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Land-use Changes and Landscape Dynamics in Western Crete

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8.1 INTRODUCTION

Crete is the fifth largest island in the Mediterranean with a surface of 8400 km^2. It is predominantly mountainous with several massifs, some of which rise to around 2500 m altitude. Nevertheless, there are also lowlands as well as mountain plains, rift valleys, notable gorges and picturesque coasts making Crete one of the most beautiful islands of the world.

Its climate is of the Mediterranean type, but is variable. The main gradients occur from east to west, from south to north and with altitude. Annual precipitation varies from less than 400 mm to more than 2000 mm and mean air temperature from about 12 °C in January to 27 °C in July (Grove *et al.*, 1993). Parent rocks are dominated by old, hard limestones while a large part of western Crete is covered by metamorphic rocks of the phyllite–quartzite series. The flora is very rich in life forms and species, a good part of which is endemic. The fauna is also very rich and variable; it is notable for the absence of large predators.

Crete has a long and turbulent history. Situated in the eastern Mediterranean, at the crossroads of Europe, Africa and Asia, it has been affected by a plethora of early civilisations. In the prehistoric period, it developed its own renowned Minoan civilisation, but later it was occupied successively by Mycenaeans, Romans, Byzantines, Moors, Venetians and Turks until it was finally reunited with Greece at the end of the nineteenth century. Nowadays, remains of the great buildings of the Minoans still exist along with chapels, forts, houses and terraces from later periods. These civilisations affected the landscape considerably.

The most notable effects have been on vegetation. It is widely believed that Crete was covered by forests in the Neolithic period, which were subsequently destroyed by humans and their activities during the Minoan period (3000–1000 BC) as well as in later periods such as the Roman and Turkish occupations (Zaharis, 1977; Tsoumis, 1985). New evidence, however, suggests that wild herbivores of tropical origin (e.g. pygmy elephants, rhinos, etc.) existed on the island before the first settlers. Domesticated plants and animals appeared about 8000 years ago. Aridification of the climate occurred around 5000 years ago, favouring lower (shorter) plant forms such as herbaceous and phryganic (dwarf shrubs) species (Rackham, 1990).

Human activities have been part of the Cretan landscape since the Neolithic period. At times their effects were severe, but such times were followed by less

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intensive periods, depending on population changes influenced by historical events (Lyrintzis and Papanastasis, 1995). In recent decades, however, landscape changes seem to be more dramatic than in any previous historical period for two main reasons: the influx of thousands of tourists in the island every year and the abandonment of rural areas by people settling in the urban centres and coastal areas of the island or abroad (Grove *et al.*, 1993).

Nowhere in Crete are the landscape changes more evident than in its western part. Western Crete is characterised by a great variety of natural features, parent rocks and soils, land-use/land-cover types, cultural elements and a rich flora and fauna. In addition, it displays all the landscape extremes: highlands and lowlands, coastal areas and inlands, intensively and extensively cultivated agricultural lands, very old and very modern settlements, abandoned and overpopulated areas (Grove *et al.*, 1993). All these features result in great landscape complexity and diversity.

In this paper, the land-use changes in 2 contrasting areas in western Crete over the past 40 years are analysed, and their impact on landscape diversity and stability is discussed.

8.2 MATERIALS AND METHODS

A zone of 42,400 ha, stretching a few kilometres across the island to the west of the city of Chania, was selected for study in western Crete (Figure 8.1). It includes the built-up north coast, extends up to the Keritis river through the Alikianou basin, stretches across the White Mountains to embrace the Omalos plateau as far as the south coast including the Sougia river basin and the Samaria National Park. It contains all types of Mediterranean ecosystems: the developed tourist areas and underdeveloped areas in the north and in the south respectively, intensively cultivated lands, a large area of the White Mountains where altitudes exceed 1800 m, three major and numerous minor gorges and a rugged coastal area of the Libyan Sea. In addition to several land uses, the study area also includes several geological substrates, such as hard limestones, phyllites and schists, marls and alluvia (Figure 8.1).

This study area has been the pilot zone of a 2-year long project (1991–1993) "A Threatened Mediterranean Landscape: West Crete", which was financed by the European Commission (DGXII) and carried out by the Universities of Cambridge, UK and Thessaloniki, Greece (Grove *et al.*, 1993). The same area was subsequently included in the project "Modelling Vegetation Dynamics and Degradation in Mediterranean Ecosystems (ModMED) phase II (1996–1997)", also financed by the European Commission (Environment Research Programme) as a contribution of the University of Athens.

In this study area, two sites with contrasting geology, topography and degree of development in particular were selected for detailed study of landscape dynamics. One site is located on the north coast and includes the overdeveloped coastal area with the intensively cultivated Alikianou basin and the surrounding hills. The area is within the administrative boundary of the villages of Agia, Agia Marina, Alikianos, Koufos, Platanias, Skines, Stalos and Fournes. Its total area is 5028 ha. The other site is located on the south coast and includes the less developed Sougia coast, the Sougia river basin and the hamlets of the Epanochori village, where the dominant activities are extensive livestock husbandry and arable agriculture. Administratively, it lies within the administrative area of the villages of Sougia and Epanochori and has an area of 5526 ha (Figure 8.1).

Land-use/land-cover types were mapped from panchromatic aerial photographs taken in 1989 using a Bausch and Lomb Stereo Interpretation System (SIS-95). The classification scheme was based on the US Geological Survey's system modified by Kazaklis and Karteris (1993). The minimum mapping unit was set at 1 km^2 and a manual method was chosen for the identification. The interpretation data were transferred from the aerial photos at a scale of 1:30,000 to conventional topographic maps at a scale of 1:15,000 by means of a Bausch and Lomb Zoom Transfer Scope (ZTS). This and the aforementioned instrument were subsequently used to compare the 1989 map with the 1945 photos and to construct tables of land-use changes between the two years. The 1989 land-use/land-cover map and the topographic and geological maps of the study area were subsequently digitised with the programme Pc-Arc/Info. Maps were produced with the programme ArcView.

In addition, statistical records were used from the National Statistical Service to trace the evolution of the changes in population, land use, agricultural crops, tree cultivation and domestic animals, especially sheep and goats, in the two sites over the last 30 to 40 years. Most of these records are based on estimates from national censuses taken every 10 years since World War II. Finally, information was also collected from the local land-management agencies on forest and range management as well as on agriculture and livestock husbandry.

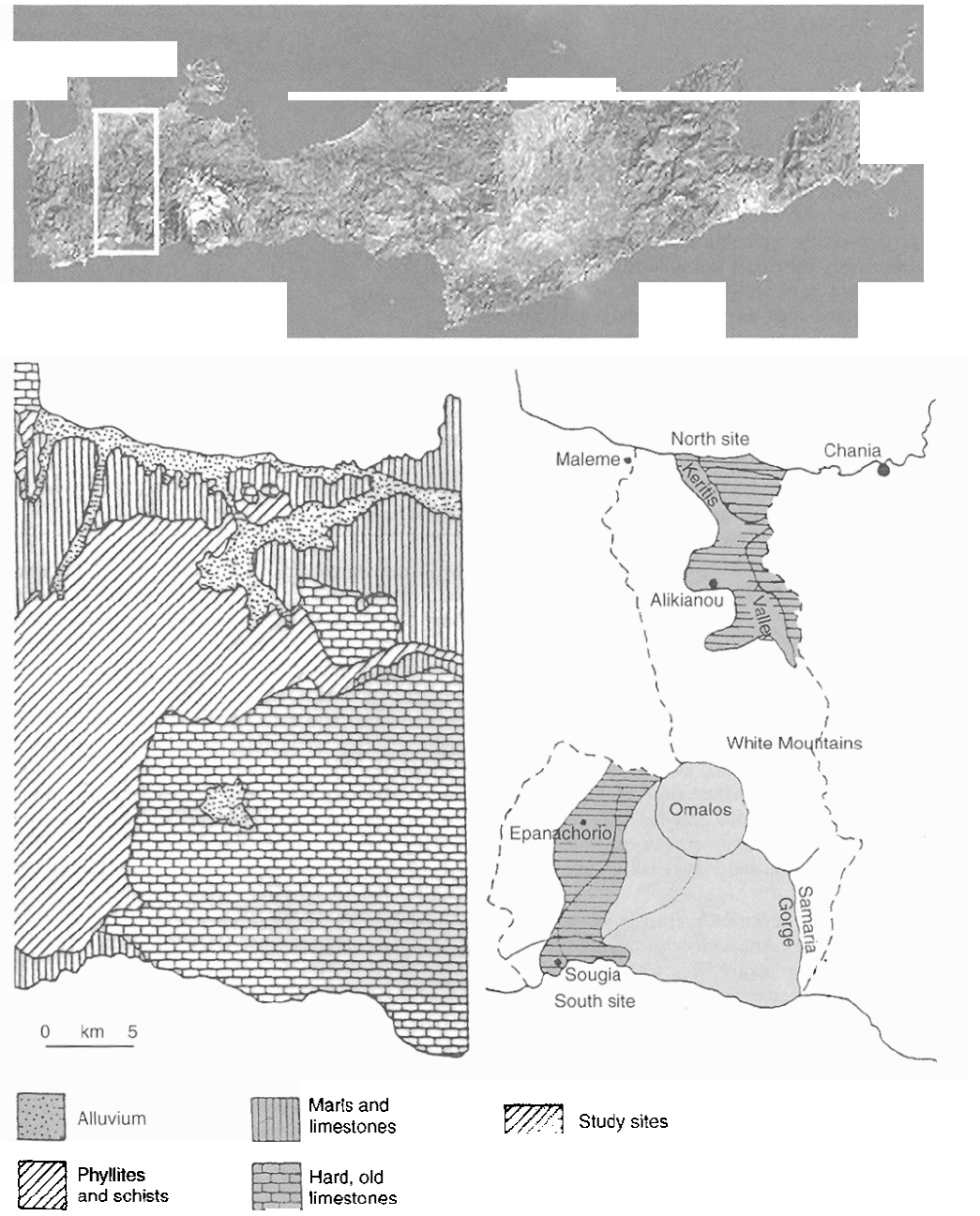

Figure 8.1 The project area in western Crete showing the geological substrate and the location of the two study sites (reproduced by permission of Dr A. T. Grove)

8.3 RESULTS

8.3.1 North site

8.3.1.1 Land-use changes

Figure 8.2 shows the land-use/land-cover types of the northern area according to our interpretation of the aerial photos of 1989. It is clear that agriculture covers the majority of the site while forests are totally absent. It is a predominantly agricultural area, and one of the most intensively cultivated and productive areas of the whole of Crete. Tree cultivation is the dominant crop while other land uses are found mainly in the hilly areas surrounding the Keritis valley. Rangelands were classified under phrygana, garrigues and maquis.

1. The "phrygana" include the dense (80% crown density or more) scrub communities with shrubs less than 1-m high, growing on several soil types. They are characterised by the dominance of seasonal dimorphic dwarf shrubs, both spiny and aromatic, such as *Sarcopoterium spinosum*, *Coridothymus capitatus*, and so on. (Papanastasis, 1977; Margaris, 1980; Arianoutsou and Faraggitakis, 1996; Arianoutsou, 1997).

2. The "garrigues" covered open scrub communities with evergreen sclerophyllous shrubs less than 1-m high, grown on all soil types (Papanastasis and Kazaklis, 1997).

3. The "maquis" classified scrub communities with tall shrubs (more than 1-m high), mainly grown on metamorphic rocks. They are characterised by the dominance of evergreen sclerophyllous shrubs, such as *Arbutus unedo*, *Erica arborea*, and so on. (Margaris, 1980; Liacos, 1982; Arianoutsou and Faraggitakis, 1996).

There have been remarkable changes between 1989 and 1945 (Table 8.1). Although cultivated lands increased over the 44-year period as a whole, this increase was minor (13%) compared to the changes within agricultural areas; olive groves and especially citrus orchards increased (29 and 176% respectively) at the expense of cereals, which substantially decreased by 79%, and rangelands, especially garrigues and maquis, which reduced by 29 and 62% respectively. Dramatic increases also occurred in the built-up areas, by about 130% in 1989 with respect to 1945, while the riverine vegetation, which mainly consisted of *Platanus orientalis* decreased by 33%.

A more detailed picture of the land-use changes between 1945 and 1989 is given by the statistical data collected by the National Statistical Service although these data are available from 1961 only. These data do not coincide with the aerial photo measurements because they are estimates. Figure 8.3(a) shows that the changes in the major land uses between 1961 and 1991 were not so profound, except between 1961 and 1971 when water bodies (e.g. river beds) decreased by 30%, apparently to be converted into arable land. The changes within the cultivated areas were more pronounced, with a decrease in annual crops (e.g. cereals) by 47% and vineyards by 85% in favour of tree cultivation, which increased by 56% between 1961 and 1991 (Figure 8.4(a)). The latter increased considerably in the 1970s (by 57% for olive trees and by 59% for citrus trees) (Figure 8.5(a)). Finally, the irrigated tree orchards greatly increased (by 121%) in the 1970s (Figure 8.6(a)) due to a 243% increase in sprinkler units (Figure 8.7(a)).

Table 8.1 Changes of land-use/land-cover types in north site of western Crete, between 1945 and 1989, based on aerial photos (area in ha)

Land-use type	Year		Change (%)
	1945	1989	
Olive groves	1544	1992	+29.01
Other tree crops	564	1576	+176.43
Cereals	1284	272	−78.71
Total agricultural lands	3392	3840	+13.20
Phrygana	190	224	+17.89
Garrigues	28	20	−28.57
Maquis	926	352	−61.99
Total rangelands	1144	596	−47.90
Forest lands	–	–	–
Built-up areas	148	340	+129.73
Riverine vegetation	216	144	−33.33
Bare ground	48	52	+8.33
Other	80	56	−30.00
Total other types	492	592	+20.33
Grand total	5028	5028	

8.3.1.2 Changes in domestic animals

Figure 8.8(a) shows the changes in the number of domestic animals between 1961 and 1991. Clearly, these gradually decreased and work animals (e.g. horses, mules and asses) almost disappeared completely. Some production animals, such as goats, pigs and poultry, appeared to increase in number in some decades but the overall trend was negative.

8.3.1.3 Human population changes

The registered population in the eight communities of the north site between 1951 and 1991 is shown in

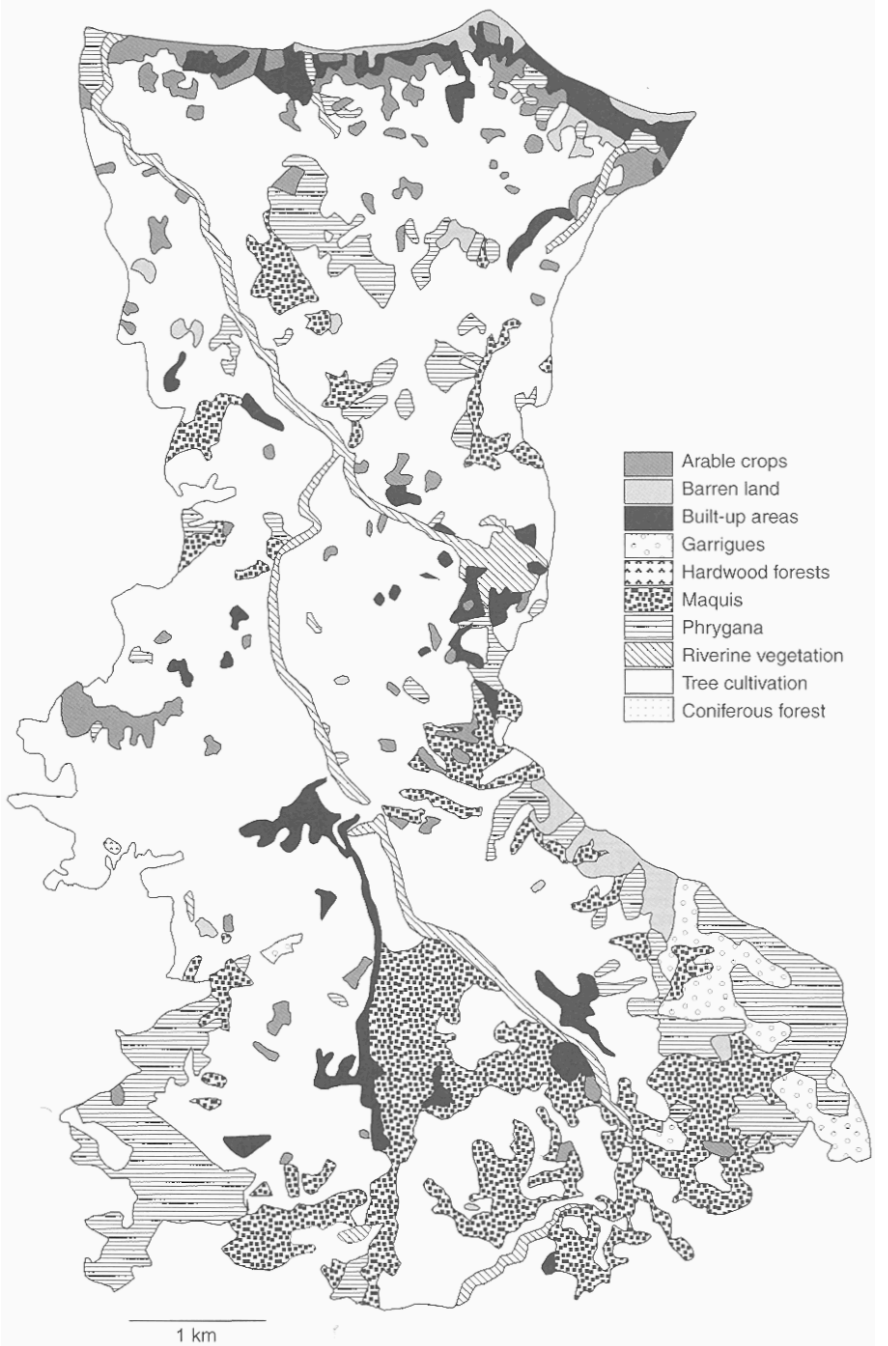

Figure 8.2 Land-use/land-cover types of the north site of western Crete based on aerial photos taken in 1989

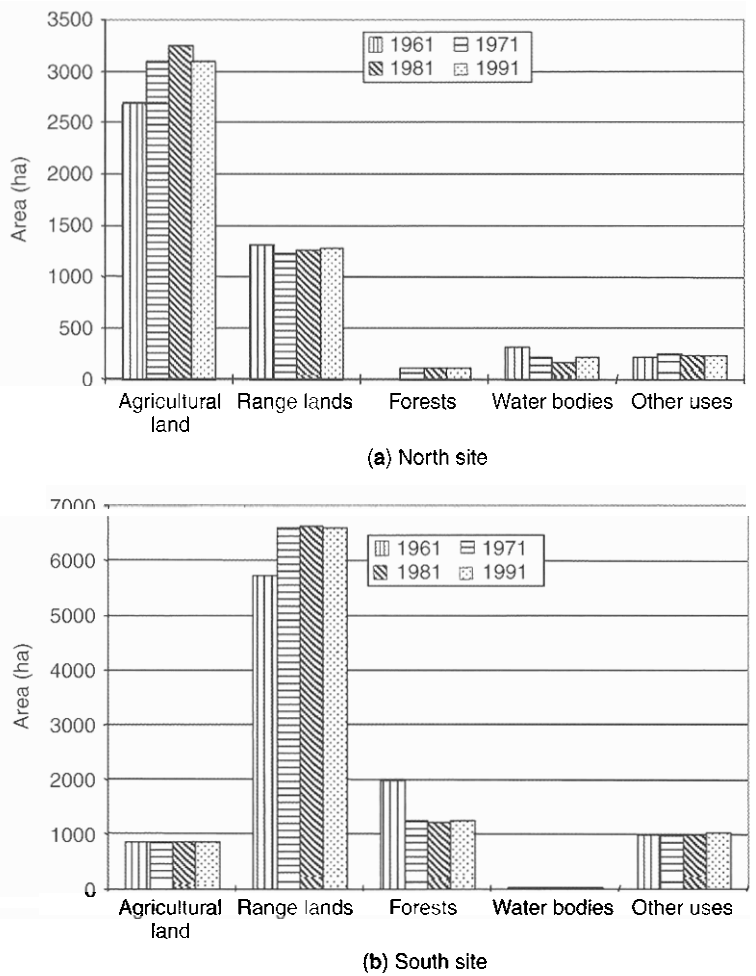

Figure 8.3 Evolution of the major land uses in the (**a**) north and (**b**) south sites of western Crete in the period 1961

Figure 8.9(a). After a gradual decline from 1951 to 1981, it picked up in the 1980s to reach the original estimate of 4665 people in 1991.

8.3.2 South site

8.3.2.1 Land-use changes

Figure 8.10 shows the land-use/land-cover types of the south site in 1989. Contrary to the previous site, there are few areas of agriculture and few built-up areas; forests and rangelands predominate. The forests are mainly coniferous, composed of *Pinus brutia* and *Cupressus sempervirens*, and were classified into three crown density classes: "dense" – which have a crown density of more than 70%, "open" – which have 30 to 70% density, and "very open" – which have less than 30% crown density.

There have been significant changes in the south site between 1989 and 1945 but these are not as remarkable as in the north site (Table 8.2). Agricultural lands were reduced by 39% due to the reduction of cereals by 62%, although there was an 80% increase in olive groves. Rangelands, especially maquis, were reduced in favour

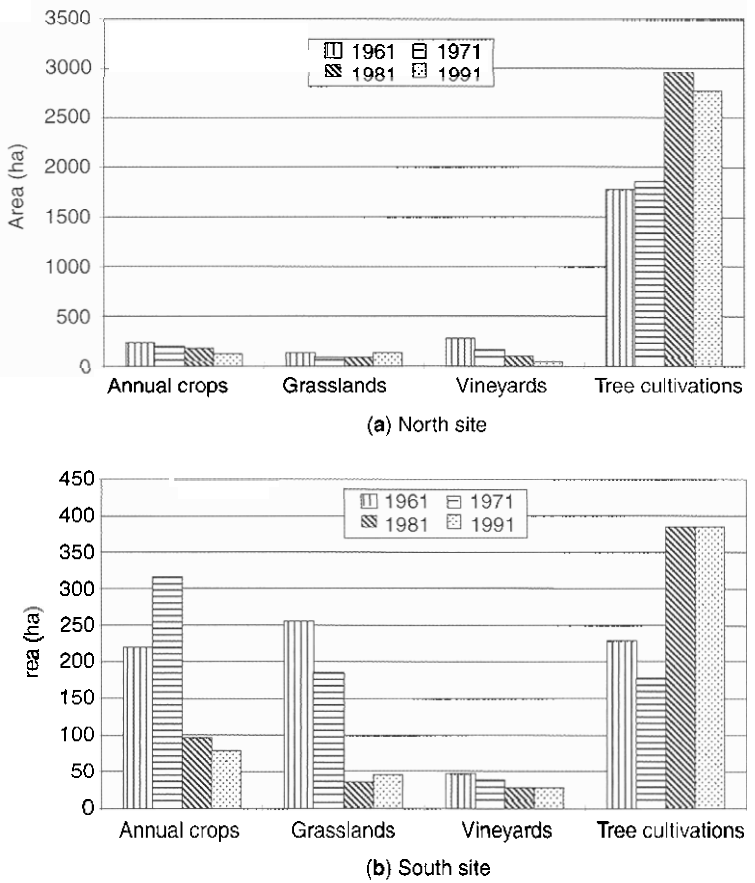

Figure 8.4 Evolution of the major agricultural uses in the (a) north and (b) south sites of western Crete in the period 1961–1991

of forests. But the most interesting change was the conversion of a sizeable proportion of the forest from open to dense stands. Built-up areas did not change but riverine vegetation also decreased, as occurred in the north site.

Complementary statistical data is provided by the National Statistical Service although these refer to the entire territories of the two village communities of the south site, Epanochori and Sougia, while the photo-interpretation data refer to only part of them. Figure 8.3(b) shows the changes in the major land uses between 1961 and 1991, which were not marked. The main point that this figure indicates is that rangelands are the major land use in the south while Table 8.2 shows that forests dominate. This difference could be attributed to the fact that most open and very open forests in Crete are grazed by domestic animals and consequently they are classified as rangelands (Papanastasis *et al.*, 1990).

Figure 8.4(b) is more consistent with the information in Table 8.2, which shows the changes in the cultivated areas from 1961 to 1991. This figure indicates that cereals decreased by 64%, vineyards by 42%, fallow lands by 82%, while tree cultivation increased by 68%. The latter increase came about almost exclusively from the increase of the planted olive trees, especially during the 1970s (Figure 8.5(b)). Neither irrigated tree orchards (Figure 8.6(b)) nor changes in the agricultural machinery (Figure 8.7(b)) are important in this site.

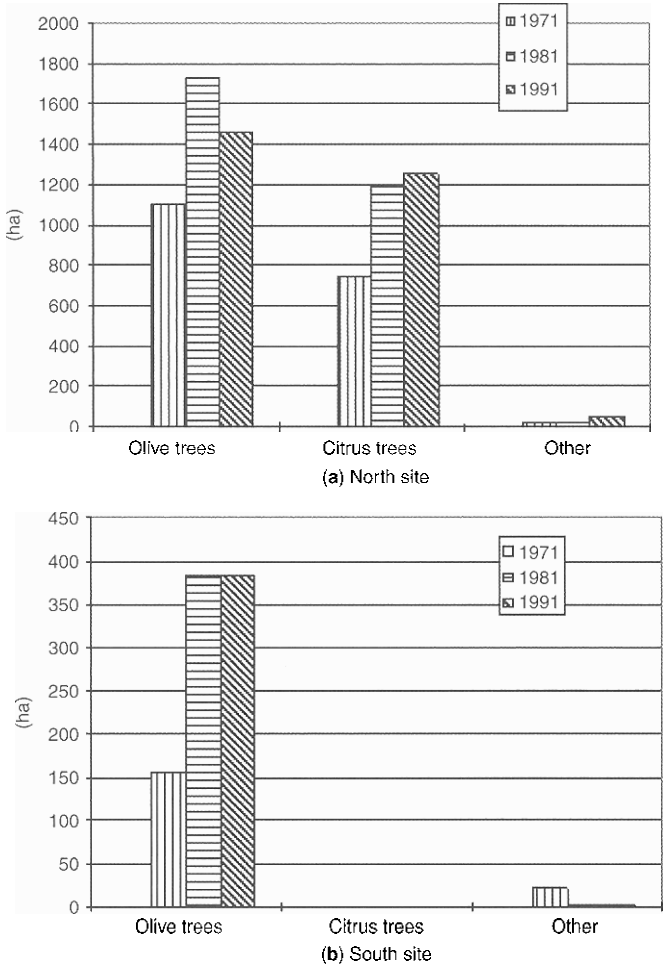

Figure 8.5 Evolution of the major tree cultivations in the (**a**) north and (**b**) south sites of western Crete in the period 1961–1991

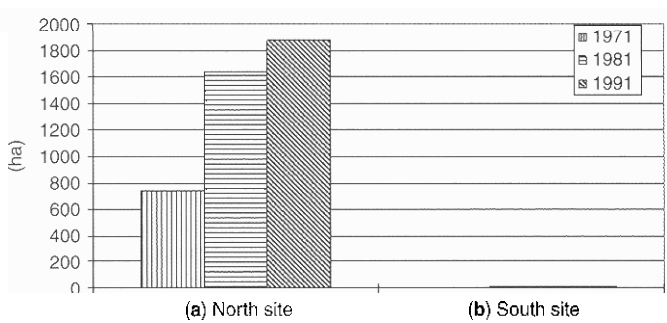

Figure 8.6 Evolution of irrigated areas in the (**a**) north and (**b**) south sites of western Crete in the period 1971–1991

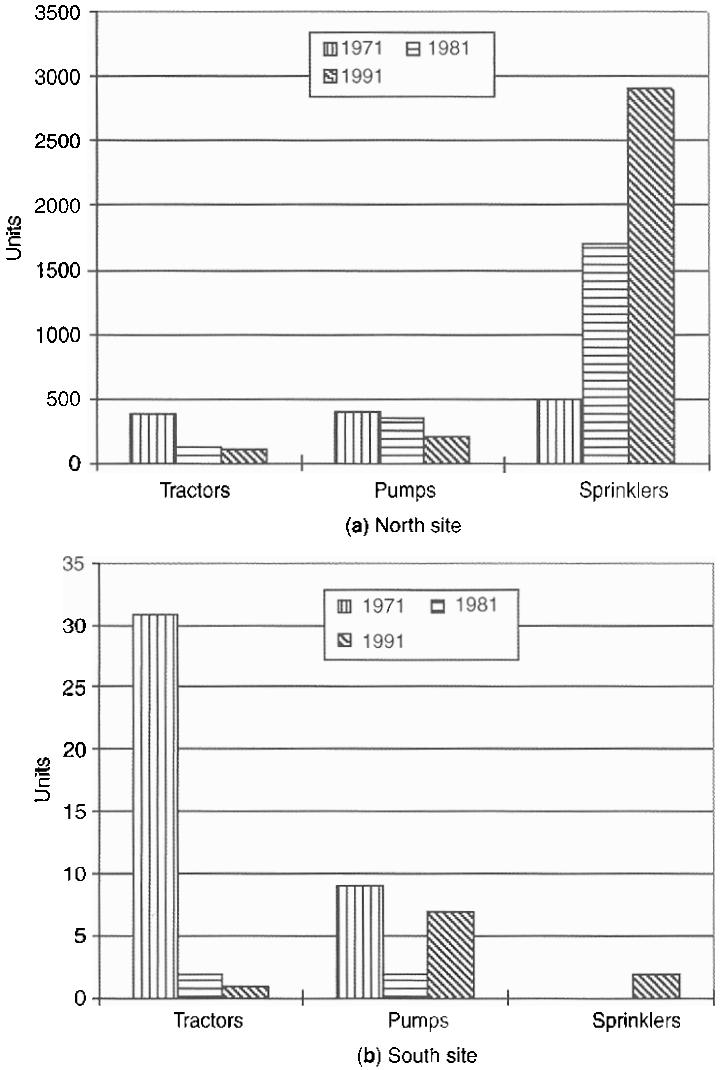

Figure 8.7 Evolution of the agricultural machinery in the (a) north and (b) south sites of western Crete in the period 1971–1991

8.3.2.2 Changes in domestic animals

As in the north site, the numbers of domestic animals decreased from 1961 to 1991 and some animals, such as horses, cattle and pigs disappeared from the region completely (Figure 8.8(b)). On the contrary, sheep and goats, although in decline until 1981, suddenly increased from 1981 to 1991 by 138 and 111% for sheep and goats respectively. The reason behind this increase is the support policy (subsidies) for livestock herders that applied after Greece joined the European Union in 1981.

8.3.2.3 Human population changes

The registered population in both the village communities of the south site decreased from 1212 inhabi-

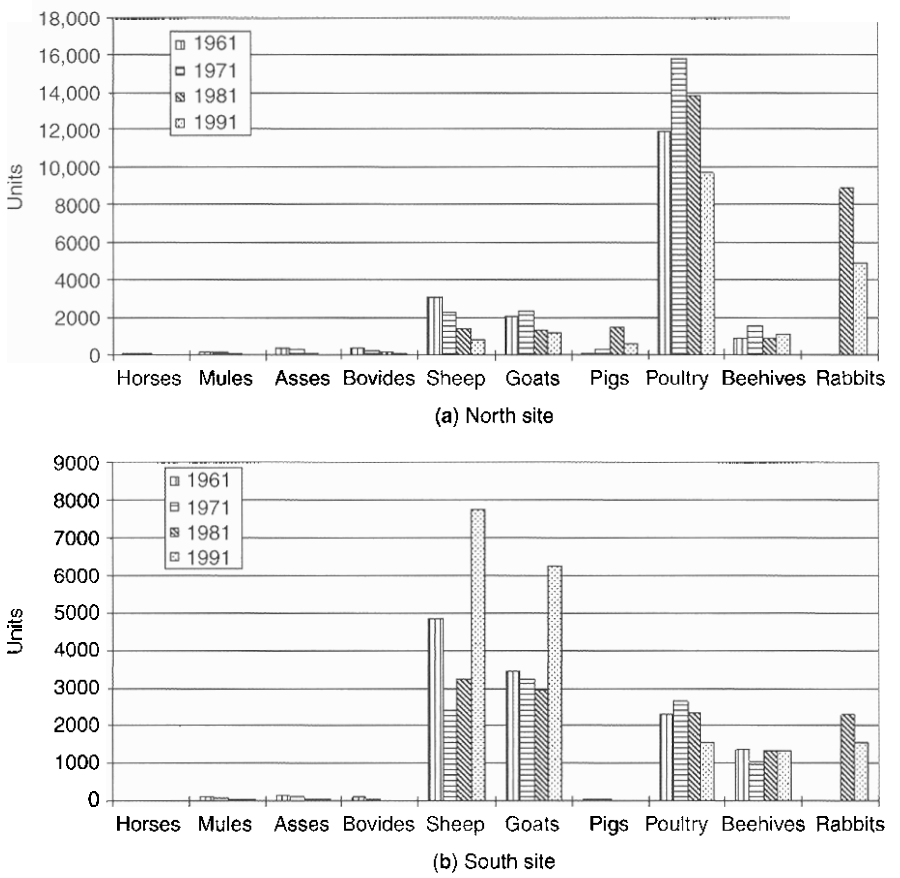

Figure 8.8 Evolution of domestic animals in the (a) north and (b) south sites of western Crete in the period 1961–1991

tants in 1951 to only 643 in 1991, a reduction of 47% (Figure 8.9(b)). However, the biggest reduction occurred in the 1960s (30%) followed by the 1980s (16%).

8.4 DISCUSSION

The two study sites have completely different landscapes. The north site is a more or less flat area largely occupied by an alluvial plain, which is cut into by the Keritis river and interspersed by low hills of mostly marls with phyllites, while limestone areas are restricted to its south-eastern end. These geomorphological characteristics, together with the fact that it receives relatively high amounts of rainfall (about 700 mm each year), have resulted in the transformation into a predominantly agricultural landscape from its early history. In addition, it has attracted many inhabitants because of its location on the north coast, which is easily accessible not only from other parts of Crete but also from mainland Greece and other Mediterranean ports.

The south site, on the contrary, is a mountainous area largely occupied by the steep slopes of the White Mountains with metamorphic rocks (phyllites) or hard limestones and crossed by the Sougia river, which is dry in the summer; marls are restricted to a narrow zone along the cost. These geomorphological characteristics have not allowed the development of agriculture except on terraces. Instead, extensive grazing by livestock is favoured, which resulted in the transformation into an agro-pastoral landscape. In addition, the location is on the less accessible south coast, away from the urban

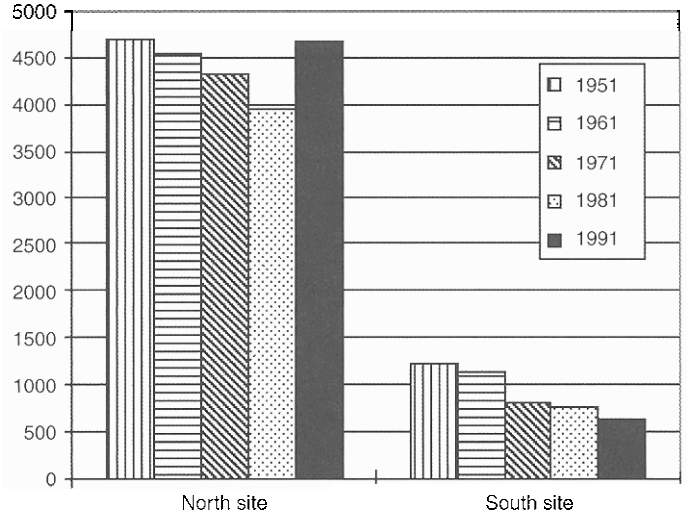

Figure 8.9 Evolution of the population in the (**a**) north and (**b**) south sites of western Crete in the period 1951–1991

Table 8.2 Changes of the land-use/land-cover types in the south site of Western Crete, between 1945 and 1989, based on aerial photos (area in ha)

Land-use type	Year		Change (%)
	1945	1989	
Olive groves	20	36	+80.0
Other tree crops	–	–	–
Cereals	104	40	−61.54
Total agricultural lands	124	76	−38.71
Phrygana	1148	1068	−6.97
Garrigues	1116	1044	−6.45
Maquis	184	128	−30.43
Total rangelands	2448	2240	−8.50
Dense forests (>71%)	1268	1764	+39.12
Open forests (30–70%)	856	608	−28.97
Very open forests (<30%)	472	462	−2.12
Total forest lands	2596	2834	+9.17
Built-up areas	8	8	–
Riverine vegetation	20	16	−20.0
Bare ground	316	336	+6.33
Other	16	16	–
Total other types	360	376	+4.44
Grand total	5528	5526	

centres of Crete and other markets of the Mediterranean, so it did not attract many inhabitants.

It seems that despite their big differences, both landscapes reached a steady state by 1945 largely because human activities were traditional and moderate, allowing natural forces, especially vegetation succession, to counterbalance the human impacts and maintain a long-term flow equilibrium. The main characteristic of this equilibrium was a spatio-temporal landscape heterogeneity, which ensured evolutionary metastability and resilience (Naveh, 1988).

Land-use changes since 1945 suggest that this dynamic landscape equilibrium has been disrupted on both sites. On the north site, the disruption was particularly dramatic, where the extensively cultivated area with its numerous crops has been transformed in an intensively cultivated monoculture of citrus and olive trees over the last 20 to 30 years. This led to a homogeneous landscape based on heavy inputs of irrigation water, fertilisers, pesticides and all kinds of neo-technological production-oriented and pollution-generating human activities. Moreover, its nearness to the city of Chania and the influx of tourists along the north coast have resulted in the increase of built-up areas at the expense of arable land. Nevertheless, the arable land increased in area as Mediterranean ecosystems were cleared, especially maquis in the hills surrounding the basin, in order to plant olive trees (Papanastasis and Kazaklis, 1997).

Less dramatic but equally disruptive were the changes in the south site, where the partial or complete cessation of traditional agro-pastoral activities, including terraced agriculture, and abandonment, has also resulted in a homogeneous landscape, characterised

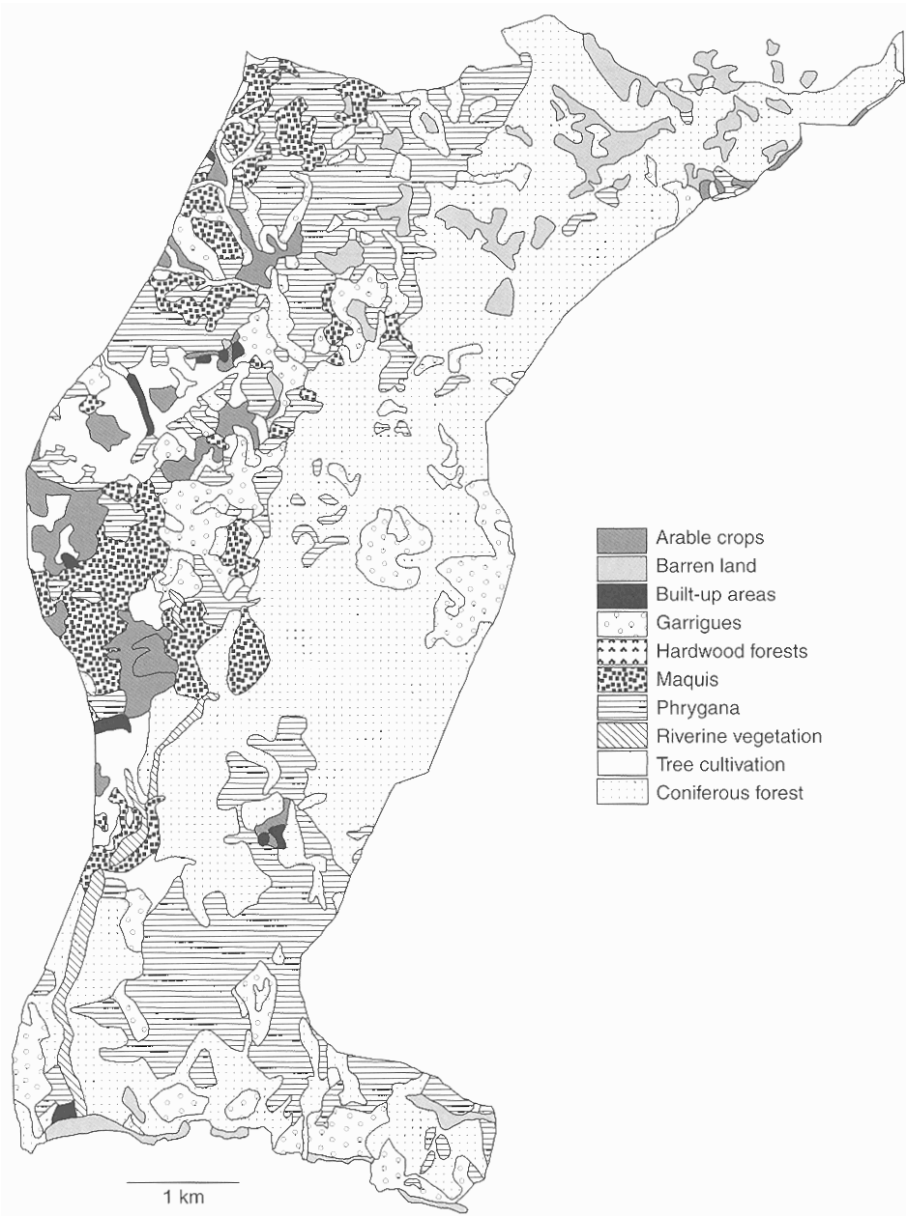

Figure 8.10 Land-use/land-cover types of the south site of western Crete based on aerial photos taken in 1989

by the expansion and the notable increased density of *P. brutia* forests, which are very prone to wildfires. The problem of wildfires was further aggravated by the shortening of the traditional burning cycle of rangelands in order to ensure more and a better standard of feed for the livestock, numbers of which have increased over the last 10 to 15 years as a result of national and EU subsidies (Ouled Belgacem

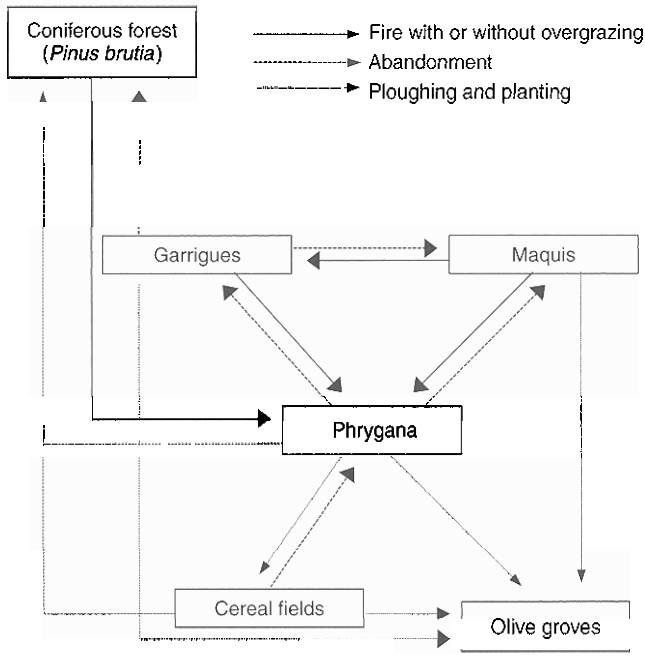

Figure 8.11 A general model of the land-cover/land-use changes in the study area of western Crete as a result of major human activities. The direction of change among the different types is largely determined by soil and parent material

and Papanastasis, 1993). All these changes have disrupted the traditional dynamic equilibrium of the agro-pastoral system.

Since vegetation is the most notable feature of landscapes, its dynamic changes demonstrate the impact of socio-economic factors on its evolution. Figure 8.11 shows the model of vegetation changes as a result of four major human activities that shaped Mediterranean landscapes in the study area; namely fire, livestock grazing, ploughing and abandonment (Papanastasis and Kazaklis, 1997). In the past, the balance of these activities resulted in a complex, highly heterogeneous and stable landscape. This stability is now threatened by neo-technological interventions, which has intensified the activities, leading to landscape homogeneity and instability.