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Effect of economic development on landscape structure and function in the Province of Seville (SW Spain) and its consequences on conservation

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SUMMARY - Changes in the landscape of the Guadalquivir River, Province of Seville, Spain, from 1750 to the present are described. The process of change has involved intensification of agriculture on fertile soils and abandonment of less fertile soils. The impact of modernization of agriculture and abandonment of land on conservation of habitats and the biota has been profound. Abandoned areas have frequently become shrubland which provides less food to wildlife, and is prone to soil erosion and fire. Cultivated areas have lost species as patches of uncultivated vegetation have disappeared. From the landscape perspective, the scale has shifted from a fine to a coarser scale, patch size has increased on abandoned areas and decreased in fertile areas. We conclude that when land is abandoned, restoration is required to avoid environmental problems and fine scale landscape heterogeneity should be maintained. A conservation policy should consider whole regions not just specific management areas, treated in isolation.

Key words: Seville, conservation, landscape, patches, scale, heterogeneity, restoration, Spain.

RESUME - "Effet du développement économique sur la structure et la fonction du paysage dans la province de Séville (S.O. de l'Espagne) et conséquences sur la conservation". Cet article décrit les modifications qui ont eu lieu dans le paysage entourant le fleuve Guadalquivir, dans la Province de Séville, Espagne, depuis 1750 jusqu'à nos jours. Ces changements ont été dûs à une intensification de l'agriculture sur les sols fertiles et à l'abandon des terres moins fertiles. La modernisation de l'agriculture et l'abandon des terres ont eu de profondes conséquences sur la conservation de l'habitat et du biote. Les terrains abandonnés sont le plus souvent devenus des maquis, peu capables d'alimenter la vie sauvage, et très vulnérable à l'érosion du sol et aux incendies. Les terres agricoles abritent un nombre moindre d'espèces, car les petits espaces non cultivés ont disparu. Du point de vue du paysage, il y a une modification d'échelle, de petite à grande, et la taille de ces "patches" a augmenté dans les terres abandonnées et s'est réduite dans les terres fertiles. Notre conclusion est que, lorsque la terre est à l'abandon, elle doit être restaurée, afin d'éviter des bouleversements environnementaux, le maintien d'un paysage hétérogène à une petite échelle étant nécessaire. Une politique de conservation devrait considérer le problème au niveau global de la région, et non pas à celui de petites zones d'aménagement traitées isolément.

Mots-clés: Séville, conservation, paysage, patches, échellé, hétérogénéité, restauration, Espagne.

Introduction

The objective of this study is to see how changes in landscape structure and function, related to economic development, have affected biological conservation in a broad mediterranean region, the province of Seville (14,000 km^2).

Study area

The province of Seville lies in the Guadalquivir valley, in south-western Spain (Fig. 1a). The climate is mediterranean, with a relatively high mean annual rainfall of 500-1000 mm. In summer, there is no rain in two months (July, August) and maximum daily temperatures

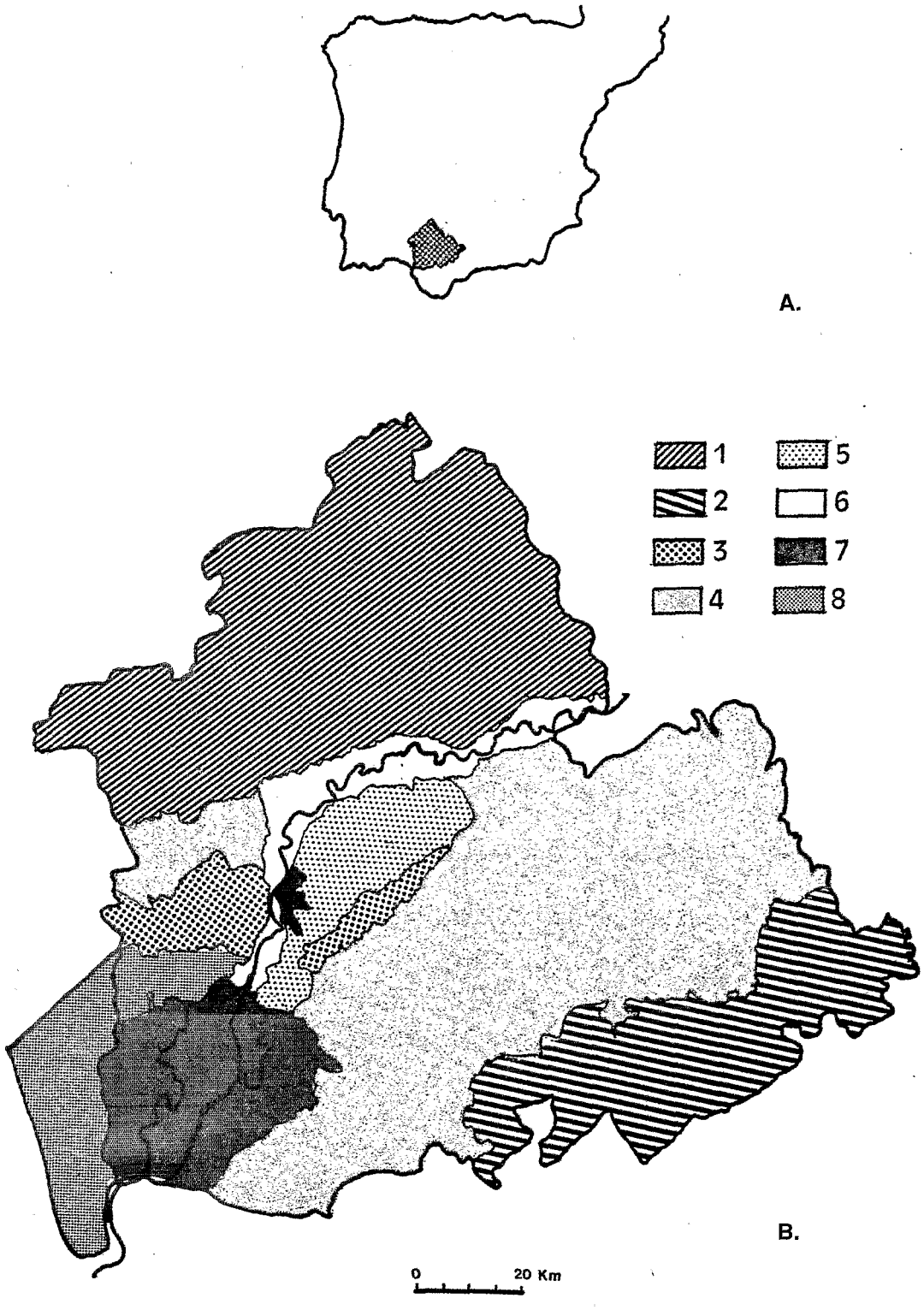

Fig. 1. a) Position of the Province of Seville in the Iberian Peninsula. b) Landscape units in the province of Seville and an adjacent area from the province of Huelva, where Doñana National Park is situated (from INIA, 1975, modified). 1. *Sierra Morena.* 2. *Southern Mountains.* Six units have been identified in the valley bottom. 3. *Plateaux.* Sandstone plateaux with underlying water table, cultivated for olives and irrigation systems. 4. *Countryside.* Black soils cultivated intensively for wheat, sunflower and olives on hillslopes. 5. *River floodplain.* Very fertile soils under irrigation. 6. *River terraces.* Coarse sediments cultivated with olive trees. 7. *Marshes.* 8. *Sand Sediments.*

are recorded of over 40 °C. The winters are mild, with frosts on fewer than ten days each year on average (I.N.I.A., 1975).

Patterns of land use over the region are associated with patterns of soil fertility (I.N.I.A., 1975; García Novo *et al.*, 1977; Junta de Andalucia *et al.*, 1985). The northern ranges (300-900 m, Fig. 1b) belong to the southern border of the Iberian Plateau, which is a peneplain partially eroded by Guadalquivir tributaries. The soils are poor and moderately acid. The dominant vegetation is natural: shrublands and open evergreen oak forests (*Quercus rotundifolia, Q. suber*) with grasslands, used for extensive livestock raising (cattle, sheep, pigs). The southern mountain ranges, also at a low altitude (300-1200 m), belong to the Penibetic system: steep, calcareous mountains raised by the Alpine movement. Natural vegetation again predominates: grasslands, shrublands and cork oak forests. The land is used mainly for livestock raising (cattle, goats, sheep), and the hilly areas are covered with olive groves. Both areas are rich in wildlife, and are also used for hunting.

The valley bottom (0-300 m) contains fine sediments that show a smoothly undulating relief, with very fertile black soils. The whole area is under cultivation. Olive trees cover the least fertile areas (river terraces, hill slopes), and cereal crops and sunflower the most fertile soils. The river floodplain is irrigated, and oranges, peaches, cotton, etc. are grown. The river marshes and sandy sediments (ancient dunes, river terraces), are the only land not utilized for agriculture, being too infertile. They are covered with natural vegetation (grasslands, shrublands, forests) and used for timber production (*Pinus pinea, Eucalyptus spp.*), cattle raising and conservation. Both the salt marshes and sand dunes comprise the Doñana National Park. The marshes are an important area for waterfowl (400,000 birds) and a wintering place for European ducks, geese and other birds. The surrounding forests and shrublands are one of the last refuges for two endangered species (IUCN, 1986)- the mediterranean lynx (*Lynx Pardina*) and imperial eagle (*Aquila heliaca*).

Changes in landscape structure and function

The landscape has changed from 1750 to the present day, with a monotonic tendency: extension and intensification of cultivated areas on the most fertile soils, abandonment of the least fertile ones (Table 1). The speed of the process is related to economic and social change.

In 1750, agricultural production was mainly for the local communities. The cultivated area was more evenly distributed over the province, with 50% of the land in Sierra Morena under crop production, and 25% of the valley bottom covered with forests and shrublands.

Table 1. Land uses at different dates in two contrasting and representative areas of Seville province; the first in the valley bottom, 150,000 ha, (Junta de Andalucía *et al.*, 1985) and the second in Sierra Morena, 140,000 ha, (M.A.P.A. *et al.*, 1986). Land uses in Sierra Morena in 1750 and 1853 from Vacher (1984).

	DATE			
	1750	1853	1956	1980
VALLEY BOTTOM				
Cultivated land	75.4	82.7	83.9	94.1
Irrigated	0.3	0.3	6.6	16.3
Herbaceous crops	61.8	53.3	43.3	67.1
Olive trees	13.3	29.0	34.0	10.7
Non-cultivated land (forests, grasslands, shrublands)	24.6	17.3	16.1	5.9
TOTAL	100	100	100	100
SIERRA MORENA				
Cultivated land	42.0	31.0	--	11.7
Continuous	1.0	1.5	1.0	1.8
Shifting	35.0	25.0	--	5.0
Olive trees	6.0	4.5	4.7	4.9
Non-cultivated land	58.0	69.0	--	88.3
TOTAL	100	100		100
Open forests with grasslands	53.0	60.0	60.0	46.0
Shrublands	38.0	33.0	34.0	40.0
Pine and Eucalyptus	2.0	1.0	1.0	7.5

At the beginning of the industrial revolution (1750-1853), the middle classes bought the land that had previously been communal property, and introduced changes in agricultural management (Bernal and Drain, 1975). The size of the cultivated area increased on the more fertile soils, and in the valley bottom olives were planted on the former grasslands, shrublands and forests. Sierra Morena was devoted to extensive livestock raising, the practice of shifting cultivation diminished and the area of grassland increased.

Throughout the next century (1853-1956), the improved traditional methods of agricultural production (rotation of cereals with legumes and grasses), improved throughout the province. Few changes in landscape struc-

ture were detected. Irrigated areas increased in size and fallow land decreased, but uncultivated areas remained as before. These areas were necessary for feeding draught animals (ox, mule) and for livestock. The latter played an essential role in fertilizing the fields.

The greatest changes were caused by the economic development which followed Second World War (1956-1980). Traditional methods of agriculture were replaced by high technology (Campos and Naredo, 1980). Full mechanization and continuous cropping with the application of chemical fertilizers and biocides are now common practice in agricultural management in the valley bottom. The cropped land now covers 95% of this area, and 20% is under irrigation. The fallow land has almost disappeared, and land units previously devoted to animal maintenance (grasslands, open forests) are now under cultivation. Olives have been replaced by the more productive sunflowers (Junta de Andalucia *et al.*, 1985).

In Sierra Morena, shifting cultivation has almost disappeared. Traditional methods of livestock raising have been improved, with the introduction of high-quality pasture species (*Trifolium subterraneum*), the crossing of the local breeds with more productive ones, and the feeding of animals with imported fodder (Campos, 1984; M.A.P.A. *et al.*, 1986). Pine and eucalyptus trees have been planted on former shrubland areas. However, the economic results have been poor and the area is being abandoned (M.A.P.A. *et al.*, 1986).

The Doñana sand dunes suffered a similar process to Sierra Morena (Ales and Martín, 1986; Granados *et al.*, 1987a). In 1640, the area was open to grazing, charcoal burning and cultivation. In the second half of the 18th century, numbers of livestock were reduced, and the area was devoted to hunting and timber production (*Pinus pinea*), the grasslands and croplands being maintained to breed game animals. In 1969, Doñana was declared a National Park. Human intervention is now prohibited throughout the area, and the croplands and grasslands are being invaded by shrub species.

How have these changes affected conservation?. Our examination will concentrate on the role of two aspects of nature conservation: the characteristics of landscape units, and their spatial distribution in the field.

Characteristics of landscape units

1. Abandoned areas

Non-cultivated or grazed areas in Sierra Morena and Doñana are covered with shrublands. The dominant species belong to the families Cistaceae (*Cistus ladanifer, C. salvifolius, C. crispus, C. libanotis, Halimium halimifolium, H. conmutatum, H. ocymoides)*, Labietae (*Rosmarinus officinalis, Lavandula stoechas, Thymus spp.)* and Ericaceae (*Erica umbellata, E. australis, E. scoparia, Calluna vulgaris)* (García Novo, *et al.*, 1977; Basanta and Sancho, 1983; Vacher, 1984). All these species have many characteristics in common: shrubs (never trees), with small unpalatable and indigestible leaves, rich in essential oils, and with large coloured flowers that are insect- pollinated. Their many small seeds form permanent seed banks in the soil, germinating after disturbance. Resprouting following disturbance is uncommon. Recently evolved, in a mediterranean climate, they are well adapted to human intervention (fire, cutting, grazing). They are considered as early colonizers in succession, and are also associated with shallow soils with a low water retention ability (Herrera, 1984).

Other species are present (*Quercus rotundifolia, Q. suber, Q. faginea, Arbutus unedo, Phillyrea angustifolia, Myrtus communis, Viburnum tynus, Erica arborea*) with different characteristics: small trees, with more palatable and digestible sclerophyllous leaves. They produce few, large, short-lived seeds in a fleshy fruit, that are dispersed by vertebrates. Seeds germinate in favourable sites (deep organic humic soils), and form seedling banks. After disturbance, they resprout from a subterranean organ, the lignotuber (Kummerow, 1988). They have evolved under temperate and subtropical climates, and are able to withstand their new mediterranean conditions. They are considered as late species in succession (Herrera, 1984). Apart from *Quercus spp.*, which were planted by man, all these species are poorly represented in the area. They are restricted to the more mesic and inaccessible places as dune depressions, steep riverbanks and north slopes (García Novo *et al.*, 1977; Fernández Ales, 1981; Basanta and Sancho, 1983; Vacher, 1984).

The dominance of small shrubs has been favoured by man's activities, such as grazing, cropping, prescribed fires and charcoal burning (Granados *et al.*, 1988). Although frequent disturbances can favour sprouting strategies rather than germination, they do not encourage the establishment of seedlings of small trees (Keeley, 1986). Charcoal burning with lignotubers, a common practice in the area, has lead to the decline of adult trees. Once these small shrublands become dominant in an area, autosuccession is common (Merino and Martín, 1981). Individuals become senescent after about 30 years, and from there onwards, dead biomass accumulates, favouring wildfires. After a fire, shrub seeds germinate, regenerating vegetation.

Vegetation in the abandoned areas has not favoured conservation. The present shrublands have fewer vertebrate species than the preceding open oak forests (Marañón et al, 1983) because less food is available (Basanta and Sancho, 1983). They are prone to soil erosion, as recurrent wildfires leave the bare soils exposed to wind and rainfall.

2. Cultivated areas

The cultivated areas have recently lost many elements that were formerly rich in wild species. Uncultivated patches (forests, grasslands, shrublands, fallowland) have almost disappeared. Olive groves, a most important wintering place for many European birds (González Bernáldez, 1981), have diminished. The changes have not improved conservation.

In forest plantations, devoted to timber production, animal diversity is low (Marañón *et al.*, 1983), and current planting techniques favour erosion (Granados *et al.*, 1987b).

Spatial patterns of land use

The spatial pattern of landscape units has changed at various scales. Landscape has lost fine-scale (1:10,000; 10^0 - 10^2 ha) heterogeneity. 60% of grassland patches in the sand dunes of Doñana have been invaded by shrubland or planted with pines (Fig. 2). The loss of fallowland in cropland areas and of shifting cultivation in rangelands like Sierra Morena has also diminished fine-scale heterogeneity (González Bernáldez, in this volume).

At medium scale (1:200,000; 10^2 -10^4 ha) patch size has increased in abandoned areas. In 1956, open oak forests dominated in Sierra Morena, and shrublands were fragmented in many patches smaller than 6,000 ha (Fig. 3). Twenty years later (1970), shrubland patch size has increased up to 25,000 ha and open oak forests have been partially fragmented. Shrubland has increased in the sand dunes of Doñana and the size of man-made areas has raised (Fig. 2), as patches of crops and prescribed fires (5-15 ha) have been replaced by patches of wildfires (> 40 ha). The only remaining grasslands are big patches associated to permanent water, as river marshes and big lagoons. Pine and eucalyptus plantations appear in patches over 1000 ha (Fig. 3) in marginal areas.

In the more fertile areas, patch size has diminished. The larger patches of natural vegetation (5,000 ha) in the valley bottom have been broken in many small ones (100- 500 ha), and many small patches (< 50 ha.) have been lost (Fig. 3). The same has happened with olive groves. Patch size of herbaceous crops has grown, as they have invaded the whole area.

The opposite trends of landscape changes at medium scale in productive and unproductive areas has increased contrasts between them. As a result, landscape structure has changed at regional scale (1:1,000,000; 10^4 - 10^6 ha) from fine-grained pattern to coarse-grained one (Fig. 4). Previously, crops, fallowland, olive groves, grasslands, shrublands and forests were present over the whole province. Now, continuous herbaceous crops cover the valley bottom, separating the big patches of natural vegetation that cover the northern, southern and coastal

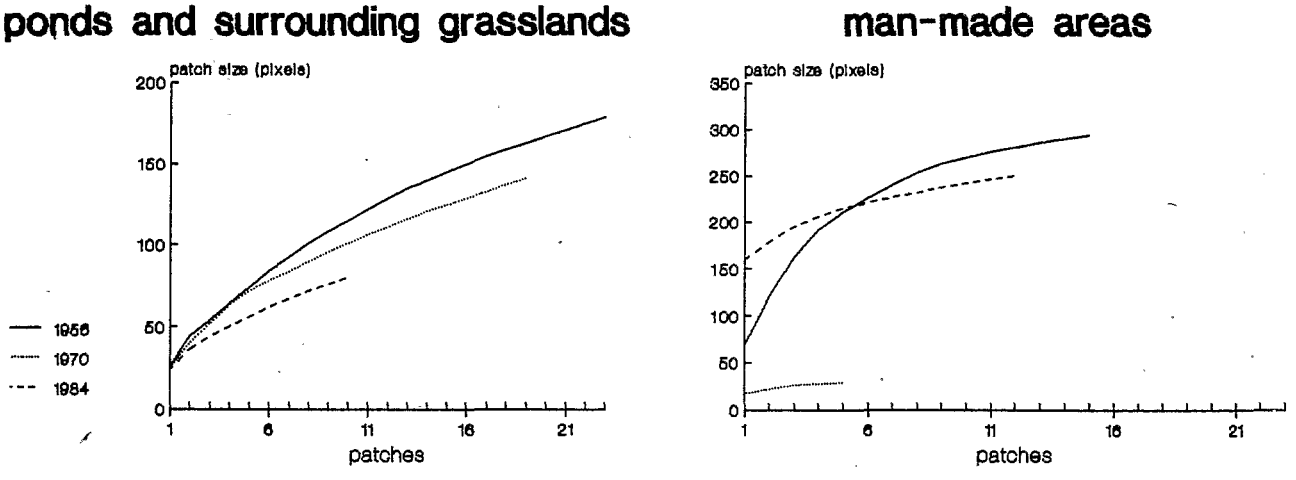

Fig. 2. Changes in patch size and number between 1956 and 1984 in a representative area (1430 ha) in the sand dunes of Doñana (Ales, 1987). Shrubland covers 60-70% of the whole area, forming a big patch. Grasslands, man-made areas (crops, prescribed fires and wildfires) and pine plantations appear in patches scattered among shrubland. Pine plantations have not been represented as they appear in only two patches: an ancient one (prior 1956) of 40 ha, and a new one (1970) of 290 ha. X axis: patches, ordered by their size. Patches smaller than 1 ha have not been represented. Y axis: cumulative patch size. Patch size is measured in pixels (1 pixel= 0.25 ha). Big patches of grasslands, associated to big permanent lagoons (Santa Olalla, Dulce), have not been represented.

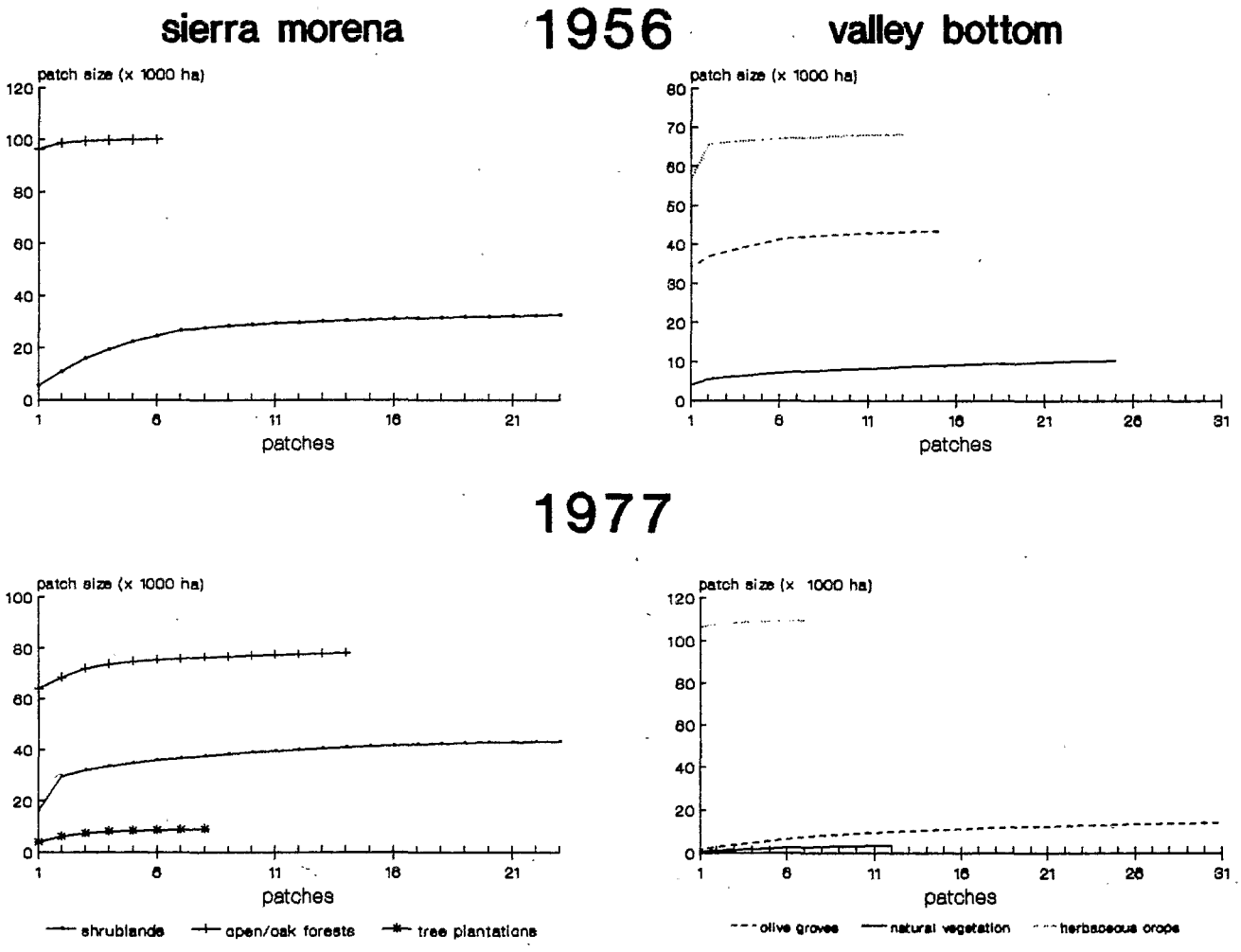

Fig. 3. Changes in patch size and number from 1956 to 1977 in the two areas of the province of Seville of Table 1 (Sierra Morena and the valley bottom). Continuously cultivated land and olive groves in Sierra Morena have not been represented as they do not change between these dates. X axis: patches, ordered by their size. Patches smaller than 50 ha in the valley bottom have not been represented. Y axis: cumulative patch size.

ranges. Relationships between areas of similar characteristics have diminished, as they become increasingly separated.

Increases in grain size have positive effects on conservation, as large areas with natural vegetation can provide shelter to species with large home ranges, as vertebrate top predators (Harris, 1984). But there are also negative effects. The spread of disturbance across a landscape is influenced by grain size. When a disturbance-susceptible habitat, as pyrophytic shrubland, passes a certain threshold of patch size, disturbance can spread through the landscape even when its frequency is low (Turner *et al.*, 1989). Since the sands of Doñana have been covered with shrubland, wildfires have become more frequent (Granados *et al.*, 1986). The extensive single-species forest plantations are very vulnerable to pests, which spread quickly, as in 1980-1984 with the Phoracantha in the eucalyptus plantations in the province of Huelva.

There are other characteristics of landscape structure that play also a very important role in conservation, as are the diversity of landscape elements (heterogeneity) and the structural links between them (connectedness). The loss of fine-scale heterogeneity in abandoned areas and of connectedness at regional scale has not improved conservation.

Spatial heterogeneity plays a very important role in maintaining species diversity in natural ecosystems, as it regulates interactions among species (Margalef, 1974). Shifting cultivation enhances herbage diversity in medi-

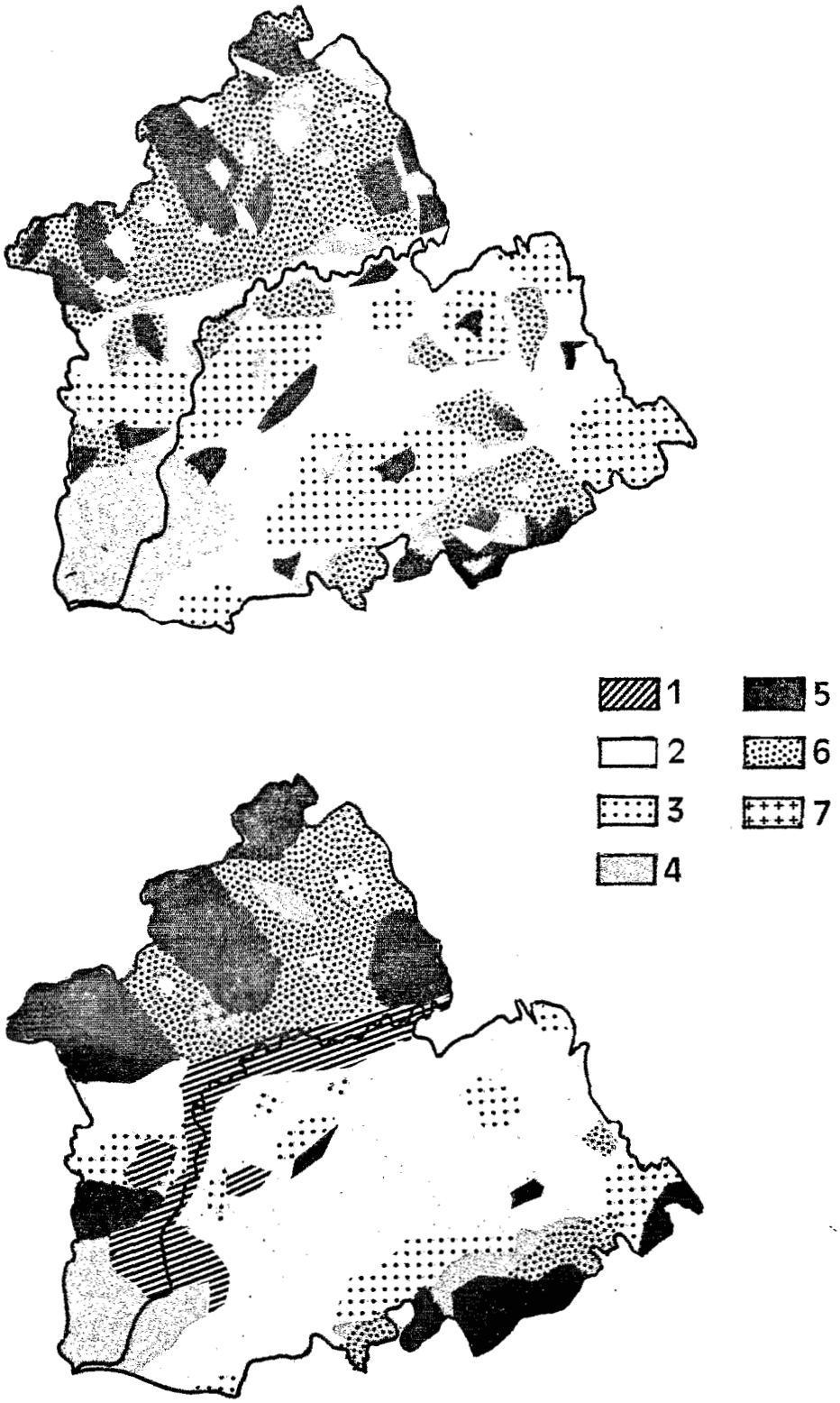

Fig. 4. Spatial pattern of land uses in the province of Seville in the past (pre-1950, upper figure) and present. It is a hypothetical reconstruction based on data from Table 1 and maps from different sources (INIA, 1975; García Novo *et al,* 1977; Junta de Andalucia *et al,* 1985; M.A.P.A. et al., 1986; M.A.P.A and Junta de Andalucía, 1986). 1. *Irrigated crops*. 2. *Non-irrigated herbaceous crops*. 3. *Olive groves*. 4. *Grasslands*. 5. *Shrublands*. 6. *Open evergreen oak forests*. 7. *Pine and eucalyptus plantations*.

terranean rangelands, as it allows the coexistence of species from different stages of ecological succession (González Bernáldez, in this volume). It also favours species that use different landscape units alternately, as many vertebrates that shelter in woods and shrublands, feeding on areas of herbage or fallow land (Margalef, 1974; Marañon *et al.*, 1983). The disappearance of small patches of crops and grasslands in the sand dunes of Doñana has negatively affected the rabbit population, a key prey species for big predators in the mediterranean ecosystems of the Iberian peninsula (Delibes and Hiraldo, 1981). This is endangering the survival of lynx and imperial eagle in the area (Aldama *et al.*, 1989).

Structural links between landscape elements control species fluxes, as connections may enhance species movement or behave as barriers (Baudry, in this volume). Previously, patches of woods and shrublands in the bottom of the valley were corridors that connected northern, southern and coastal ranges, allowing the expansion and genetic interchange between populations living in these areas. As these patches disappear, the great cereal steppes of the valley bottom have isolated the less transformed areas, and may lead to the local extinction of many species, specially those with large home ranges as is the case of the iberian lynx and imperial eagle in Doñana (Aldama *et al.*, 1989).

Conclusions

Two main conclusions can be drawn from this study.

- First, whenever land is abandoned, it must be accompanied by restoration. Ecosystems become so altered by centuries of use that they experience great difficulty in self-regulation, leading to serious problems (erosion, fires). In those abandoned areas which are intended for conservation, succession should be favoured by the introduction of mature species.

- Second, whatever the conservation policy, it should take into account the spatial structure of the landscape. Good conservation requires a certain degree of fine-scale heterogeneity. Abandoned zones should be restored by introducing multispecies patches and by creating mosaics which combine shrubland and woods with different dominant species and varying levels of human intervention. The abandoned zones should spread more homogene-ously throughout the whole territory in order to create heterogeneity in those areas which are at present being exploited over their whole range. Topics for future research include the optimum patch size and distribution of landscape units.

It can be deduced from this second conclusion that any rational conservation policy must consider the whole territory, and not concentrate only on those areas of special interest. If these areas remain isolated in a hostile environment, many of their species may become extinct, and the entire policy will have been unsuccessful, as is the case at present in Doñana.

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