004; Romero-Calcerrada *et al.*, 2004), GIS can also assist in the development of landscape planning and management tools and in resolving potential conflicts. The measurement of the impact 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 and 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 is an integrated and hierarchical spatial framework that incorporates both the physical and cultural dimensions of landscape. Physical data are used to delineate polygons which define uniform physical conditions of geological structure and lithology, soil type, landform and climate. In the context of northwest Europe additional cultural information on settlement pattern, land use and woodland cover is used to subdivide areas of uniform physical environment. Thus a coherent and integrated spatial 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. There is currently only limited interest in this approach in Mediterranean countries. For example, in Portugal (Pinto-Correia *et al.*, 2002) there is an initiative to develop a national-scale map of land cover at the broad scale. The work produced 128 major landscape units for the entire continental part of Portugal, organized into 22 regional groups. The units are being used as the spatial framework for deriving indices of change and pressure at the landscape scale. This changes include, for example, the rate of agricultural change, intensification or extensification of agricultural systems, concentration or disappearance of farm units; density of human-built elements and measures of landscape pattern from air-photographs such as density and diversity of patches of semi-natural vegetation. Elsewhere, landscape classification has been employed to predict the distribution of coastal plant communities (Acosta *et al.*, 2003) in central Italy and to establish the relations between human impact and vegetation in western Crete (Tzatzanis *et al.*, 2003). Moreover, landscape character is forming the basis of the design of habitat networks for the restoration of cork oak (*Quercus suber* L.) on Sardinia (Vogiatzakis and Careddu, 2003) and for deriving indices of ecological condition for the island of Gozo, Malta (Cassar, personal communication). Perhaps one of the most significant advantages of a landscape character approach is the potential to develop options for future landscapes across different landscape types. There is increasing recognition that policies in the past have not always been sensitive to the often subtle differences in the physical *and* cultural aspects of a landscape, and that landscape character provides the potential to account for such differences in the development and implementation of future policy.

There is also increasing evidence that planners, land managers, etc, need to be involved in the decision-making process to ensure the success of the implementation of policies for the future. Moreover, there is the need to design a multifunctional landscape which will accommodate diverse, often conflicting, activities such as conservation, recreation and agriculture. An important question to be addressed in landscape planning is how can a landscape accommodate change?

Two fundamental concepts linked to this question are landscape sensitivity and capacity. Landscape sensitivity, be it ecological, cultural or perceptual, is the ability of a landscape to accommodate change or development while capacity refers to the amount of this change (Swanwick, 2004). A future challenge therefore is to develop ways to measure the different components of sensitivity as well as tools to respond to different spatial scales of change within a landscape. Diverse examples of change may include the location of a new tourist resort, often the case in the MB, or the development of landscape-scale habitat networks through woodland creation in order to reduce isolation and fragmentation as employed in northern Europe (see Lee *et al.*, 2002). This requires the development of techniques to visualize the future landscape to communicate the impact of change to both policy-makers and local people. The use of GIS for these assessments provides a convenient and relatively standardized means to manage the range of information and scales involved but also the ability to map every aspect of the work, increasing accessibility of the method and the findings. In particular, novel visualization approaches for the identification, evaluation and communication of changes in the landscape are now supported by GIS and can be used to provide insights into the evolution of landscapes in the past and options for change in the future (McLure and Griffiths, 2002; Appleton and Lovett, 2003; Brabyn, 2003). Appleton and Lovett (2003), for example, have demonstrated the potential of VRML (virtual reality mark-up language) within a GIS for presenting different 'biodiversity scenarios' for a lowland agricultural landscape in England. Visualization techniques simulate the visual appearance of a landscape as realistically as possible using a combination of digital elevation models (DEMs) to allow for perspective views of the landform from different elevations and directions and feature simulation. These techniques can promote in particular stakeholder participation and lead to improved outcomes when considering options for future landscapes in the Mediterranean Basin.

V Conclusions

The global importance of Mediterranean-type ecosystems, especially those of the Mediterranean Basin, makes the need for conservation measures a priority. Conservation efforts are faced with common problems throughout the Mediterranean Basin, including fire, overgrazing and tourism development, combined with inadequacy of legislation or ineffective enforcement as well as the lack of political commitment to protect the natural habitats. However, the scale of these problems and the means/tools to solve them reflect a clear divide between the countries of the north and south Mediterranean, as already pointed out by several authors (see di Castri, 1981; Allen, 2003). For example, in the north the traditional agrosilvopastoral systems are collapsing (Pinto-Correia, 2000) while in the south human population continues to increase and there is an intensification of animal husbandry (Allen, 2003). Mediterranean countries that are member states of the European Union have better resources and quality of information as well as stricter enforcement of conservation legislation (see Morillo and Gomez-Campo, 2000; Moreno-Saiz *et al.*, 2003) than those outside the EU (Kaya and Raynal, 2001; Green *et al.*, 2002).

The efficient assessment of biodiversity requires a variety of biological, ecological and cultural information. Even in countries like the United States and the United Kingdom, where this information is readily available, it is generally not acquired as part of a coordinated environmental management system. As often pointed out, this information is scattered among different organizations in incompatible formats, making its location and integration problematic (Griffiths *et al.*, 1999). The urgency for conservation in the MB requires the use of all new tools available for conservation assessments and for pinpointing appropriate conservation targets. During the last 30 years parallel developments in computer-based cartography and modelling have improved the capacity to acquire and analyse information and therefore the possibilities to extend ecological research whether for nature conservation or planning purposes. The main and indispensable tool for these purposes is GIS due to its ability to merge data from different sources, construct spatial models or incorporate models built externally, increasing the speed of assessments while reducing the costs involved (Franklin, 1995; Guisan *et al.*, 2002).

Although GIS is now widely used by researchers in the MB, its full potential has not yet been realised. Emphasis has been placed mainly on the storage and management of information and there has been some limited spatial analysis, while gaps have been identified on predictive mapping, gap analysis and landscape ecology applications. What seems to have been neglected is an explicit link between GIS research and policy implementation at the landscape context. This is particularly the case for the south and east Mediterranean.

As this review has shown, there is a bias in the current literature towards EU countries and the lack of information from North Africa, the east Mediterranean and the Balkans. The absence of studies from these areas might be real or simply a language artifact. There might be studies in Arabic or Slavic that are not widely disseminated to the western world. This is one more proof of the area's diversity and the need for increased collaboration and knowledge transfer throughout the Basin.

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