MAN AS DESIGNER OF MEDITERRANEAN LANDSCAPES

Robustness of the thousand-year-old story of humans and ecological systems in the Mediterranean

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Summary

What makes the structure and dynamics of coupled natural and human systems difficult to describe and interpret in the Mediterranean region is the extreme diversity in space and time of both environments and human societies. The succession of civilisations that waxed and waned over several millennia have had great impact on biota and ecosystems everywhere in the Basin, resulting in many changes in the structure and dynamics of landscapes. Human societies have been so closely intermingled with their environment that a complex 'co-evolution' has been claimed to shape the interactions between ecosystem components and humans. Two schools with opposite views traditionally considered the consequences of human pressures on Mediterranean ecosystems. The 'Ruined Landscape or Lost Eden theory' argues that human action resulted in a progressive and cumulative degradation and desertification of Mediterranean landscapes. The second school challenges this pessimist view and argues that humans actually contributed to keep Mediterranean landscapes as they progressively established since the last glacial episode. I will show in this chapter that (i) One cannot understand the components and dynamics of current biodiversity and ecosystem functioning in the Mediterranean without taking into account the history of human-nature interactions, ii) Various and ingenious systems of land use and resource management provided a framework for the blossoming of Mediterranean civilisations, (iii) Combined with the domestication of plant and animal species, these systems had both positive and negative feedback cycles at local and regional levels through empirical trial and error processes that kept ecosystems running on the long term, presumably making them robust and resilient, (iv) Assuming that human action can be considered as a surrogate for large-scale disturbance, such patterns give support to the diversity-disturbance hypothesis

according to which intermediate levels of disturbance promotes biological diversity. A high degree of resilience of Mediterranean ecosystems presumably resulted in a dynamic coexistence of coupled natural-human living systems that have been characterized by stability, diversity, and productivity for many centuries. The collapse of traditional rural land use systems at the end of the 19th century, and especially after the two world wars completely changed the relationships between humans and nature in the Mediterranean. This chapter takes up some ideas and data that have been published in the book *Biology and Wildlife of the Mediterranean Region* (Blondel and Aronson (1999).

Introduction

The Mediterranean has been a cradle for the birth, blooming, and collapse of some of the most prestigious and powerful civilizations in the world. Their impact on biota and ecosystems everywhere in the Basin have existed for so long that some authors, e.g., di Castri (1981), did not hesitate to claim that a complex 'co-evolution' has shaped the interactions between them and humans through long-lasting but constantly evolving land use practices. Two contrasting theories consider the relationships between humans and ecosystems in the Mediterranean. The 'Ruined Landscape or Lost Eden theory', first advocated by painters, poets and historians in the 16th and 17th centuries, and then by a large number of ecologists, argues that human action resulted through deforestation and overgrazing in a progressive and cumulative degradation and desertification of Mediterranean landscapes. This theory denounces the destruction of the former magnificent forests which were supposedly so lush and large that a monkey could have travelled from Spain to Turkey almost without leaving the crown of the trees! One example of this view has been vividly depicted by David Attenborough in his book, *The First Eden. The Mediterranean World and Man* (Attenborough 1987, see also Naveh 1973, McNeil, 1992) and Thirgood (1981) emphasized at least ten millennia of 'resource depletion' to describe the interaction of man and the Mediterranean forest. Challenging this pessimist view the second school dismisses the supposedly detrimental effects of humans arguing that the imaginary past idealized by artists and scientists does not acknowledge the fact that humans actually contributed to keep Mediterranean landscapes as they progressively established since the last glacial episode, stressing that savannah-

like landscapes are characteristic of the Mediterranean (Grove and Rackam 2001). Truth is inevitably between these two extremes which are of crucial interest in the scope of a discussion on the robustness of coupled natural and human systems. The lack of quantified data on what landscapes and ecosystems looked like in the course of history and the extraordinary complex human history of the region with many ups and downs in the fate of human societies, combined with the huge diversity and highly dynamic structure of Mediterranean habitats, makes it extremely difficult to reconstruct the ecological trajectory of natural communities and how living systems accommodate to both the intrinsic variability of Mediterranean bioclimates and human activity.

Apart from some remote mountainous areas, there is hardly any square metre of the Mediterranean basin which has not been directly and repeatedly manipulated and more or less‘re-designed’ by man in the course of the 300 generations or so of human occupation of the region. At a regional scale, the constant re-design of landscapes and habitats had profound consequences on the distribution, dynamics and turnover of species and communities. Changes in the distribution of species and local extinction events were more or less compensated by intraspecific and interspecific adaptive differentiation that occurred as a response to man-induced habitat changes (Naveh 1994). There is much evidence, including comments by Latin writers, e.g. Polonius and Virgilus, that the landscapes that resulted from these changes have been empirically designed in such a way that they were most probably highly resilient and robust insofar as traditional land uses were maintained, which has been the case for centuries.

Several millennia of interaction between man and nature

Thanks to its geographic situation at the margins of three continents, which resulted in a composite biogeographic origin of its flora and fauna, combined with an extremely complex geological history and geomorphology, the Mediterranean is a region of dramatic variety of species, habitats, landscapes and peoples. As Grove and Rackam (2001) put it, taking the island of Crete as an example, ‘Crete, a splinter of land 250 x 50 km, is a miniature continent with its Alps, its deserts and jungle, its arctic wastes and its tropical gorges, where an afternoon’s walk goes from something looking like Wales to a rough equivalent of Morocco’. Charcoal remains found in this island suggest that

during the Middle and late Minoan culture (*c.* 4000-3000 yr BP) the landscapes around the city of Kommos consisted of intricate mosaics of cultivated fields and orchards alternating with semi-natural woodlands exploited for wood and other products for centuries without interruption (Shay *et al*. 1991).

Just as it was for plants and animals, the Mediterranean Basin has always been a crossroads for humans so that human tribes and cultures of extraordinary diversity have produced a mosaic of cultural landscapes which have added and superposed their biological and cultural characteristics to the previous ones. From the dawn of human history a great many populations of *Homo erectus, H. neanderthalensis* and then *H. sapiens* were distributed all around the Mediterranean, dating back to 700 000 yr BP in Algeria and 450 000 yr BP in the Eastern Pyrenees (Tautavel man). In the Levant, Turkey, and Mesopotamia, records of permanent human settlements go back to the inter-glacial periods of the late Pleistocene and human remains have been found in the island of Sardinia, dating back to 20 000 yr BP (Sondaar *et al*. 1995).

According to Naveh and Dan (1973) human impact has had direct and sustained effects on Mediterranean living systems since at least 50 000 years but a true 'revolution' occurred about 10 000 years ago, when hunters in the Near- and Middle-East began to produce their own food supply and thus laid foundations for the domestication of plants and animals. Each successive culture kept some features from the previous ones and added new features so that landscapes result from the superimposition of a series of land use practices each of which leaving signals that are still visible today (Dupouey *et al*. 2003). Of course, the fate and various wealth of societies much varied in time, which had consequences on the pressure of man on living systems. For example, following the catastrophic second half of the 14th century when the Black Plague struck southern Europe, a demographic renaissance took place, accompanied by renewed clearing and cultivation of lands which had been abandoned during an entire century of famine and plague.

The first significant impact of humans, long before the Neolithic revolution and the establishment of permanent settlements, was the probable role of man in the extinction of a number of large mammals at the end of glacial times, including on islands which have also been colonized and man-transformed for nearly as long as the continental lands. If

the overkill hypothesis suggested by Martin (1984) to explain the sudden disappearance of so many species of large mammals in the northern Hemisphere at the end of the Pleistocene is still in debate (see e.g., Owen-Smith 1987), there is much evidence of the direct responsibility of man in the extinction of the 'megananofauna' of Mediterranean islands. This fauna included strange mammal assemblages with dwarf hippos and elephants of the size of pigs and dogs (Diamond 1992). Archaeological sites in Cyprus showed that human colonization of that island began as early as 10 500 yr BP (Simmons 1988) and was soon followed by the slaughter of these mammals. The disappearance of large mammals had important consequences on the structure of landscapes by eliminating their role as key species that contributed to open forests, maintaining them in a mosaic-like structure.

By far the most obvious consequence of human action has been forest destruction as shown by a great many palaeobotanical, archaeological, and historical records. Forests extend today over 85 million hectares, that is a mere 9.4% of the area of the Mediterranean Basin (Marchand 1990) and Quézel (1976) estimated that no more than 15% of the 'potential' Mediterranean forest vegetation remains today, while the rest in more or less advanced stages of deforestation and soil degradation. Pollen diagrams showed that large-scale Neolithic deforestation in the Alps and the Pyrenees coincided with a warmer, moister climate, and the steady expansion of cereal culture as a result of human demographic expansion (Triat-Laval 1979). Forest destruction had two consequences. The first was the progressive replacement of deciduous broad-leaved forests by evergreen sclerophyllous forests and matorrals which, in combination with an increase in habitat patchiness over time, had many consequences on the distribution of populations and species as well as on their genetic diversity. The second consequence of forest destruction was a generalized desiccation of the Mediterranean as a whole because of the rupture in water balance as a result of changes in water-flows. As plant cover decreased, surface runoff and stream flow increased, often resulting in a dramatic increase in soil erosion in many parts of the Basin, especially in North Africa.

The prerequisites for establishing sustainable land use systems

Various systems for capturing and managing resources provided a basis for the blossoming of Mediterranean civilisations. Forest management through wood-cutting and coppicing, controlled fire, plant and animal domestication, livestock husbandry, grazing, and browsing, as well as water management have been for centuries the main tools for producing 'intermediate disturbance' regimes which were a golden rule for establishing sustainable agro-silvo-pastoral ecosystems.

Managing fire

The use of fire by Palaeolithic hunter-gatherers goes back at least 500 000 years in parts of the Mediterranean (Naveh 1974, Trabaud *et al*. 1993) and was used for a variety of purposes. Managing and living with fire has been an immemorial challenge for Mediterranean peoples because the combination of forest cutting and fire lighting was a prerequisite for the development of grazing and browsing areas by domestic ruminants, hence being one of the most important forces shaping Mediterranean landscapes. Fire has been and still is the factor that had the highest structural effect on ecosystems and landscapes. When landscapes were intensively managed by dense rural populations who regularly lighted them intentionally, most fires were not harmful since they were immediately attended to and quickly controlled. Fires are disturbance events that contributed to maintain the 'moving mosaic' of communities and ecosystems at the scale of landscapes (Pickett and White 1985), playing just as important a role as grazing in the maintenance of open spaces and the management of mosaic landscapes.

Domestication of plant and animal species

Domestication of animals and plants began about 10000 yr BP in the Mediterranean Basin, and started earlier in the eastern part than in the western part of the Basin because the so-called Fertile Crescent, the area that stretches from the Jordan valley through Syria, Turkey, and the mountains, plains and valleys of Iraq and Iran, was a region of intense human development in a particularly rich and productive area.

The precise origins of agriculture probably occurred concurrently with the domestication of animals in the Mediterranean between 9000 yr BP and 11000 yr BP,

especially its eastern part which is one of the most important centres of origin for crop plants of worldwide importance (Hawkes 1995). Vavilov (1935) noticed that many ancient cultures and cultivated plants prototypes come from the Fertile Crescent. Estimates approach around 500 cultivated crop species and varieties in the Mediterranean Basin. The invention of agriculture divided the plant world linked to agricultural practices into two parts, the 'segetal' and the 'non-segetal' (Zohary 1973), and created a barrier between what might be called 'anthropogenic' and 'primary' plants. It also separated modern history into a 'segetal era', which began with the Neolithic domestication of plants, and the earlier, 'pre-segetal era'. Cultivated plants in the Mediterranean included grain crops forage plants, oil-producing plants, fruit crops, vegetables, and a vast range of condiments, dyes and tannin agents. Many protein-rich pulses were domesticated in Neolithic farming villages of the Near-East, between 9000 and 8000 yr BP, and then accompanied cereals in their rapid spread throughout the Old World. The perennial alfalfa was apparently domesticated in the Middle-East sometimes between 6000 and 8000 yr BP, and from there was carried east to all parts of the Basin. Hybridizations, autopolyploidy, and introgressions took place with related perennial species including *Medicago falcata* in northern Europe, *M. glutinosa* in the Caucasus, and *M. coerulea* and *M. glomerata* in the Mediterranean Basin (Lesins and Lesins 1979). At least two natural hybrids are recognised as good species *(M. media* and *M. varia)* arising from cultivated alfalfa back-crossing with *M. falcata*. In many species, adaptive intraspecific variation occurred as a response to man-induced selection and habitat changes over millennia, resulting in the differentiation of a burst of local ecotypes and gene pools in plant species, with region-specific characters fitting them to local climate and environmental conditions.

Domesticated races of wild cattle, deriving from the Auroch (*Bos primigenius*) and of the Water buffalo (*Bubalis bubalis*), appeared more than 6000 years ago, perhaps from forms that were domesticated in Mesopotamia (Pfeffer 1973). Bull worship was long celebrated in many regions as best exemplified by the Egyptian Bull-God, Apis, and the famous Minotaur of Crete. Together with cattle, animals which have been soon domesticated or semi-domesticated were either predators, such as dogs because of their importance in protecting other domesticated animals from predators, or generalist

animals such as the wild boar which followed human groups to take advantage of their edible refuse. Other domesticated mammals of prime importance were horses (*Equus caballus*) and donkeys, domesticated from a wild Ass (*Equus asinus*) in Libya, 5000 yr BP. The exceptional qualities of the donkey, including its physical endurance and proverbial frugality, made this animal an invaluable daily companion in the harsh, dry, and mountainous Mediterranean environments. The Donkey's services to man included transportation of heavy loads on large pack saddles, pulling of ploughs, turning of mill stones, raising of water, threshing of wheat. When finally dead, the donkey provided excellent meat as well as tough hides used in the manufacture of parchment, clothing, and drum skins. But the domesticated animals of paramount importance for Mediterranean peoples and which have had the most widespread impact on Mediterranean ecosystems through grazing and browsing are sheep and goats, especially the latter which is a highly adaptable browser able to survive on very sparse fodder in mountainous terrain and semi-desert. Local varieties of sheep and goat occurred in almost all the large Mediterranean islands as well as in the oases on the borders of Morocco, Algeria, and Tunisia, and the oasis of El Fayum in Egypt (Georgoudis 1995). The most ancient domesticated goat remains were found in archaeological sites near Jericho, in the Jordan valley, and are dated at *c*. 8700 yr BP. The diversity of livestock breeds in the Mediterranean reflects the diversity of environments where humans selected their animals. Domesticated mammals provided meat, milk, wool, and skins for the manufacture of tools, clothing and tents, as well as an additional work force that multiplied the possibilities for working the land.

An extraordinary variety of ecotypes and gene pools of cutivated plants and domesticated animals have been selected over millennia by traditional agriculturists and pastoralists, with region-specific characters which fitted them to local climates and environmental conditions. Successful selection of local varieties and phenotypes was especially likely in the Mediterranean Basin which has been the theatre of local genetic differentiation during isolation of biotas in the many refuges that existed during glacial times as repeatedly shown from studies on the variation of genetic diversity across Europe (Taberlet *et al*. 1998, Hewitt 2000, Blondel and Mourer-Chauviré 1998). Speciation events should become more likely, particularly in plants, when previously isolated species are brought together and given the opportunity to hybridize, which

presumably occurred many times as a consequence of warming climates during inter-glacial times. In addition, speciation events may be promoted by the re-design of landscapes and habitats by humans. Such re-design may result in vicariance events causing allopatric distributions in which populations become isolated from one another. Small founder populations and subsequent genetic changes that they experience in their new habitat conditions could lead to the formation of new species. Although many hybridization events fail to produce fertile taxa, some do so and some of them, following changes in chromosome arrangements may form new genetically isolated and distinct species (Abbott 1992). The combination of local differentiation during glacial times and human-induced selection processes resulted in the production of more than 145 varieties of domesticated bovids and 49 varieties of sheep (Georgoudis 1995). Over the centuries, hundreds of varieties of olive, almond, wheat, and grape of economic value, which have been selected by humans definitely added to the biological diversity of the Mediterranean. For example, at the turn of the previous century, 382 named cultivars of almond were in use on the island of Mallorca alone (Socias y Company 1990). As pointed out by Diamond (2002), through the process of domestication, human influence on populations undoubtedly constituted a considerable selective factor in their evolution. Varietal inheritance of many cultivated plants results from a long history of peoples and anthropogenic activities, and is constituted today by thousands of cultivated varieties. For example, the olive tree, which is the most emblematic plant species of all Mediterranean cultures, currently constitutes a complex of many wild forms (*Olea oleaster*) as well as weedy types classified as *O. europaea* var *sylvestris*, and many cultivars classed as *O. europaea* var. *europaea* (Terral *et al*. 2004). Recent genetic studies have shown that selection on cultivars has occurred in different genetic pools, showing that olive domestication occurred in many parts of the Mediterranean Basin (Besnard *et al*. 2002), probably appearing for the first time as far back as the fourth millennium BC in Palestine (Zohary and Spiegel-Roy (1975).

Water management

The struggle for water has always been a vital thread in the history of all Mediterranean peoples and ingenious systems for collecting and storing rainwater have been used

unchanged for millennia. A great many systems sometimes dating back at least to the Chalcolithic period, 4500 to 5000 yr BP have been designed to hold the water diverter from the flood to fill city and farm reservoirs and for directly irrigating cultivated fields downslope. Near-Eastern peoples built and maintained elaborate and nearly labor-free systems of waterproof mortar first invented around 3300 BP. In the steppes and desert regions of Syria, Iraq, and Iran, an ingenious system of well-chains called *foggara* was developed whereby long inter-connected series of wells allowed underground transportation of water over many kilometres (Reifenberg 1955). In Turkey, a Hittite carving from the 8th century BC and ruins of irrigation networks testify the existence of long lasting irrigation devices dating back to the Seldjoukide Empire. The Nabateans, starting around 2500 BP, were particularly organised and determined in the practice of rainfall harvesting, as shown by the extraordinarily large cities they built in some of the most arid and desolate regions of the Near East, for example the ancient Biblical city of Sela, in southern Jordan, which was renamed Petra by the Nabatean Arabs. Then, the Romans carried runoff agriculture and water diversion systems to a high art. With their vast, centralized government, and large pools of forced labour, the Roman rulers were especially well placed to undertake large-scale construction, water transport and irrigation systems under a variety of conditions all around the Basin.

Terraces

In the highly dissected mountainous areas of the Mediterranean Basin, terracing has always been a time-consuming and tedious but necessary activity. Cultivated terraces were both a means of fighting against erosion and a water-saving device preventing water run-off. Hand-built stone terraces permitted cultivation on slopes ranging from 20% to 75%, sometimes requiring carrying soil up from the valleys on people's or animals' backs (Lepart and Debussche 1992). Until the early 20th century, terrace cultivation remained a hallmark speciality that indelibly shaped Mediterranean landscapes, from the mountains right down to the bottom of the valleys. Terraces were cultivated with a wide range of legumes, as well as a number of Mediterranean trees that have more or less disappeared from modern usage in farms and gardens, such as the Christ's thorn (*Paliurus spina-christi*) which was then widely used as a 'living fence' (Amigues 1980).

Carob trees were once planted very extensively primarily as a forage and fodder tree in association with sylvo-pastoral systems. Many Mediterranean landscapes, especially in Italy, are so indelibly marked and shaped by these artificial constructs that can remain for so many centuries that the Roman cadastre is still visible today from aerial photographs (Chouquer *et al*. 1987).

Traditional landscape designs

The re-shaping of landscapes through wood-cutting and the various activities described above allowed Mediterranean peoples to make the best profit of their domesticated plants and animals, and develop rural systems which, for an observer of the 21st century, appeared to have been quite sustainable judging by their very long persistence through time. Traditional Mediterranean civilisations were basically established everywhere in the basin upon a fine balance between agricultural and pastoral activities, with forest and woodlands being cleared and exploited as needed in the near vicinity of farms and villages. Gaston Roupnel (1932) explained how the "*primitive clearing"*, was the nucleus from which the first hamlets and villages expanded creating within large forest blocks a network of clearings more or less connected depending on the local geomorphological configuration of landscapes. Land use practices were basically related to a sedentary or at most a semi-nomadic life style including three main types of activities: wood exploitation and management, cultivation, and pastoralism. Domestic pastoral systems traditionally took different forms, depending on resource availability, local factors and cultural traditions: i) sedentary livestock raising, involving both stall feeding and free grazing, ii) semi-nomad pastoralism whereby the whole household moved with the herd, iii) the 'transhumance' system where only the herder moved with the stock. Transhumance is a remarkably well-adapted form which consists of biannual movements of herds and flocks between a lowland area and high summer pastures. The high plateaux and mountainous areas that typically delimit Mediterranean-type ecosystems, have traditionally served as an 'escape zone' for animals, where herds and flocks could find refuge, food, and water during the hot and dry Mediterranean summer. The semi-nomadic system of 'transhumance' dates back at least to the Bronze age and the routes followed by shepherds in the different regions were often those established by migration routes of

wild animals, especially the large herds of deer. The distances covered in the biannual movement of transhumance are typically of 100-300 km in magnitude in southern France and northern Italy but can reach up to 500-700 km in the semi-arid regions of southern Spain, southern Italy, and North Africa (Brisebarre 1978).

Landscape design varied considerably from one region to the next and from one historical period to the next, as a result of changing demographic, sanitary, and socio-economic conditions. It also varied from year to year with a practice of fallowing land every three or four years, producing a typical 'moving mosaic' which characterized all Mediterranean landscapes. Basically, rural peoples lived in autarky from their own crops, relying for survival on wheat, olive, milk, cheese, wine, meat from domestic and wild animals, and a large variety of domestic and wild fruits, as well as the innumerable natural products people could find in matorrals and woodlands. Autarky was largely imposed by the isolation of a myriad of small river basins separated by mountainous ridges. Over time, a large number of local land use systems, more or less clearly delineated in space, arose in the various Mediterranean hinterlands. They vary greatly according to regions and ethnic groups but the two best known are the Roman *Sylva-saltus-ager* system and the Dehesa-Montado systems.

The Sylva-saltus-ager land use system

The most influential and well known of all ancient land use systems in the Mediterranean area was the triad called *Silva-saltus-ager* (woodland-pasture-field) which was widespread in most areas of the Roman empire while the Dehesa-Montado system characterised land use practices in the Iberian peninsula and in many islands. The two systems provided the same services but differed in the spatial organization of the three main activities, cultivating, grazing, and forest products harvesting (Fig. 1). In the *Sylva-saltus-ager* the three activities occurred in separate areas whereas they were all combined in a single area in the second. The plot (or field) was the smallest unit of rural space used by farmers and was also the basis for cadastral registration and taxation (Lepart and Debussche 1992). Plant and animal macroremains as well as assemblages of pollen grains and soil properties found in several archaeological sites in France provided an insight into agricultural practices which may have been used by Roman farmers for centuries. In

an insightful archaeological study of French forests, Dupouey *et al*. (2002) demonstrated that the signature of agriculture and pastoralism dating back to the Romans are still visible today in the form of a mosaic distribution of certain plant species (e.g. *Vinca minor, Ribes uva-crispa*) which are typically linked to ancient human settlements, and soil properties (C: N ratio, soil phosphorus) which always occurred in the vicinity of human settlements. It is difficult to speculate about the robustness or stability of these coupled human and natural systems but their long-lasting history indicates that they provided the same kind of goods and services for centuries. Wise management of fields for long term sustainable services is indicated by the fact that Latin authors repeatedly mentioned the need for regular fertilization, using ashes, animal or green manure (Depouey *et al*. 2002).

In the cultivated part of the landscape near the nucleus of the villages, legumes (*Pisum sativum, Lens esculenta, Vivia* spp.*)* were intensively cultivated on carefully managed terraces. Plot limits often coincided with geomorphologic borders with rocky areas being often covered with forest to be used for wood, charcoal, and other forest products while stony plateaux were used primarily for extensive grazing of livestock. Animal bones found in archaeological sites indicate significant sheep rearing, together with goat, horse and cattle. Olive groves and vineyards were planted on terraces but also on thin soils at the foot of the hills, while cereal crops were cultivated on the deepest, most fertile soils, in the plains or in inter-montane valleys. The olive tree provides a good bio-archaeological model because this tree has occupied since prehistoric times a major place in the culture of Mediterranean peoples (Terral *et* al. 2004). The most energy-demanding crops requiring irrigation, fertilizers and a large amount of manpower were grown closest to the villages, mainly on terraces. As recently reported by Dupouey *et al*. (2002) present understorey vegetation differs widely among the categories of ancient land uses. Several centuries of farming during Roman times induced gradients in soil nutrient availability and plant diversity that are still measurable almost 2000 yr later. Modification of soil physical properties, conservation by biochemical cycling of changes in soil chemistry induced by cultivation, and the very low colonizing or competitive ability of some ancient forest species are the most likely mechanisms responsible for this long term impact.

The forest part of the triad was used for many purposes (Fig. 2): extensive grazing and browsing as well as for harvesting forest products, including semi-domestic fruits and nuts such as Pistachia (*Pistacia vera*, *P. atlantica* and *P. palestinus*), almond trees, olive and carob trees, Hawthorn (*Crataegus lacinata*) and a Pear (*Pyrus elaeagrifolia*). Various services and products forests offer to people have always been much more varied in the Mediterranean area than further north in Europe, including bee-keeping, hunting and gathering of useful plants, fruits, mushrooms, game, honey, shelter, medicinal plants, cork, tanning agents, and resins. In southern Europe, until the end of the 18th century, the Downy oak *Quercus humilis* (deciduous) and Holm oak *Q ilex* (evergreen) were used to make charcoal and for industry (glasswork, metallurgy). Since the Iron Age, charcoal has been the main source of energy in the Mediterranean area as testified by the myriad of ancient charcoal production sites, up to 40 sites per hectare, which are still visible in many woodlands. Thanks to the fine balance achieved among woodlots, pastoral grasslands, shrublands, and open spaces reserved for cultivation, the resulting mosaic greatly contributed to the biological diversity of Mediterranean landscapes.

Grazing, even heavy grazing is not necessarily a threat for biodiversity in Mediterranean habitats. The high degree of resilience of Mediterranean matorrals, especially in the presence of a balanced load of grazers and browsers, either domesticated or wild, can result in a dynamic coexistence of living systems characterized by great stability, diversity, and productivity (Etienne *et al*. 1989). Comparing two islands off Crete, one heavily grazed by the Cretan wild goat (*Capra aegragus cretica*) and the other ungrazed, Papageorgiou (1979) demonstrated that plant species diversity is much higher in the former than in the latter. Experiments have shown that population densities of gazelles in Israel of *ca* 15 individuals/km² not only allowed an optimal harvesting of animals each year but also resulted in a significant increase in plant species diversity of the rangelands (Kaplan 1992). The main conclusion is that a moderate grazing intensity keeps the full potential of species diversity and also optimises ecosystem productivity. Seligman and Perevolovsky (1994) obtained similar results in their review of both sheep and cattle grazing systems in the eastern Mediterranean. Some pastures in the eastern Mediterranean have been continuously grazed by domestic ruminants for more than 5000 years.

The Dehesa-Montado system

In the dehesa (in Spain) and montado (in Portugal) systems, the three main rural activities i.e., forest products harvesting, livestock husbandry, and agriculture are pursued conjointly in a single space. These systems combine extensive grazing of natural pastures and intermittent cereal cultivation (oats, barley, and wheat) in park-like woodlands, mostly consisting of Cork oak (*Quercus suber*), Holm oak and smaller numbers of deciduous oaks (*Q. faginea* and *Q. pyrenaica*). Livestock grazed acorns or chestnuts and grass under open forest or woodland cover, while annual or perennial crops were sown between planted or protected fruit or forage trees where they took advantage of the shade provided in summer. Various wood products were collected in the process including timber, charcoal, tannin, and cork. A variety of grazing animals were raised, including pigs, sheep, goats, cattle, and bulls. The dehesas and montados showed a remarkable stability, biodiversity, and sustained productivity since more than 800 years as a result of their balanced two-tiered vegetation structure, heavy incorporation of animal husbandry, and botanically-rich mosaic-like herbaceous plant layers (Joffre and Rambal 1993).

The two types of traditional land use systems, *ager-saltus-silva* and dehesa-montado both had positive albeit different effects on various components of diversity. Clearing forest on a large proportion of an area to plant pastures and crops allowed many species of shrubby and grassland habitats to colonize the area, thus increasing biological diversity at the scale of landscapes, the so-called gamma diversity. One may hypothesize that the other two components of diversity, namely alpha- and beta-diversity differed greatly between the two systems as a response to a different distribution of habitat patches - ‘coarse-grained’ in the *ager-saltus-silva* triad, and ‘fine-grained’ in the dehesa-montado system. The former was presumably characterised by moderate alpha diversity and a high beta diversity at the scale of individual plots whereas dehesa-montado was presumably characterized by still higher alpha diversity but much lower beta diversity at a similar spatial scale. Gamma diversity was probably of a similar order of magnitude in the two systems (Fig. 2). For many groups of plants and animals, the main consequences of traditional landscape design by humans in Mediterranean habitats have not been so much a decrease in overall species richness at a regional scale as a tremendous advantage for species adapted to drylands and shrublands, as opposed to forest dwelling species.

These two systems are examples whose sustainability derives from sub-optimal production, an adaptation to the highly variable Mediterranean climate (Joffre and Rambal 1993). Successful mimic systems should look for complementary species according to the 'M5' golden rule – Making Mimics Means Managing Mixtures (Dawson and Fry 1998). Mediterranean habitat mosaics have been for centuries a model illustrating the soundness of this 'M5' rule. Dehesa-like systems which developed over centuries, proved to be particularly robust and well adapted to local constraints. They are increasingly being recognized as well-adapted and economically viable multiple-use agro-ecosystems for promoting sustainable development in many farming areas of the Mediterranean Basin.

Lessons from the past: the limits to robustness and resilience

From the viewpoint of robustness of coupled human-natural systems in the Mediterranean, the main question is: how have Mediterranean ecosystems been resilient and resistant to these long-lasting human pressures? Is it possible to demonstrate that some kind of co-evolution between humans and living systems resulted in a sustainable ecosystem functioning and balance between extinction and immigration/differentiation of biota? Although it is admittedly difficult to speculate on ecosystem functioning of the past, it has been suggested that the low invasiveness of Mediterranean ecosystems, which sharply contrasts with the situation in many other regions in the world, especially the four Mediterranean-type regions (California, Chile, Cape Province, southern parts of Australia), could be a result of the strong interactions between humans and ecosystems. One possible explanation for this low invasiveness is that Mediterranean ecosystems have been subjected to continuous disturbance of fluctuating regimes and intensity over many millennia, which, accompanied by thousands of spontaneous colonization events, made ecosystems progressively more resistant with 'old invaders' preventing potential 'new invaders' (Drake *et al.* 1989) to enter the Basin.

From archaeological and historical records, and observing their response to current disturbance events such as rangefires Mediterranean ecosystems seem to resist heavy human impact and regenerate after abandonment or heavy degradation. The long-lasting management of Mediterranean space until the end of the 19th century, with a continuous

but fluctuating exploitation of all available resources, did not result in calamitous decrease in biodiversity, hence running counter the Ruined Landscapes theory. Overall, it appears that human activities have in fact been beneficial for many components of biological diversity in the Basin. Gomez-Campo (1985), Pons and Quézel (1985), and Seligman and Perevolotsky (1994) have all argued that highest species diversities in the Mediterranean area are found in frequently but moderately disturbed sites, giving support to the diversity-disturbance hypothesis (see Huston 1994). The endless re-design of Mediterranean landscapes through various traditional systems probably much benefited to biological diversity in the Mediterranean area over several millennia. In order to understand how biological diversity and sustainable ecosystem functioning succeeded to persist across so many centuries without irreparable damage, a useful approach is to analyze the feedback mechanisms that keep ecosystems 'running'. Positive and negative feedback cycles at local or regional levels through a long empirical trial and error process has presumably been the strategy that kept the long term running of ecosystems and biological resources. This idea is illustrated in Fig. 3. The highest biological diversity in Mediterranean ecosystems probably did not occur in woodlands, even the pristine ones depicted by the first circle in Fig. 3, but rather in the various agro-sylvo-pastoral systems described in this chapter (Fig. second circle upper left). Then, as human pressures became stronger, especially when disturbance regimes reached some threshold values, diversity declined, and ecosystems followed new trajectories leading to alternative stable states that characterize either highly productive industrial style agriculture of heavily degraded ecosystems such as badlands. As pointed out by Scheffer and Carpenter (2003) surprisingly large shifts can occur in ecosystems and these shifts can be attributed to alternative stable states. For example gradual changes in land use practices or in the use of chemicals or other factors might have little effect until a threshold is reached at which large shifts occur that might be difficult to reverse.

Acknowledgements

Literature

Figure legends

Fig. 1. Predicted changes in values of three components of diversity, i.e., α-diversity (within habitat), β-diversity (between habitat) and γ-diversity (regional) in two traditional land use systems in the Mediterranean region, the Roman triad "*Ager-saltus-sylva*" and the "dehesa-montado" in the Iberian peninsula as compared to diversity in the primitive oak woodland. (Blondel and Aronson 1999).

Fig. 2. Changes in the use of forests and matorrals in southern France over the past 250 years. Dotted lines indicate a gradual increase or decrease of utilization. Thickness of the lines indicate the relative importance of each activity. Notice that most activities abruptly stopped after the two world wars, WWI and WWII (after de Bonneval 1990 and Soulier 1993 *in* Blondel and Aronson 1999).

Fig. 3. Changes in the diversity and ecosystem dynamics as a result of human pressure. Long lasting changes in landscapes result in shifts from one ecological trajectory to a new one when ecological thresholds are reached. Notice that the highest diversity presumably occurred in moderately disturbed ecosystems through agro-sylvo pastoralism. The number of arrows on the circles indicate the relative richness of ecosystem dynamics (after Woodward *in* Blondel and Aronson 1995).