THE SPANISH DEHESAS: A FINANCIAL APPRAISAL OF HOLM OAK (*Quercus ilex*) REGENERATION

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SUMMARY

Spain's 2.25 million hectares of dehesa woodlands are managed for livestock, fuel wood and charcoal production. They also provide wildlife habitat, outdoor recreation, aesthetic values and are considered to be of outstanding ornithological interest. However, in recent years, in an attempt to raise farm profitability, farmers have increased the number of livestock grazing on their land. Concern regarding poor holm oak has led policy makers in Spain to investigate whether or not domestic herbivory threatens the holm oak population. An ecological-economic model is constructed from four case-study sites in Extremadura. The model is used to define grazing thresholds commensurate with the long-term sustainability of holm oak. Results indicate that farmers under *highly* intensive grazing regimes (> 2.0 Ewe Equivalents/ha) have a negative impact on natural regeneration. However, results also show that it is unlikely that farmers engaged in *moderately* intensive livestock management regimes (< 1.5 EE/ha), will lead to the demise of holm oak. The model is also used to determine changes in farm income brought about by potential restrictions in livestock management strategies for complying with grazing thresholds. This information is then used as likely payments that a farmer would require in compensation for the supply of environmental goods associated with holm oak habitat. These results could be used to guide conservation practices and contribute towards the development of agri-environment policy associated with dehesa agro-ecosystems.

KEY WORDS: Holm oak
Regeneration
Management agreement

INTRODUCTION

The dehesas of Extremadura, southwest Spain, comprise an agrosilvopastoral system dominated by holm oak *(Quercus ilex)* and cork oak *(Q. suber)* over an understorey of herbaceous annual and perennial species which extends over more than 50,000 km^2 (Campos, 1984; Ruiz, 1986; Montoya, 1989). These tree species have been selected to produce a variety of forest products for animal and human consumption (Campos, 1984; Ruiz, 1986). Dehesas are widely recognised as being of exceptional conservation value (Baldock *et al.,* 1993; Telleria and Santos, 1995; Díaz *et al.,* 1996). They support several species which are rare or globally threatened including Black vultures *(Aegipius monachus)*, Spanish imperial eagles *(Aquila adalberti)*, black stork *(Ciconia nigra)* and common cranes (Alonso *et al.,* 1990; González *et al.,* 1990).

However, in recent years, there has been concern about the apparent poor regeneration of holm oak throughout Extremadura's dehesas due to browsing by domestic livestock (Montero, 1988; Sears, 1991; Campos, 1992; Cuartas and García-Gónzalez, 1992; Huntsinger and Bartoleme, 1992; Herrera 1995; ICONA, 1995; Eden, 1996; Díaz *et al.,* 1997). Several studies also speculate that European Union subsidies may have encouraged excessive grazing of dehesa rangelands affecting the long-term productivity of holm oak (Sears, 1991; Campos, 1992; Cuartas and García-Gónzalez, 1992; Huntsinger and Bartoleme, 1992; Eden, 1996; Diaz *et al.,* 1997).

There are two main areas, which have not been considered in the study of dehesa holm oak regeneration. First, on farms which use natural regeneration and employ transhumance the effects of actually varying livestock stocking rates have largely been ignored. Previous studies have focussed on hypothetical consumption of holm oak by domestic livestock but did not record actual damage to plants in relation to livestock intensity (Cuartas and García-Gónzalez, 1992). Other studies have focussed on acorn consumption by livestock and seedling damage by trampling (Herrera, 1995).

Second, it is not clear what the actual costs in terms of compensation might be of varying livestock stocking rates (using transhumance) to allow for natural regeneration. Campos (1992) estimated the financial costs of complete stock exclusion in a cork oak woodland in order to achieve adequate re-stocking. This study dealt with cork oak, not holm oak. It also evaluated the costs and benefits of planting, not natural regeneration. No studies have been conducted which evaluate incentives with respect to natural regeneration despite the fact that this is the traditional method of re-stocking used by the majority of dehesa farmers. Assessments which are not based on natural regeneration are likely to inaccurately represent the financial cost incurred by most dehesa farmers and this may have important implications for the level of compensatory payments offered to farmers in encouraging participation in regeneration programmes.

This paper is concerned with land use extensification to maintain stands of holm oak. First, it aims to establish whether or not the holm oak population is endangered by domestic livestock and to determine the effects of different levels of grazing intensity on the population of holm oak. Second, it seeks to estimate the costs to dehesa farmers of complying with stocking rate restrictions which promote holm oak habitat and its associated biodiversity. The process of conducting research of the type described above for individual farms is somewhat inefficient and cannot be justified financially. A better approach would be to develop a series of systematic sets of relationships between holm oak habitat and management variables that can be represented in an integrated model.

SPECIFICATION OF THE ECOLOGICAL-ECONOMIC MODEL

The first step in the construction of such a model involves gathering empirical results which have been used to construct the dehesa agri-environment management model (DAMM). Results from the DAMM model are now established and the model has been used to determine the precise effects on the holm oak population of varying stocking intensity (van Rensburg, 2001). However, the DAMM model is restricted in that it predicts ecological effects of agri-environment policy, not economic outcomes. Decisions made by dehesa farmers are driven by policy change and market forces that affect the economic efficiency of different enterprises and input allocation between different uses. The appraisal of agri-environment policy requires joint consideration of both the ecological effects of changing management practices as well as an investigation of the financial costs of the policy. To do this, the DAMM model needs to be combined with an economic simulation model in order to establish, for each management scenario, a costing of changes in management necessary to bring about desirable ecological aims. The dehesa economic management model (DEMM) has been specifically developed to do this. This model is now established and enables an assessment of the economic response functions to different livestock stocking rates (van Rensburg, 2001). The specification of the DEMM model required a knowledge of all costs and revenues associated with holm oak wooded dehesa farms. This was then used to develop a series of functional forms which specified the relationship between livestock stocking rate and revenue, cost and net benefit functions. The model links non-linear cost and net benefit functions to predict the effects of reductions in stocking rate on farm profitability. These established models will be used in this paper to predict the effects of different policy scenarios which involve a reduction in farming intensity.

METHODS: EMPIRICAL ESTIMATION OF PRODUCTION PROCESSES

This study carried out three different procedures:

1) To determine whether livestock affect the population of holm oak we recorded data on animal numbers and natural regeneration in 32 0.2 hectare nested plots on 4 farms. For the purposes of this paper these farms are referred to as F1 (farm 1) to F4 (farm 4). These farms were sampled at eight different livestock densities (four replicates), ranging from 0.94 - 2.02 ewe equivalent units (EE) per hectare. Livestock stocking rates are measured in ewe equivalents because sheep are the dominant species considered in this study (van Rensburg, 2001). In each of these 32 plots, the age, number, height and condition of seedlings and saplings were measured (Reid and Ellis, 1995).
2) To establish if the holm oak population is endangered by domestic livestock or not data on age specific mortality and reproductive rates under varying livestock intensities were gathered under different stocking rates. This information was used to construct the DAMM model.
3) To determine the costs to dehesa farmers of complying with stocking rate restrictions which promote holm oak, sample plots as well as personal interviews were used which provided detailed ecological data as well as on revenue and cost summaries. This information was used to develop the DEMM model. Farmers were assumed to be fully-informed rational profit-maximisers and risk-neutral in decision making. Constant (1995) prices were employed assuming that prices of all inputs and outputs would increase at an equal rate, inputs were valued at their

market price and outputs valued at farm gate price. All prices are expressed in Spanish pesetas.

RESULTS

Procedure 1: The impact of high livestock stocking rates on holm oak

The first major finding of this study was that relatively high livestock stocking rates (> 2 EE/ha) have a negative effect on the abundance, size and condition of seedlings and saplings. Patterns of distribution indicate that the majority of all seedlings occurred on sites with low to moderate stocking rates. Table 1 shows that farms with the lowest stocking rates (F1 and F2) had the greatest number of seedlings and saplings whilst sites with the highest stocking rates recorded the lowest number of seedlings and saplings.

Table 1

The percentage of seedlings and saplings recorded (per ha) for each of the sites. Results from ANOVA tests indicate significant differences between the mean number of seedlings and saplings found on each of the sites [$F_{3,28}$ = 3.01; * = P = < 0.05]. n = 32

Sites	Stocking rate	Seedlings	Saplings	Total *
F1	0.94	28	39	30
F2	1.36	40	41	40
F3	1.69	12	10	12
F4	2.02	20	10	18
Total		100	100	100

[F1 = farm 1].

The table shows results from ANOVA tests which indicate significant differences between the mean number of seedlings and saplings found on each of the sites. About 40 % of seedlings and saplings were observed on F2 alone, while only 12 % were observed on F3. Together, F1 and F2 recorded 70 % of all saplings. An enquiry into seedling growth in response to livestock revealed that seedlings recorded on moderately grazed plots were significantly taller in height than seedlings recorded on intensively stocked sites.

Table 2 indicates differences in seedling heights for the sites for seedlings of varying ages. Mean seedling heights for all sites are compared with F1 (which had the tallest seedlings) and are expressed as a percentage of the height attained by F1 seedlings. The table shows that seedlings established on F1 and F2 sites for all ages were in general taller than those growing on F3 and F4. It can be seen that mean heights of 3 year old seedlings recorded on F4 were only 51 % of the mean height of seedlings recorded on F1. Differences between sites were significant for seedlings aged 3 and 5 years old.

Table 2

ANOVA model shows significant differences in seedling heights between farms for 3 year old seedlings [$F_{3,23}$ = 3.49; P = < 0.05] and for 5 year old seedlings [$F_{3,15}$ = 7.77 P = > 0.005]. Mean seedling heights are expressed as a percentage of the height attained by farm 1 seedlings

Age	Seedling heights	Farms			
		F1	F2	F3	F4
3	Expressed as a % of F1	100 *	75 *	68 *	51 *
5	Expressed as a % of F1	100 **	92 **	75 **	50 **

* = (P = > 0.05); ** = (P = > 0.005).

An enquiry into the physical condition of seedlings and saplings showed that the proportion of seedlings which were browsed increased with stocking rate from 66 % to 90 % from moderately grazed to intensively stocked sites (Table 3). The amount of saplings which were damaged by livestock also increased from 9 % on F1 to 63 % on F4.

Table 3

Percentages of seedlings and saplings affected by livestock browsing for each of the sites

	Farms			
	F1	F2	F3	F4
% of seedlings browsed	66	82	88	90
% of saplings browsed	9	21	51	63

The results from the DEMM model presented in Table 4 suggests that sites with very high stocking rates (> 2 EE/ha) may lead to the eventual disappearance of holm oak altogether. Despite high initial tree densities, the model predicts that the population of holm oak is threatened on F4 and the number of trees declines to about 25 trees per hectare (extensive) (after 100 years) due to high rates of seedling mortality.

The population on F3 (extensive) increased slowly, and eventually maintained a stable but relatively low population of about 16 trees per hectare. The population on all F1 and F2 increased over a period of 100 years, prior to reaching the steady state. Both these farms maintained healthy populations of mature trees of more than about 40 trees per hectare, and a mixed age class distribution due to a relatively high population of saplings and high rates of survival for the seedling class.

Table 4

Predicted changes to holm oak population for different sites under current management (per ha) using the DAMM

Site	EE/ha	(1)	(2)	(3)
F1	0.94	53 (58)	5	38
F2	1.36	54 (60)	3	39
F3	1.69	20 (16)	–	17
F4	2.02	25 (0)	–	51

(1) = tree density after 100 years (figure in brackets = tree density at steady state).
(2) = time taken (in years) to reach a population of 40 mature holm oak per ha.
(3) = initial tree density.

Procedure 2: The impact of moderate stocking rates on holm oak.

The second major finding is that complete livestock exclusion may not always be necessary to achieve target natural regeneration levels of holm oak (van Rensburg, 2001). The model predicts that dehesa woodlands at *low and moderate* stocking rates (< 1.5 EE/ha) do not face an imminent decline and on none of these sites do trees disappear altogether. Simulations of the model were undertaken to simulate a possible management or Environmentally Sensitive Area (ESA) agreement whereby typical restrictions involve a reduction in livestock intensity to facilitate holm oak establishment. The results of this procedure are presented in Table 5 where livestock stocking rates are set at 65 % and 80 % of current stocking rates on a permanent basis. The results given in Table 5 show an increase in the population of holm oak under reduced grazing intensity. The table indicates that with 80 % of current stocking rates the holm oak population achieves steady state populations of holm oak of between 45 - 77 trees per ha. Under 65 % of current

Table 5

Predicted changes to holm oak population under reduced grazing intensity of 65% and 80% of current stocking rates using the DAMM

	% Changes in herbivory adjusted from current levels				
	65% of current herbivory		80% of current herbivory		
Site	**(1)**	**(2)**	**(1)**	**(2)**	**(3)**
F1	68 (77)	3	61 (77)	4	38
F2	72 (83)	1	60 (70)	2	39
F3	42 (56)	85	32 (45)	63	17
F4	55 (60)	0	44 (45)	0	51

(1) = tree density after a 100 years (figure in brackets = tree density at steady state).
(2) = time taken (in years) to reach a population of 40 mature holm oak per ha.
(3) = initial tree density.

stocking rates the population of holm oak reach equilibrium population levels of between approximately 56 and 83 trees per ha. Reductions in livestock stocking rates on F3 and F4 are predicted to increase the population of holm oak and lead to steady state values of around 45-60 trees/ha. Predicted aesthetic quality is, therefore, likely to be positively enhanced under regimes which reduce stocking rate.

Procedure 3: Costs of dehesa holm oak extensification

This procedure specifies the actual costs associated with extensification. Table 6 shows that to maintain a population of holm oak of more than 40 trees per ha both F3 and F4 would have to reduce their stocking rates to 80 % and 65 % of current levels for a period of 100 years. Thus, livestock stocking rates must be kept at or below 1.5 EE/ha for both of these sites if target tree densities are to be maintained. Table 6 summarises changes in net benefits predicted by the DEMM model for F3. The table shows that in order to maintain target tree densities of 40 trees per ha on F3 this would require stocking rates to be reduced from 1.69 EE/ha to 1.35 EE/ha at a cost of 775 pts per ha per year.

Table 6

Extensification costs for F3 (at 80% of current herbivory) and F4 (at 65% of current herbivory)

Farm	Site	(1)	(2)	(3)	(4)	(5)
F3	80 % of current herbivory (*1.35)	45	63	3,059	2,284	775
F4	65 % of current herbivory (*1.31)	60	0	3,650	1,805	1,845

(1) = steady state tree density (3) = net benefits (NB) under current management
(2) = years to steady state. (4) = NB under reduced stocking rates.
(4) = compensation costs. * = EE/ha under reduced stocking rate; (£1.00 = 210 pts).

Table 6 shows changes in net benefits predicted by the DEMM model for F4. The table shows that in order to maintain target tree densities of more than 40 trees per ha this would require stocking rates to be reduced from 2.02 EE/ha to 1.31 EE/ha at a cost of 1,845 pts per ha per year.

In view of the importance of reducing public expenditure on ESA policy, both the DAMM and DEMM models were run to identify potential least-cost management scenarios for the maintenance of stable target holm oak populations. These models can, therefore, be used to distinguish between farms which involve low compensation costs, and those farms that require high payments for a specified target tree density.

For example, Table 7 shows the compensatory costs required to induce farmers to reduce baseline stocking rates to a hypothetical target stocking rate of between 0.8 - 1.5 EE/ha. It indicates that stocking rate reductions from 2.02 to 1.25 EE/ha on Farm 4 would cost 2,090 pts compared to 415 pts to reduce grazing from 1.36 EE/ha to 1.25 EE/ha on Farm 2.

Table 7

Compliance costs of meeting target stocking rates of between 0.8 - 1.5 EE/ha for the 4 farms. Stocking rate reductions from 2.02 to 1.25 EE/ha on F4 would cost 2,090 pts compared to 415 pts to reduce grazing from 1.36 EE/ha to 1.25 EE/ha on Farm 2

Sites	EE/ha	Target rate of EE/ha			
		0.80	1.00	1.25	1.50
F1	0.94	817	134	0	0
F2	1.36	2,825	1,647	415	0
F3	1.69	3,910	2,732	1,499	534
F4	2.02	4,501	3,323	2,090	1,125

Clearly, some sites have a greater potential to achieve target tree densities at lower cost than others. This is because the net benefits and, hence, opportunity costs of a given reduction in stocking rates on the F4 site are greater than for F2. Hence the amount required to compensate F4 for a loss of income under a given change in farming activity is greater for F4 than for F2.

DISCUSSION

The results of this study indicate that livestock have a negative effect on the abundance, size and condition of seedlings and saplings. Indeed, the DAMM model shows that in areas with high livestock stocking rates (> 2 EE/ha) a decline in the holm oak population may result. The DAMM model also suggests that on sites with low tree densities, and high animal stocking rates the prospects of a well developed mixed-age class stand of holm oak are slim. Hence, for the foreseeable future, holm oak establishment cannot rely on seed sources from mature trees to maintain a stable population of holm oak. These results concur with observations made by Herrera (1995) in the case of cork oak dehesas in Extremadura. He suggests that on sites with high densities of ungulates, low population density of mature trees, and lack of effective dispersal agents, potential for natural regeneration is very restricted.

However, this study also shows that recruitment is possible at low livestock stocking rates particularly where tree densities are high. Model runs for sites with moderate livestock stocking rates and good tree densities predict stable equilibrium populations in excess of target tree densities of 40 trees per ha.

These results contrast with the model developed by Elena *et al.,* (1987) who predicted an annual decline of 240,775 trees from 1984, implying complete disappearance by 2,065, eighty four years later. The DAMM model predicts slower rates of holm oak population decline than estimated by Elena *et al.* (1987). A possible explanation for the varied effects of these predictive models for holm oak may be due to the fact that these predictions were made during the 1970s and 1980s. At that time government policies were promoting the grubbing of holm oak and their replacement by agricultural crops and fuel wood and charcoal prices were high (Campos, 1992; Díaz *et al.,* 1997). Such activities are no longer a threat. In recent years the price of firewood and charcoal has fallen and because of legislation (Ley de la Dehesa, 1986) enacted to prevent tree cutting, clearing has now ceased and farmers are expected to carry out activities to maintain populations of existing mature trees. Further, the model of Elena *et al.* (1987) does not incorporate data on the effects of domestic livestock on holm oak recruitment and it does not take account of the inherent variability associated with ecological conditions on different farms across different regions of Extremadura. Studies which do not record age -specific survival data (Cuartas and García-Gónzalez, 1992) in relation to small changes in livestock density are likely to give imprecise predictions on the impact of livestock on the holm oak population.

A number of explanations for the persistence of holm oak under a moderate grazing regime could be advanced. First, results from this study show that seedlings observed on sites with relatively abundant synchronous regeneration exhibited less signs of browsing damage than on sites with fewer specimens. Further, on such sites seedlings that exhibit superior vigour were seen to surround themselves with other seedlings or saplings forming a dense impenetrable thicket in the form of a dome that protects them from browsing. These clumps of vegetation impede livestock access and whilst seedlings on the perimeter of the thicket are heavily browsed these act to protect vigorous saplings at the centre of the clump which eventually grow above the browseline and become permanently established as mature trees. Consequently, there is too much browse for moderate densities of browsing animals. The amount of hypothetical holm oak intake is not evenly spread across individuals and this allows for the transition of vigorous specimens to saplings and mature trees. Eventually, these individuals are selected by farmers for formation pruning.

Second, it is possible that morphological adaptations by holm oak have enabled the species to persist in spite of browsing. Holm oak is also known for its high sprouting potential (Espelta *et al.*, 1995) and resistance to fire and grazing. Holm oak also uses defensive strategies against browsing including the incidence of prickly leaves (particularly among young seedlings) which may enable this species to persist under grazing. Indeed, some studies endorse the view there is a long history of grazing of holm oak in the Mediterranean basin and that, far from restricting holm oak consumption in this region, domestic livestock have favoured its expansion (Clutton Brock, 1987; Bran *et al.,* 1990).

Third, studies from other regions of the world show that stand density appears to have an effect on the level of browsing. Andren and Angelstam (1993) noted that high density stands (> 1,500) of young scots pine in Sweden are less vulnerable to browsing by moose. They report that browsing was reduced when the density of young trees exceeded about 1,500 trees per hectare. Staines (1995) has also suggested that there is a relationship between animal density, and the number of trees. For a given animal density, sites with fewer trees will be browsed much more heavily than well-stocked stands.

Results from grazing models used in other regions of the world provide a useful comparison with the DAMM model. Modelling has shown that plant populations may be little affected by low levels of herbivory. Kienast *et al.,* (1999) used a succession model –FORECE– to assess the long-term dynamics of alpine forests in central Europe. They reported that moderate levels of browsing posed no threat to the long-term survival of these forests and did not alter the successional sequence of forest development. However, simulations of the FORECE model under a high intensity grazing regime show that high browsing pressure does reduce recruitment and alters the forest structure considerably, leading to high rates of tree mortality and more open forests. The spatial model developed by Weber *et al.* (1998) and applied to the southern Kalahari shows that high levels of grazing led to shrub invasion. Jeltsch *et al.* (1997) also reported that when grazing intensity reaches a critical level, shrub cover increases, drastically lowering the productivity of the range. The simulation model used by Jorritsma *et al.* (1999) showed that domestic herbivores can have a significant impact on forest development. Their model indicates that the presence of 1 cow (equivalent to 0.8 - 1 LSU or 4-5 EE/ha) per ha virtually eliminates recruitment entirely.

Dehesa woodlands characterised by low tree densities, high stock densities and severe competition from herbaceous annuals are likely to have low levels of recruitment. Excessively high animal densities, particularly of goats, should be avoided in such areas. Moderate numbers of sheep should be used where possible to facilitate initial establishment, followed by grazing by cattle and goats. The negative association between livestock and holm oak recruitment needs to be considered further by policy-making bodies. Areas of high vulnerability require the formulation and implementation of management guidelines to restrict intensive grazing, and policies need to be designed to support this.

CONCLUSIONS

Adjustments in farm income that arise as a consequence of restricted management practices have been evaluated using an integrated ecological - economic model. This integrated model can be used to distinguish between farms, which involve low compensation costs, and those farms that require high payments for a specified target tree density. Compensation payments may be relatively low on sites managed under low intensity stocking regimes. On the other hand, the cost of achieving the same habitat on more intensive areas might be considerable. Clearly, some sites have a greater potential to achieve these wider public goals than others.

The analysis presented in this study illustrates how different modelling approaches from 2 separate disciplines (ecology and economics) can be combined to produce useful supporting information to advise policy decision-making. Environmental goods have been identified from an ecological perspective and a costing system for their supply has been shown. Drawing on examples from other countries, the results from this study suggest that the modelling framework could be used for the analysis of potential environmental policy change.

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RESUMEN

La dehesa española: un enfoque financiero de la regeneración natural de la encina *(Quercus ilex)*

En España existen 2,25 millones de hectáreas de dehesas arboladas que se destinan a la producción de recursos de pastoreo para la ganadería, las especies cinegéticas, la producción de leña y de carbón. También proveen un hábitat para la vida salvaje, valores estéticos y recreativos, y son consideradas como zonas de excepcional interés ornitológico. Sin embargo, en lo últimos años con el objetivo de aumentar la rentabilidad de estas tierras, los agricultores han incrementado la carga ganadera respondiendo a los estímulos de las subvenciones públicas. La preocupación por la escasa regeneración natural de la dehesa de encinas ha conducido recientemente a estudiar incentivos para contrarrestar la amenaza que representan el sobrepastoreo del ganado doméstico sobre las poblaciones de encinas. Se construye aquí un modelo bioeconómico basado en cuatro estudios de casos realizados en la comarca de Monfragüe y su entorno (Extremadura). El modelo es usado para definir límites de pastoreo, acordes con la sustentabilidad de la encina a largo plazo. Los resultados indican que los agricultores con regímenes de pastoreo trashumantes altamente intensivos (mayores de 2,0 ovino equivalente/ha) generan impactos negativos sobre la regeneración natural de las encinas. Sin embargo, los resultados también muestran que es poco probable que los agricultores, con sistemas de manejo trashumantes moderadamente intensivos (menores de 1,5 ovino equivalente /ha), conduzcan a la desaparición de la encina. El modelo también se usa para determinar los cambios en las rentas agrícolas generados por restricciones potenciales en las estrategias de la gestión ganadera, para cumplir los límites de pastoreo. Esta información es utilizada para estimar las posibles compensaciones a los agricultores, por proveer servicios ambientales asociados con el hábitat de la encina. Estos resultados pueden ser empleados para orientar las prácticas de conservación y contribuir al desarrollo de políticas agro-ambientales, asociadas a los agro-ecosistemas de dehesa.

PALABRAS CLAVE: Dehesa de encinas
Regeneración natural
Compromisos de gestión

REFERENCES

ALONSO J.A., ALONSO J.C., MUÑOZ-PULIDO R., 1990. Areas de invernada de la grulla común *Grus grus* en España. In: Distribución y demografia de la grulla común (*Grus grus*) en España. Alonso J.A., Alonso J.C. eds. ICONA, Madrid.

ANDREN H., ANGELSTAM P., 1993. Moose browsing on scots pine in relation to stand size and distance from forest edge. Journal of Applied Ecology 30, 133-142.

BALDOCK D., BEAUFOY G., BENNET G., CLARK J., eds. 1993. Nature conservation and new directions in the EC common agricultural policy. Institute for European Environmental Policy, HPC, Arnhem.

BRAN D., LOBREAUX O., MAISTRE M., PERRET P., ROMANE F., 1990. Germination of *Quercus ilex* and *Q. pubescens* in a *Q. ilex* coppice. Long-term consequences. Vegetatio 87, 45-50.

CAMPOS P., 1984. Economia y energía en la dehesa Extremeña. Ministerio de Agricultura, Pesca y Alimentación (MAPA), Madrid.

CAMPOS P., 1992. Spain. In: Forests: market and intervention failures, five Case Studies. Wibe S., Jones T., eds. Earthscan, London.

CLUTTON-BROCK J., 1987. A natural history of domesticated mammals. Cambridge University Press and British Museum (Natural History), Cambridge and London.

CUARTAS P., GARCÍA-GÓNZALEZ R., 1992. *Quercus ilex* L. browse utilisation by caprini in Sierra de Cazorla and Segura (Spain). Vegetatio 99-100, 317-330.

DÍAZ M., CAMPOS P., PULIDO F.J., 1997. The Spanish dehesas: a diversity in land-use and wildlife. In: The common agricultural policy and its implications for bird conservation. Pain D. J., Pienkowski M.W., eds. Academic Press, London.

DÍAZ M., GONZÁLEZ E., MUÑOZ-PULIDO R., NAVESO M.A., 1996. Habitat selection patterns of common cranes *Grus grus* wintering in holm oak *Quercus ilex* dehesas of central Spain: effects of human management. Biological Conservation 75, 119-123.

EDEN P., 1996. Farming in the Portuguese montados. La Cañada 5, 6.
ELENA R.M. *et al.,* 1987. El carbon de encina y la dehesa (MAPA) Madrid, Spain.
ESPELTA J.S., RIBA M., RETANA J., 1995. Patterns of seedling recruitment in West-Mediterranean *Quercus ilex* forests influenced by canopy development. Journal of Vegetation Science 6, 465-472.
GONZÁLEZ L.M., BUSTAMENTE J., HIRALDO F., 1990. Factors influencing the present distribution of the Spanish imperial eagle *Aquila adalberti.* Biological Conservation 51, 311-319.
HERRERA J., 1995. Acorn predation and seedling production in a low-density population of cork oak *(Quercus suber* L). Forest Ecology and Management 76, 197-201.
HUNTSINGER L., BARTOLEME J.W., 1992. Ecological dynamics of *Quercus* dominated woodlands in California and Southern Spain: a state transition model. Vegetatio 99-100, 299-305.
INSTITUTO PARA LA CONSERVACIÓN DE LA NATURALEZA (ICONA), 1995. Segundo inventario forestal nacional. Ministerio de Agricultura Pesca y Alimentacion, (MAPA). Madrid.
JELTSCH F., MILTON S.J., DEAN W.R.J., VAN ROOYEN N., 1997. Analysing shrub encroachment in the southern Kalahari: a grid based modelling approach. Journal of Applied Ecology 34, 1497-1509.
JORRITSMA I.T.M., VAN HEES A.F.M., MOHREN G.M.J., 1999. Forest development in relation to ungulate grazing: a modelling approach. Forest Ecology and Management 120, 23-24.
KIENAST F., FRITSCHI J., BISSEGGER M., ABDERHALDEN W., 1999. Modelling successional patterns of high-elevation forests under changing herbivore pressure - responses at the landscape level. Forest Ecology and Management 120, 35-46.
LEY DE LA DEHESA, 1986. Ley sobre la dehesa en Extremadura, BOAE, nu. 100, de 29 de Mayo 1986.
MONTERO G., 1988. Modelos para cuantificar la produccion de corcho en alcornocales *(Quercus suber* L*)* en función de la calidad de estación y de los tratamientos selvícolas. Tesis doctoral. INIA, Madrid.
MONTOYA, J.M., 1989. Encina y encinares. Agroguias, Mundi Prensa. Madrid.
REID R.S., ELLIS J.E., 1995. Impacts of pastoralists on woodlands in South Turkana, Kenya: livestock mediated tree recruitment. Ecological Applications 5, 978-992.
VAN RENSBURG T.M., 2001. The spanish dehesas: an ecological economic analysis of holm oak *(Quercus ilex)* woodlands and bird diversity. Unpublished PhD thesis.
RUIZ M., 1986. Sustainable food and energy production in the «Spanish dehesa». The United Nations University, Paris.
SEARS J., 1991. Case study of European farmland birds: 1. Mediterranean steppelands, Spain. 2. The dehesa system, Spain. RSPB, Sandy.
STAINES B.W., 1995. The impact of red deer on the regeneration of native pinewoods. In: Our pinewood heritage. Forestry Commission. Conference proceedings, 1994. Inverness. Forestry Commission, RSPB, SNH. Surrey.
TELLERIA J.L., SANTOS T., 1995. Effects of forest fragmentation on a guild of wintering passerines: the role of habitat selection. Biological conservation 71, 61-67.
WEBER G.E., JELTSCH F., VAN ROOYEN N., MILTON S.J., 1998. Simulated long-term vegetation response to grazing heterogeneity in semi-arid rangelands. Journal of Applied Ecology 35, 687-699.