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Productive model of evergreen oak and annual pastures in Extremadura (Spain)

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SUMMARY – *Dehesa* or *montado* is a Mediterranean agro-silvo-pastoral system characterized by the presence of trees, *Quercus ilex* and *Q. suber*, and annual pastures. Acorn production is used to feed pigs, and pasture is grazed by cows, sheep or goats. The surface area of Extremadura *dehesas* accounts for one million hectares, 95% of which is *Q. ilex*. The objective was to identify the optimal stocking rate. A simulation model was used to determine stoking rates for Iberian pigs and dry cows in Extremadura. The model runs with daily weather data from Extremadura Station Network, soil from Extremadura soil database, and tree cover from the Third National Forest Survey. A database was built for each input and was displayed using ArcGis. Simulated average pasture yield was 3615 kg/ha and acorn production was 249 kg/ha. The model estimated that the optimal stocking rate ranges from 0.3 to 0.8 Iberian pigs per ha and from 0.1 to 0.9 cows per ha.

Keywords: Acorn, biodiversity, dehesa, *Quercus ilex*.

RESUME – *"Modèle productif du chêne vert et pâturages annuels d'Estrémadure". La* dehesa *ou* montado *est un système agro-sylvo-pastoral méditerranéen caractérisé par la présence d'arbres,* Quercus ilex *et* Q. suber*, et de plantes annuelles. La glandée est utilisée pour nourrir les porcs et la prairie est pâturée par les vaches, brebis ou chèvres. La surface de dehesas en Estrémadure est de 1 031 174 ha, avec une prédominance de* Q. ilex *(95%). L'objectif était d'obtenir la charge animale optimale. Un modèle de simulation dehesa a été utilisé pour déterminer la charge animale optimale de porcs ibériques et de vaches en Estrémadure. Le modèle fonctionne avec des données météorologiques journalières, des données pédologiques et des données du couvert forestier. Une base de données a été élaborée pour chaque variable d'entrée et visualisée à l'aide d'ArcGis. Le rendement moyen simulé de production fourragère est de 3615 kg.ha^{-1} et la glandée est de 249 kg.ha^{-1}. La charge animale optimale est de 0.3 à 0.8 porcs.ha^{-1} et de 0.1 à 0.9 UGB.ha^{-1}.*

Mots-clés : *Gland, biodiversité, dehesa,* Quercus ilex*.*

Introduction

The open parkland called *dehesa* in Spanish and *montado* in Portuguese is a Mediterranean agro-silvo-pastoral system characterized by the presence of natural trees, *Quercus ilex* and *Quercus suber*, annual pastures and some times crops. The *dehesa* is one of the most important natural agroforestry systems in south Europe. It covers more than three million hectares, in Spain and Portugal plus some areas in south France. The Iberian pig distinguishes this system from others due to the peculiar fattening mixed system. During the fattening period pigs are feed with the acorns dropped under the trees.

Tree-annual pasture interaction is part of the multi-functional role of this system. In Extremadura and other areas of the Iberian Peninsula acorn production is used to feed pigs, and pasture is grazing by cows, sheep or goats. The evergreen oak is the main tree species in the Iberian Peninsula. Extremadura *dehesas* surface is of 1,031,174 ha with 95% of *Quercus ilex*. Acorn production in *dehesas* is among 400 and 700 kg ha^{-1}, with a corresponding mature tree density among 40 and 60 tree ha^{-1}. The annual variability on acorn production is due to physiological behaviour of the tree and abiotic factors. Although, the evolution of this system takes place on different ways, from agricultural, environmental and social interest, it is necessary to better understand this complex system and their

productions in order to be able to revise the legislation and to set up an effective sustainable planning (particularly the management of Denomination of Origin for Iberian pig in Spain).

The difficulty of stock management, and in particular of the *agro-silvo-pastoral* resources, is related to the multidimensional character of the corresponding administration decisions. Indeed, any resolution will affect different aspects simultaneously: economic of production, environmental, social, with character multi functionality (Díaz-Ambrona, 1998). The objective of this work is to know both acorn and annual pasture potential production in Extremadura.

Methodology

Location

The Extremadura region is located at the southwest of the Iberian Peninsula. This region covers more than four million hectares (6% of the Iberian Peninsula). Elevation reaches almost 2400 m but is mostly 300 to 500 m. Climate is Mediterranean with some ocean influence. Lower temperature during the winter is 3.2ºC and average maximum temperature during summer is 34ºC, with annual mean of 16ºC. Average annual rainfall is 487 mm with high annual variability in the range of 300-800 mm. During summer, rainfall falls below the 50 mm (10% annual rainfall).

Model Dehesa

We have applied a simulation model to determine evergreen oak acorn and annual pasture production. The model Dehesa (Díaz-Ambrona *et al.*, 2007) is divided into five submodels: Climate, Soil, Evergreen oak, Pasture and Grazing. The first three require the introduction of the following inputs: (i) daily weather data (maximum and minimum temperatures, precipitation and solar radiation); (ii) the soil input parameters for three horizons (thickness, field capacity, permanent wilting point, and bulk density); and (iii) the tree characterization of the dehesa (tree density, canopy diameter and height, and diameter of the trunk). The initial stocking rate is considered like an exogenous variable and it must be introduced by the user in term of cows or dry ewes by hectare. The model has a daily basis. Biomass growth depends on solar radiation interception, soil water balance, and air temperature. Water uptake by annual pasture occurs from topsoil to actual root depth, while evergreen oaks, formed by mature trees, are able to uptake water from all the soil layers. Consequently annual pasture production is limited by available water (soil available water/pasture potential evapotranspiration), but also by radiation (photosynthetically active radiation use efficiency equal to 1.39 g MJ^{-1} and extinction coefficient to 0.4) and temperature (optimum temperature of 15º to 25ºC, minimum and maximum temperatures of 3º and 37ºC respectively). Evergreen oak biomass production (photosynthetically active radiation use efficiency equal to 0.738 g MJ^{-1} and extinction coefficient to 0.7) is distributed between: leaves, roots, acorns, trunk, and branches.

Model calibration has been made from literature data and model validation has been made comparing simulated results with field production of acorn and annual pasture in Extremadura (Díaz-Ambrona *et al.* 2007). Pasture production was measured in three representative *dehesas* and four randomly grazing exclusion cages (1 × 1 m^2) per site were used to apply in open-closed cut method, measures were made each month from October to June.

Databases

The model needs to run input of daily weather, soil, and tree cover data. With these data Dehesa model calculates daily forage and acorn production. A data base was build for each input and visualized using ArcGis map. Climatologic daily data were collected from Extremadura Weather Station Network (REDAREX). We used 19 stations with data from 1999 to 2007, which reported solar radiation, maximum and minimum temperature, and rainfall. Missing data were estimated as simple average between two valid data. Soil data base was made following the digital Spanish soil map. Then for each soil classes we assigned a soil type profile description obtained from the Extremadura soil data base (Table 1). Soils organic matter is less than 2% and pH is mostly 5 to 7.

Table 1. Soil distribution in the *dehesas* of Extremadura (Spain)

Soil type (FAO)	Soil taxonomy'99	Cover (%)	Parental geology	Texture
Eutric Cambisol	Inceptisol	42.9	Slates	Medium fine
Dystric Cambisol	Inceptisol	12.6	Granite	Medium
Dystric Planosol	Alfisol	9.6	Granite	Medium
Dystric Lithosol	Entisol	7.2	*"Rañas"*†	Coarse
Eutric Fluvisol	Entisol	4.8	Slates	Medium
Chromo-Calcic Luvisol	Alfisol	3.2	Limestone	Medium fine

†Spanish term used to refer an old river terrace with quartzite sand and gravel.

Tree cover data base was made from Third National Forest Survey for Extremadura (IFN3) (Villanueva Aranguren, 2007). The method followed to do IFN3 was based on a classification of dominant forest formations which constitute units of vegetation. *dehesas* were differentiated and divided into five categories (F1: *Q. ilex* 5-19%, F2: *Q. ilex* 20-39%, F3: *Q. ilex* 40-100%, F4: *Q. ilex* and *Q. suber* 20-100%, and F5: *Q. ilex* and *Q. suber* 20-70% of soil tree cover). These categories cover 962,595 ha, other 68,580 ha were not included because dominant vegetation was shrub with *Q. ilex*. This classification of *dehesas* is an asset for our work.

Results and discussion

Localization and characterization

The zoning of the *dehesas* of *Quercus ilex* was established starting from the numerical cartography of the IFN3 of Extremadura. The land covered by *dehesas* corresponds mainly to the plains of Extremadura and thus to a relatively homogeneous and regular area from the point of view of geomorphology. Evergreen oak *dehesas* soils in Extremadura are Cambisol Eutric (42.9%), Cambisol Dystric (12.6%), Planosol Dystric (9.6%) and Lithosol Dystric (7.2%). *Dehesas* dominat forest land distribution is F2 (46.5%), follow by F3 (36.6%), F1 (12.5%), F5 (3%), and F4 (1.4%).

Productivity

All simulated pasture average yield was 3615 kg DM ha^{-1}. Optimal stoking rate resulted on 0.6 – 0.7 Livestock Units (LSU, dry cows over two years) ha^{-1}. Simulations of different grazing species showed significant differences between annual forage availability for cows (3705 kg DM ha^{-1}) and sheep (3525 kg DM ha^{-1}). Grazing with sheep reduced annual average stocking rate from 0.7 to 0.6 LSU ha^{-1}. These productions are according with Murillo *et al*. (2005).

Average annual acorns production in *dehesas* of Extremadura was 249 kg ha^{-1}, and the carrying capacity for fattening hogs was 0.5 pigs ha^{-1}. Simulate optimal stocking rate across Extremadura was from 0.2 to 0.8 Iberian pigs ha^{-1} and from 0.1 to 0.9 LSU ha^{-1} (Table 2). Main driving force for *dehesa* productivity is soil type for pasture, and tree cover for acorn production. Highest pasture productivity was obtained on soil Dystric Planosol (Alfisol), Dystric Cambisol and Chromo-calcic-luvisol, for type of *dehesas* F3 and F5; these soils only cover 22.4% of Extremaduras's *dehesa*. Lowest productivity was obtained on Dystric Lithosol (Table 2). In this case a good tree cover sustained 0.5 pig per hectare. Simulated acorn productivity is according with field measures of García *et al.* (2005), although other authors measured production over 600 kg acorn ha^{-1} (Poblaciones *et al*., 2004; Rodríguez-Estévez *et al.,* 2007). Tree canopy cover is an important factor to correct acorn simulation, the data base extracted from IFN3 is incomplete for this work. Each dehesa class represents a hug rank of canopy cover and in two cases (F4 and F5) are mixtures of trees (*Q. ilex* and *Q. suber*).

Table 2. Maximum and minimum simulated annual average productivity on *dehesas* of Extremadura (Spain)

Soil	Tree cover	Weather station	Pasture kg DM ha^{-1}	Acorn kg ha^{-1}	Stocking rate	
					LSU ha^{-1}	Pigs ha^{-1}
Dystric Planosol	F5 20-70%	Coria	7320	172	0.9	0.3
	F3 40-100%	Coria	4025	432	0.7	0.8
Dystric Lithosol	F4 20-100%	Mérida	901	122	0.4	0.2
	F3 40-100%	Tejeda de Tiétar	187	246	0.1	0.5

Conclusions

The influence of tree on pasture potential production is inversely proportional to the canopy cover. Acorn production increase with tree canopy cover until stabilizing itself, and will decrease if density becomes too high (more than 80% soil tree cover) at that point there is competition between the trees. This study allowed the application of the model dehesa within the framework of a territorial approach on a regional scale. It is a method for characterization of homogeneous units of dehesa. The results of production obtained for Extremadura region make possible to have a general outline of productivity of different types of dehesa but more detail information about tree density and cover is needed. That could be regarded as a starting point for the study and the definition of a zoning of the Denomination of Origin for the production of Iberian pig based on acorn.

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