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Application of the state-and-transition approach to conservation management of a grazed Mediterranean landscape in Greece

Vasilios P. Papanastasis* and Dimitrios Chouvardas
Laboratory of Rangeland Ecology, Faculty of Forestry and Natural Environment, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece

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ABSTRACT

Traditionally, management of rangelands is based on the successional theory for vegetation developed by Clements. This approach, which came to be known as "the range succession model", assumes a progressive change of vegetation towards the final (climax) stage and considers grazing as a primary driver of its dynamics. This model cannot be applied in Mediterranean rangelands, however, because they are largely modified plant communities and their final stage is usually a forest or dense woodland. Such "climax-type" vegetation is not necessarily best for conservation, nor does it serve the best management objective. In addition, rangelands are fragmented areas within Mediterranean landscapes requiring an integrated approach to their conservation and management. The "state-and-transition model" developed over the last 15 years seems to be more appropriate for Mediterranean rangelands, because it accommodates a broader spectrum of vegetation changes compared to the range succession model since, besides successional factors, several management factors are also considered. In this paper, a site-specific state-and-transition model is developed for a representative Mediterranean area of northern Greece after analyzing the socio-economic and land cover/use changes for a 33-year period. The model includes four states (arable lands, grasslands, evergreen shrublands, and deciduous oak forests) and seven transitions, all of them management-related. These transitions provide an adequate explanation of the vegetation changes that occurred in the study area and can serve as measures to confront the re-dominance of woody vegetation in the region. It is concluded that the state-and-transition approach provides an effective framework for conservation management of Mediterranean rangelands and landscapes.

Keywords: range succession model, vegetation, socio-economic changes, land cover/use changes, Greece

INTRODUCTION

Rangelands are dominant plant communities in the Mediterranean basin countries. They occupy more than 50% of the Mediterranean area and include halophytic steppes, grasslands, several types of shrublands, and open forests (Le Houérou, 1981). Although they provide a wide variety of products and services such as fuel wood, fruits, honey, biodiversity, erosion control, and environmental amenities, their main use is grazing by domestic animals. Livestock husbandry has a long history in the Mediterranean region (Le Houérou, 1981; Papanastasis, 1998). In addition, rangelands are parts of Mediterranean landscapes that have been shaped by agro-pastoral activities at least since the Holocene

*Author to whom correspondence should be addressed. E-mail: vpapan@for.auth.gr

(Naveh and Lieberman, 1994).

Management of rangelands is based on vegetation dynamics. This is because vegetation is not only the expression of the current environmental and management factors, but also incorporates prior ecological events and management interventions and constitutes the basis for rangeland evaluation (Briske et al., 2005).

Traditionally, vegetation dynamics in rangelands has been expressed by the succession theory developed by Clements (1916). According to this theory, plant communities progress to a single persistent state (the climax), mainly determined by climate, or regress from it along predictive courses of defined communities in response to environmental changes or human actions. Consequently, management of rangelands was related to the stages of secondary succession with the climax representing excellent range conditions (Sampson, 1919; Humphrey, 1945; Dyksterhuis, 1949; Parker, 1954; Ellison, 1960). The range succession model, however, does not work well on rangelands where the climax is a forest or dense woodland (Smith, 1988; SRM Task Group, 1995). Such is the case of Mediterranean rangelands. The majority of these ecosystems are considered "manmade" plant communities. They have been derived from forests after modifying or even destroying them through clearings, wildfires, and overgrazing over the centuries and maintained as such by human activities (Tomaselli, 1977; Le Houérou, 1981; Papanastasis, 1981; Thirgood, 1981; Naveh and Lieberman, 1994). This means that they are not climax but rather modified communities. For this reason, the range succession model, which is based on species composition or production of the climax vegetation, cannot be applied in the Mediterranean rangelands. Therefore, it is impossible to assess them based on the undisturbed climax vegetation, first of all because it is very difficult to find or reconstruct it, and, most important, it does not often suit the management objectives.

On the other hand, Mediterranean rangelands are parts of complex landscape mosaics that have been shaped by closely interwoven natural and cultural processes and multivariate anthropogenic functions (Naveh, 1988). Such mosaics also include forest communities and arable fields. In addition, Mediterranean landscapes are particularly vulnerable to socio-economic factors (Farina, 1998). These factors are much more important in causing land cover/use changes than environmental ones, particularly after World War II when socio-economic variables greatly altered Mediterranean ecosystems and landscapes (Bankov, 1998; Bonet et al., 2004; Papanastasis et al., 2004; Shoshany et al., 2004; Ispikoudis and Chouvardas, 2005). It is of great importance, therefore, to identify and study historical land cover/use changes and their spatial pattern in order to understand landscape dynamics (Turner and Rusher, 1988).

Remote sensing information, produced by satellite or aerial photography, combined with Geographic Information Systems (GIS) have become powerful tools for evaluation of land cover/use and monitoring its changes (Naveh and Lieberman, 1994; Zonneveld, 1995; Farina, 1998). Several studies have been carried out over the last years describing methods for analyzing these changes through time with the use of air photography and GIS in several parts of the world (e.g., Miller et al., 1995; Mast et al., 1997; Duncan et al., 1999; Lopez et al., 2001; Mendoza and Andres, 2002; Zaizhi, 2002; Mazzoleni et al., 2004). Socio-economic changes combined with the results of photointerpretation can produce valuable information regarding the causes of landscape evolution (Torta, 2004).

In Greece, Mediterranean landscapes are largely fragmented areas, composed of relatively small patches of sites with different physical and productive characteristics. These patches are covered by various seminatural plant communities such as grasslands, phrygana, maquis, and forest ranges, intermingled with forest and arable lands. Such mosaics of different land cover/use types have been established and maintained primarily by management factors (e.g., grazing, burning, firewood cutting, farming) on top of environmental ones (e.g., climate, soil, topography) over a long period of time (Papanastasis, 2004). If these factors change, new plant communities appear that adapt to the new conditions over the years. Such vegetation changes can be better expressed by the state-and-transition model proposed by Westoby et al. (1989). According to this model, rangeland dynamics can be described by a set of discrete states of vegetation on a particular area, which are demarcated from each other, and a set of possible transitions between these states. The latter are trajectories of change that are precipitated by natural disturbances and/or management actions and often cross sites. Consequently, the state-and-transition model is more appropriate to express vegetation dynamics at the landscape level than the range succession model, which has been developed for evaluation of vegetation changes within a particular site (Stringham et al., 2003)

In order for the state-and-transition concept to be operational, specific models must be created that describe the details of vegetation dynamics for particular situations (George et al., 1992; Llorens, 1995). Such models, however, have not been developed for the Mediterranean rangelands and landscapes, as far as we know. In this paper, diachronic socio-economic and land cover/use data are used to construct a state-and-transition model for a specific area in Greece as an attempt to develop a new approach to conservation management of Mediterranean landscapes.

MATERIAL AND METHODS

Study area

The study area is part of Lagadas County, located 30 km NE of the city of Thessaloniki, Macedonia (23°19′00″N, 40°43′36″E). It is inhabited by 10 village communities assembled in 5 municipalities that cover an area of about 250 km^2 (Fig. 1). The main land uses are rangelands (62.2%), arable land (30.4%), forests (5.4%), and settlements (1.7%) (National Statistical Service of Greece, 1995). Rangelands include grasslands with less than 10% shrub cover, dominated by the warm season grasses (e.g., *Chrysopogon gryllus* (L.) Trin and *Dichanthium ischaemum* (L.) Roberty), and shrublands dominated by kermes oak (*Quercus coccifera* L.). Forests are dominated by deciduous oaks (e.g., *Quercus pubescens* Willd., *Q. frainetto* Ten.). Arable land is cultivated with annual crops, mainly cereals. Mean annual precipitation amounts to 585 mm and the mean minimum temperature of the coldest month is below 1 °C, resulting in a semi-arid Mediterranean climate with cold winters. The geological substrate is dominated by metamorphic rocks.

Rangelands are state-owned areas but communally grazed by livestock (Papanastasis, 1981). This means that every local inhabitant (villager) has the right to use these areas for grazing his domestic animals the whole year round. During the winter months, though, animals are usually kept in the barn and fed with hay and concentrates or graze in artificial pastures established in private agricultural lands (Yiakoulaki et al., 2002). The latter ones cultivated with cereals are also communally grazed during the summer months after harvesting and before the new crop is established in mid-autumn (Yiakoulaki et al., 2003). Finally, communal grazing is often applied to forests, which are not managed for timber production due to their poor condition. On the other hand, rangelands are considered as forest lands and besides being grazed by livestock they are also used by local people for fuel wood collection.

Social and management data

Information on the human population employed in the primary sector of each village community, namely in agriculture, forestry, and livestock husbandry, as well as its age structure was collected from statistical records for 1961 and 1991, the years when census data were available (National Statistical Service of Greece, 1962, 1994a). Also, data on afforested areas were collected from the Forest Service of the study area during the period 1981–2001. In addition, the economic activities as well as the national and European Union policies for

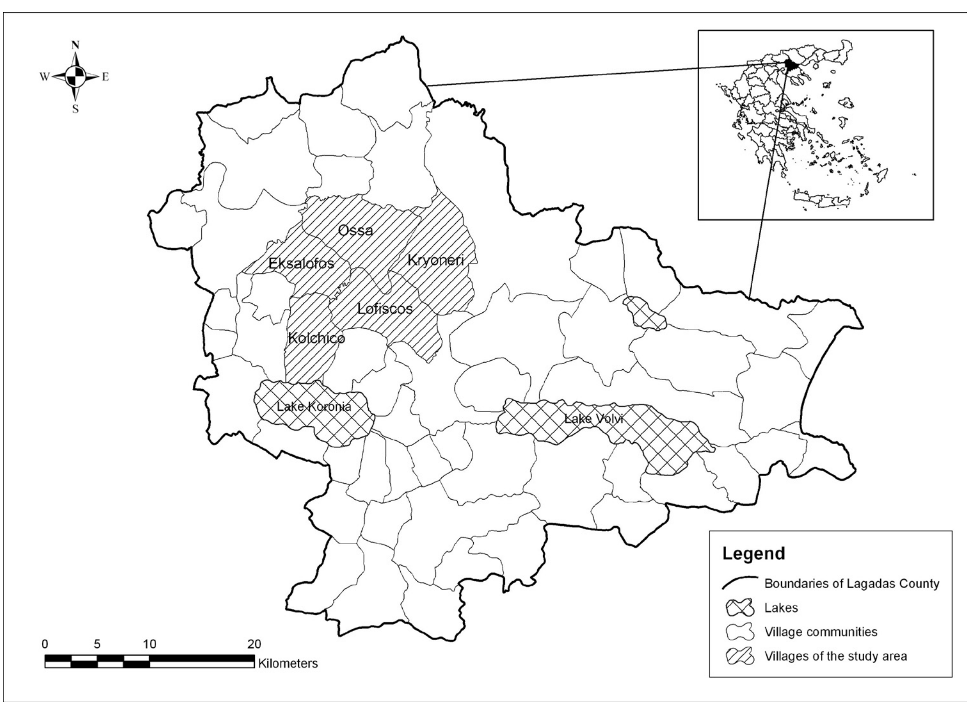

Fig. 1. Map of Lagadas County with the study area.

land management applied in the study area were examined by interviewing regional and local government officials.

For livestock, the numbers reported in the agricultural statistics separately for cattle, sheep, and goats were compiled for the years 1961, 1971, and 1991, the census years. No reliable data could be found for 1981. In addition, the area of rangelands in these three years was taken using again the statistical records (National Statistical Service of Greece, 1966, 1978, 1994b).

Combining the information collected for animal numbers and rangelands in each village community, the diachronic stocking rate was calculated. It was expressed in sheep equivalents per hectare and year. One sheep equivalent was taken equal to one adult sheep or goat or one-fifth of a cow. The calculation was done by dividing the number of sheep equivalents with the area of rangelands in each village community. For cattle, only the ones grazing in rangelands were considered, namely beef cattle since the dairy cattle are raised in barns and rarely visit rangelands; for sheep and goats, the entire stock registered in each village community was taken into account, except for a small portion raised in barns that never uses rangelands.

Air-photo interpretation of land cover/use changes

In order to identify and evaluate the trends of change among different land cover/use types, a sequential series of panchromatic air photographs for 1960 and 1993 were used, as suggested by Vos and Stordelder (1992) and Farina (1998). The air photographs were transformed into raster format using an A4 scanner and were registered, rectified, geometrically corrected, and joined with the use of the special computer software program Erdas Imagine v8.5 (Erdas, 1999; Tsakiri, 1999). The joined air photographs finally produced photo mosaics for each period of 1960 and 1993, similar to orthophotos.

To determine the land cover/use categories, the proper classification system was chosen based on the land cover/use nomenclature used in the Corine classification system (Heymann, 1994). A small adaptation of this system was done in order to define three crown cover classes in forests and shrublands, namely, open (10–40%), medium (41–70%), and dense (71–100%) (Karteris, 1990). Each photo mosaic was interpreted on the computer monitor screen and the land cover/use polygons were digitized using the Erdas Imagine v8.5 (Erdas, 1999). Digital data of the land cover/use polygons were saved in vector format and introduced in ArcInfo v7.2 software. The topology of a GIS was constructed in these polygons and a proper database was built up (ESRI, 1994).

The results from on-screen interpretation were confirmed using classical stereoscopic interpretation techniques such as standard photographic keys (tone, texture, pattern, shape, and size) on the original air photographs (Lopez et al., 2001), and with several field trips on site.

In the final step of the procedure, the digital diachronic land cover/use data sets were introduced from ArcInfo to Microsoft Excel and PowerPoint software and a graphical presentation of an empirical model of land cover/use change trend for the time period 1960–1993 was constructed.

RESULTS

Socio-economic changes

During the study period significant socio-economic changes occurred, which affected the management of rangelands and landscapes. Following a general national trend, rural people started to move out of the study area in the early 1960s to go to the urban centers or abroad for a better life, resulting in the abandonment of the traditional management activities. This trend was continued up until 1991, when the total population was reduced by 20%. The most dramatic decrease, however, occurred in the population employed in the primary sector, which was reduced by 41.7% compared to 1961. In addition, the age structure of the population changed, with fewer younger people staying in the area as compared to the older ones, who increased in 1991 compared to 1961 (Fig. 2).

In the meantime, the tractor was brought to the area and became widely used in arable farming, while since 1981, when Greece joined the European Union, subsidies started to be given to farmers to increase crop production. On the other hand, the charcoal industry declined. According to Paratsikidou (2005), the average amount of charcoal production was 800 tons/year before 1960 but reduced to only 85 tons/year in the subsequent years up to 1969, when it was completed stopped. The species used for coal were oaks. Also, the collection of kermes oak for fuelwood by local people was gradually decreased and eventually stopped as households turned to fossil fuel for their cooking and heating needs. Finally, the Forest Service responsible for management of forests and forest lands initiated an afforestation program to increase the area covered by high forests. During the 1980s and 1990s, 3494 ha of grasslands were planted with pines in several parts of Lagadas county including the study area. The majority of these plantations were carried out from mid-1980s to mid-1990s (Fig. 3). No afforestation was done over the

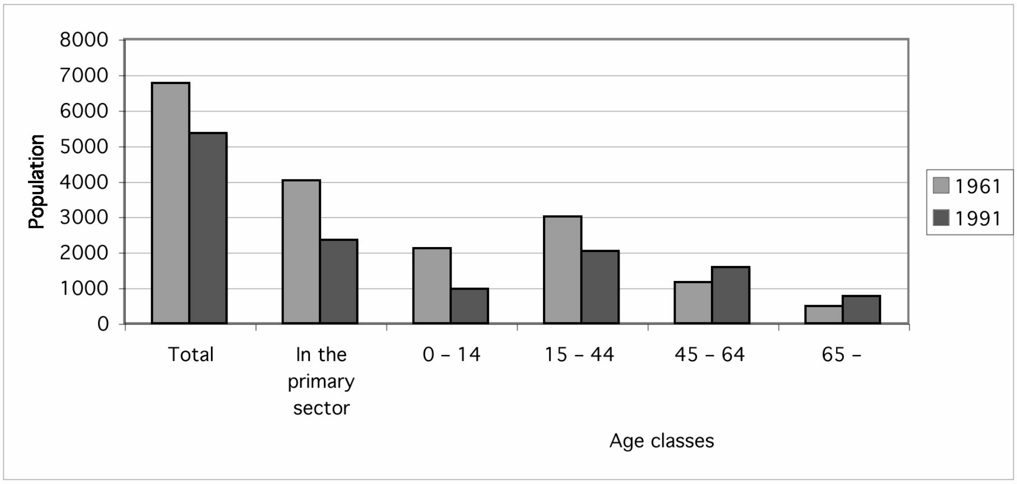

Fig. 2. Human population (total and employed in primary sector) and age class distribution in the study area in 1961 and 1991.

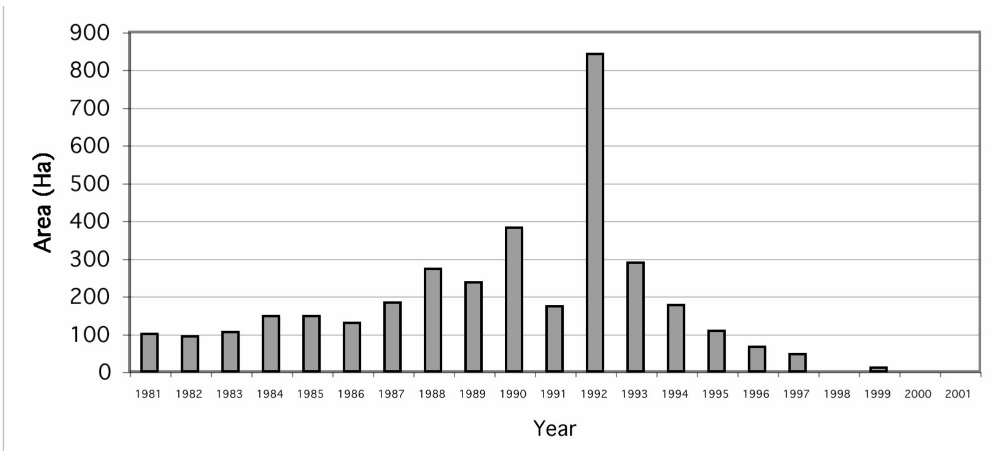

Fig. 3. Area afforested in Lagadas County from 1981 to 2001.

past five years. However, since the mid-1980s farmers were financially encouraged by the European Union to plant forest trees in marginal arable land.

Impressive changes occurred in livestock husbandry, too. Figure 4 shows the evolution of livestock numbers over the study period. It is clear that cattle were much less than sheep and goats all along, and all kinds of animals decreased in the decade from 1961 to 1971, especially sheep and goats. In the period from 1971 to 1991, sheep and cattle numbers continued to decrease but goats substantially increased. Since 1981, subsidies were also provided to livestock farmers, which encouraged them to increase the livestock numbers, but this increase was mainly of goats. Nevertheless, the total numbers of livestock grazing in 1991 did not reach the level of 1961. The stocking rates for the various kinds of animals are shown in Fig. 5. It is evident that the rates for cattle were reduced over the period because fewer animals grazed in rangelands. Also, sheep stocking rates were reduced, although not as much as cattle. On the contrary, the stocking rates of goats were increased in 1991 to the level of 1961. Nevertheless, the global stocking rate in sheep equivalents in 1991 remained less than the one in 1961.

Land cover/use changes

The results of photo interpretation and land cover/use changes over the 33-year period are shown in Table 1. It is clear that all major land cover/use types were increased from 1960 to 1993 except grasslands. More specifically, the largest increase occurred in forests (by 35%), followed by shrublands (by 12%), arable lands (by 10%),

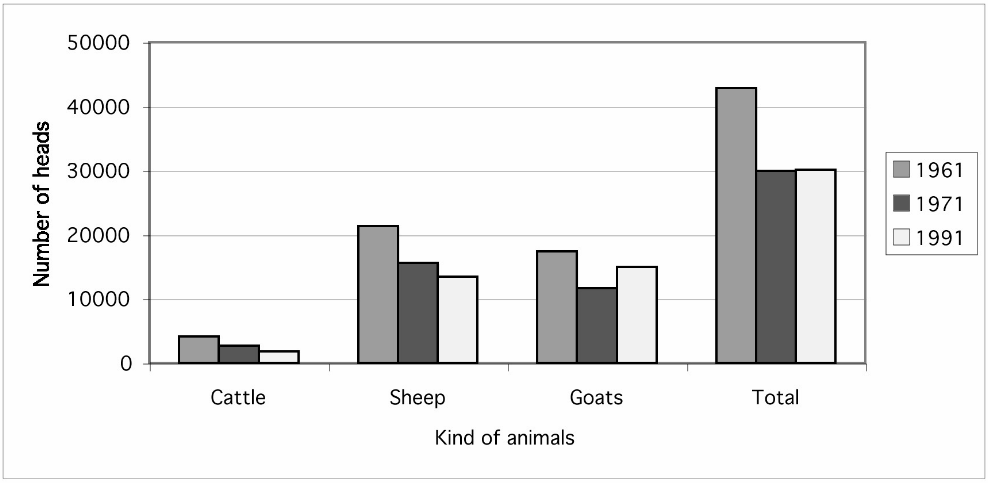

Fig. 4. Livestock numbers per kind of animals in the study area.

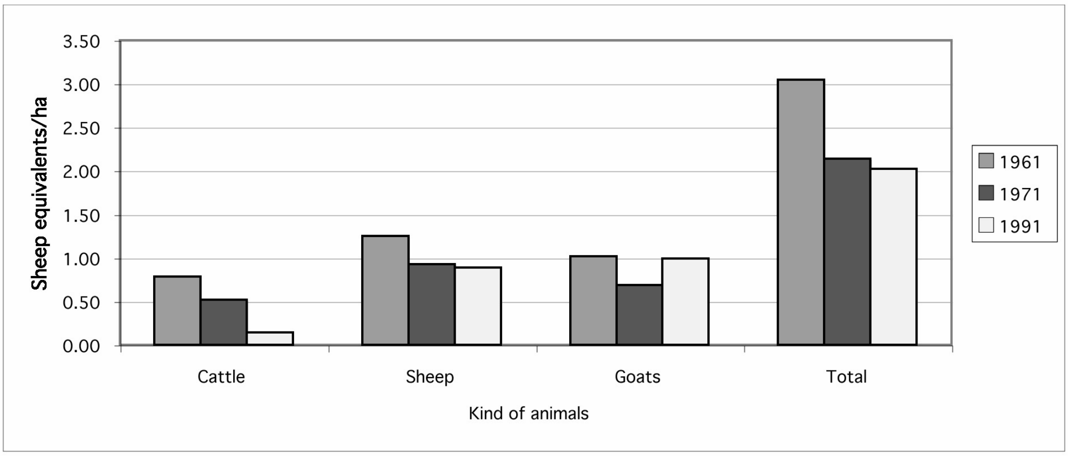

Fig. 5. Stocking rate (sheep equivalents /ha) for the various kinds of animals over the study period.

and other areas (by 5%). On the contrary, grasslands were dramatically decreased (by 71%). Looking at the three cover classes of shrublands, it is obvious that only the medium and dense ones were increased (by 45% and 49%, respectively), while the open class was decreased (by 23%). In contrast, all cover classes of forests were increased, especially the dense one (by 22%, 22%, and 55%, respectively). These results suggest that the woody vegetation cover was substantially increased in the study area over the 33-years period.

Figure 6 shows the various land cover/use changes over the study period. A large proportion of grasslands (29%) was transformed into open shrublands, due to kermes oak and other shrubs (e.g., *Pyrus amygdaliformis* Vill.) encroachment; another important proportion (21%) was converted to arable lands; and a third one (14%) to open forests, apparently due to the afforestation applied by the Forest Service during the study period and especially in the 1980s and 1990s. Another 14% of grassland reduction went into medium shrublands and medium and dense forests due to the expansion of these types in the grassland-shrubland and grassland-forest ecotones, especially in the higher altitudes. Eventually, only 22% of the total area of grasslands stayed unchanged during the time period. On the contrary, grasslands received no input from the other land cover/use types except a small one from arable lands, indicating that only a small proportion (>5%) of arable lands was abandoned to become grasslands during the study period.

Although shrublands received a heavy input from grasslands and a much smaller input from arable lands,

Table 1
Land cover/use types in 1960 and 1993 (in ha)

Type[1]	1960	1993	Difference
Arable lands	7533.2	8308.3	+775.1
Grasslands	4446.6	1280.7	-3165.9
Shrublands	7638.4	8515.7	+877.3
Open (10–40%)	3820.2	2943.7	-876.5
Medium (41–70%)	2678.3	3879.3	+1201.0
Dense (71–100%)	1139.9	1692.7	+552.8
Forests	4530.8	6119.0	+1588.2
Open (10–40%)	1425.8	1734.5	+308.7
Medium (41–70%)	1276.3	1550.4	+274.1
Dense (71–100%)	1828.7	2834.1	+1005.4
Other (settlements, bare areas)	305.8	320.7	+14.9
Total	24454.9	24544.2	+89.3

[1] Percentages within parentheses express crown cover.

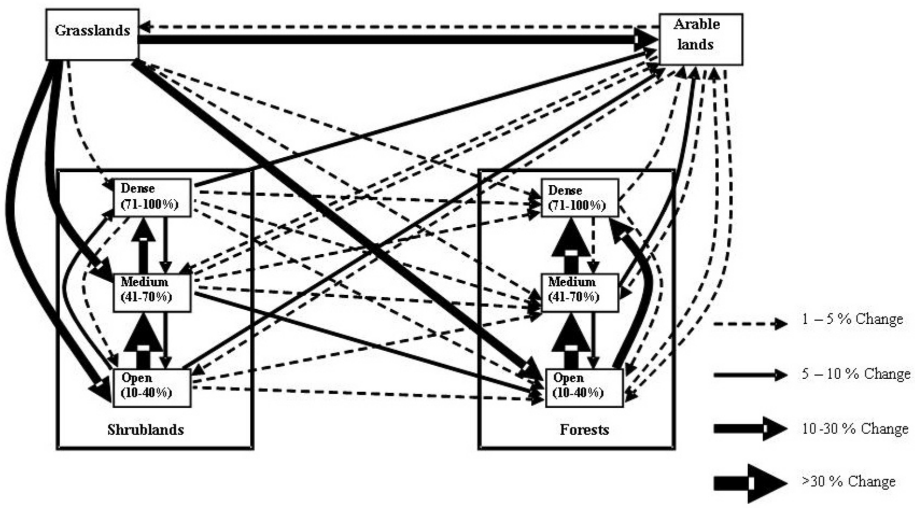

Fig. 6. Trends of changes among different land cover/use types between 1960 and 1993. (The percentage change of the arrows refers to the original size of each type in 1960.)

they lost part of their area, which was converted either to forests, especially open and medium, or to arable lands. These losses, however, were less than the gains from grasslands, resulting in a net increase of their area in the study period. The interesting finding is that shrublands received no input at all from forests, suggesting that no conversion of forests to shrublands seems to have occurred during the study period. On the contrary, significant changes occurred within shrublands, where there was a progressive increase of the shrub cover, particularly from the open to medium classes. This increase, however, was not totally linear since some open shrublands became dense without going through the medium-class density, while there was also a small reduction of dense stands in favor of the medium and open ones.

Forests received inputs not only from grasslands and shrublands but also from arable lands, while they lost part of their area only in favor of arable lands. Otherwise, they behaved like shrublands by showing a clear progressive increase from open to medium or dense forests. On the contrary, no significant changes occurred the other way around, namely from dense to medium or open forests.

Setting up the appropriate state-and-transition model

Based on the diachronic land cover/use changes, four states and seven transitions were identified (Fig. 7) by applying the methodology suggested by Westoby et al. (1989). They are the following:

Catalogue of states

State I. Arable lands with annual crops (e.g., cereals).

State II. Grasslands dominated by the perennial warm season grasses *Chrysopogon gryllus* (L.) Trin and *Dichanthium ischaemum* (L.) Roberty.

State III. Evergreen shrublands dominated by kermes oak (*Quercus coccifera* L.).

State IV. Deciduous oak forests dominated by *Quercus pubescens* Willd., and *Q. frainetto* Ten. Plantations of pine trees (*Pinus brutia* Ten., *P. nigra* Arnold., *P. pinaster* Aiton.) are also included.

Catalogue of transitions

Transition 1. Abandonment of arable farming.

Transition 2. Putting to farming abandoned arable fields or opening up of grassland state-owned land to farming.

Transition 3. Reduction of grazing pressure by goats.

Transition 4. Planting trees to create forests.

Transition 5. Reduction or complete cessation of shrub cutting for charcoal or fuelwood.

Transition 6. Expanding arable farms at their borders by shrub and tree cutting or burning followed by ploughing.

Transition 7. Converting marginal arable lands into farm forests.

DISCUSSION

Model evaluation

The states of the model represent distinct plant communities separated from each other by large differences in vegetation structure, biodiversity, and management objectives (Bestelmeyer et al., 2003). For example, arable lands are covered by cultivated annual species, grasslands by spontaneous annual and especially perennial herbaceous species, shrublands by evergreen shrubs, and forests by broadleaved tree species. At the same time, the same states represent distinct land use types accommodating quite different human needs. For example, arable lands produce crops; grasslands are mainly grazed by sheep and cattle; shrublands are mainly used for goat grazing and firewood production; forests are mainly used for timber. In other words, the four states are sustainable plant communities created and maintained to meet specific human needs. In the Mediterranean context, such states can be considered as legitimate management options (Perevolotsky, 2004) and comply with the condition set by Westoby et al. (1989) that management rather than theoretical criteria should be used in identifying states in a particular situation.

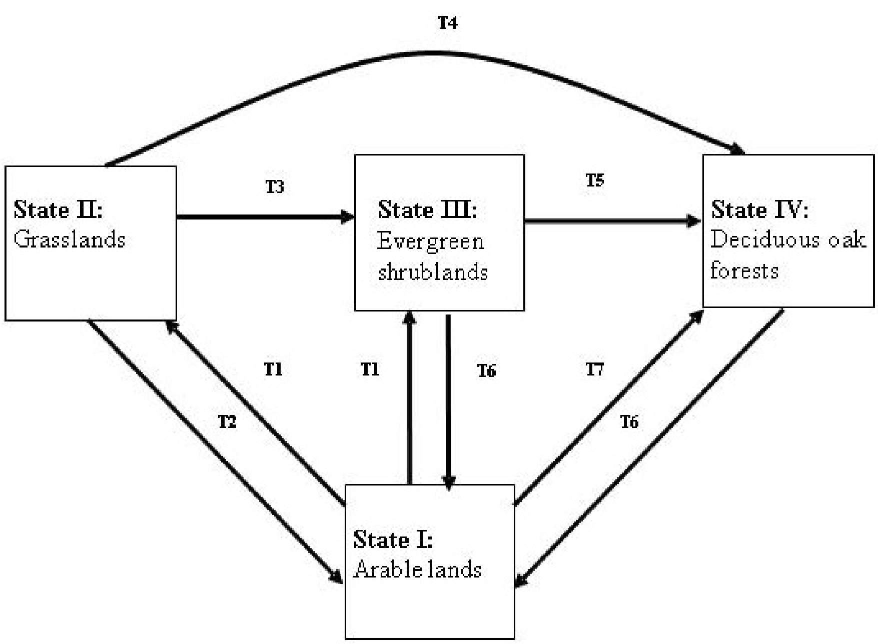

Fig. 7. The state-and-transition model for the Lagadas study area showing the four states (boxes) and the seven transitions (T). (T1: Abandonment of farming activities, T2: Ploughing and cultivation, T3: Reduction of grazing pressure by goats, T4: Afforestation with pines and other species, T5: Reduction or complete cessation of coal and fuel wood collection, T6: Expanding arable farms, and T7: Establishment of farm forests).

The transitions, on the other hand, represent shifts from one state to another as a result of changes in management objectives dictated by socio-economic changes. The abandonment of arable farming (Transition 1), for example, was triggered by the reduction of the rural population, especially of young farmers, over the study period. This transition, however, was counterbalanced and overwhelmed by opening new farms in grasslands (Transition 2) or expanding the existing farms in grasslands at the expense of neighboring shrublands and forests (Transition 6), apparently due to European subsidies provided to farmers in order to stay in farming and increase their income (Zioganas, 1999). As a mater of fact, grasslands, shrublands, and forests are communal lands for grazing and fuelwood collection (Papanastasis, 1981, 1988), and their conversion to arable lands, although not officially allowed, is often tolerated for political reasons. On the other hand, the expansion and overgrowth of shrubs (particularly kermes oak) was triggered by two transitions, the reduction of goat grazing pressure (Transition 3) and of shrub cutting for firewood and charcoal (Transition 5) due to reduced goat numbers and the lack of demand for such products, respectively, during the study period. Finally, the expansion of forests was triggered by the afforestation practices in grasslands (Transition 4) and in arable lands (Transition 7).

The same transitions can also explain the changes within states, especially in shrublands and forests. However, the open and medium crown cover classes of both states could be considered rather as transient states (Westoby et al., 1989), since they are not expected to stay long, particularly in forests. Alternatively, they could be thought of as plant community phases or serial stages linked with community pathways (Stringham et al., 2003) that flow in both directions (Fig. 6). Consequently, the state-and-transition model developed does not preclude succession as being one of the factors involved in vegetation changes of the study area. Briske et al. (2005) suggest that the state-and-transition models can also incorporate the range succession model in studies of vegetation dynamics.

Clearly, the transitions identified represent irreversible changes since the new states created will not come back to the previous ones unless a counter-transition is applied. For example, abandoned farms will not become arable fields again unless ploughing and cereal cropping is applied. This means that the transitions proposed can also be considered as thresholds in the sense that once they have been crossed, a new transition should be applied to return to the previous state in order to meet a specific management objective and at the same time restore the damaged ecological processes (Stringham et al., 2003; Walker and Meyers, 2004). On the other hand, the fact that no environmentally driven transition was identified should be attributed to the rather short study period, during which no major environmental changes, such as climate changes or major wildfires, occurred in the area. The short-term weather changes that may have occurred should have affected the speed rather than the extent of management transitions. Given the lack of long-term land cover/use data in Greece, the model could also be used for predicting future vegetation and developing scenarios of land cover/use changes on the basis of statistical data (Bankov, 1998; Verburg et al., 2002).

Implications for conservation management of the landscape

The state-and-transition model developed refers to the whole landscape and stresses the close connection of rangelands with forests and arable lands. In other world, it suggests that management of rangelands cannot be accommodated without considering the other land cover/use types, too. Consequently, it provides a suitable framework for designing and implementing an integrated management of the studied landscape. For livestock production, which is the main economic activity in the study area, the model indicates that it cannot be helped if arable lands continue to expand at the expense of rangelands, while further increase of the woody cover can only result in the reduction of available forage to grazing animals, particularly sheep and cattle (Platis and Papanastasis, 2003). Similarly, if arable lands are abandoned from farming or planted with forest species, livestock production also is going to be negatively affected, since cereal stubble is an important source of feed for the animals during the summer months (Yiakoulaki et al., 2002). Consequently, if sheep and cattle have to be increased and accommodated, the area covered by grasslands should also be increased. According to the model, this should be mainly done through the arable lands abandoned from farming activities. Otherwise, goat numbers should further increase in order to control the invaded shrubs to grasslands as well as the closing up of shrublands. All these options should be considered in planning sustained management of rangelands in the study area.

The model developed, however, suggests that grazing management is not enough to control vegetation changes. In particular, livestock grazing is involved only in the transition from grasslands to shrublands and secondarily to the one from shrublands to forests. Goats cannot control the growth of shrubs, especially of kermes oak once they grow out of their reach (Liacos et al., 1980; Papanastasis and Liacos, 1991; Carmel and Kadmon, 1999). In addition, goats also consume herbaceous species, which they prefer to kermes oak in certain seasons of the year such as spring (Papachristou and Nastis, 1993; Yiakoulaki and Nastis, 1995). The inability of goats to fully control shrub outgrowth can be shown by the fact that although their stocking rate was substantially increased from 1971 to 1991, kermes oak shrublands continued to expand and get more dense. This development implies that, besides goats, additional measures should be implemented to control shrub invasion and outgrowth including mechanical clearing (Papanastasis et al., 1991).

According to Naveh and Lieberman (1994), one of the main problems of dynamic conservation management of Mediterranean landscapes is the re-dominance of woody vegetation following the abandonment of the traditional agro-pastoral activities or protection. Such evolution results in dense, species-poor, and highly combustible shrublands and woodlands. The increased woody cover over the last 33 years at the expense of grasslands and the open shrublands and forest in the study area creates a number of threats, the most important being the fire hazard and the reduction of biodiversity. Although natural fires are not known to occur in the area, the potential of wildfires set intentionally or accidentally by people is high given the increased flammability of the dominant shrub kermes oak (Dimitrakopoulos, 2001). On the other hand, Papoulia et al. (2003) found more bird species in open than in dense kermes oak shrublands in the study area, while Papadimitriou et al. (2004) found higher plant diversity in grasslands than in kermes oak shrublands. For rehabilitating wood-invaded ecotopes in open landscapes semi-natural, multistructural, and stable plant communities should be established after applying several management interventions including reseeding, fertilizing, selective weed control, and agroforestry (Naveh, 1988; Naveh and Lieberman, 1994). In addition, grazing management, if properly applied, can result in reduction of fire risk and increase of biodiversity (Naveh and Whittaker, 1975; Perevolotsky and Seligman, 1998). According to Noy-Meir (1998), the conservation of biodiversity in native grassland communities can be best ensured by the application of moderate to heavy grazing over most of the landscape.

Landscape conservation of the study area should aim at the establishment of a highly heterogeneous landscape with increased bio-and ecodiversity, environmental stability, and sustainability (Naveh, 1994). Such a target can only be achieved by human intervention since all transitions identified in the model are management-related. The model developed can serve as a tool in selecting and taking the appropriate management decisions so that not only livestock production but also other landscape products and services are also ensured. Consequently, it constitutes a dynamic approach to conservation management of Mediterranean landscapes that can be tested and applied in other parts of Greece as well, and possibly in other Mediterranean countries as well.

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