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RESEARCH ARTICLE

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Changes in the pastoral sheep systems of semi-arid Mediterranean areas: association with common agricultural policy reform and implications for sustainability

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Abstract

The dynamics of sheep systems the Mediterranean region have been influenced by reforms coming from the Common Agricultural Policy, and the general economic evolution of markets. The aim of this study was the analysis of the structural changes that occurred between 1999 and 2009, and the identification of future implications for the sheep systems in Andalusia region, Spain. Analysis of the structural changes allowed the generation of strategic information, identified trends that should suggest new rural policies and changes that are likely to have social and environmental impacts, and lastly, prioritize future research. The application of multivariate methodology allowed clustering the farm population into four groups. The typology of these systems was determined by variables related to the sheep subsystem, by the set of agricultural activities, and by changes in swine husbandry, within a context of changes in land tenure and the drive for agricultural intensification. Major modifications of extant systems included a 42% reduction in the number of farms, a decrease in sheep numbers, replacement of native rangelands with improved pastures, olive trees and orchards, a reduction of traditional extensive pastoral activities, and increases in hog production in *Dehesa* grasslands. Given the historical economic and social importance of the sheep-cereal system, the observed substantial modifications of land use suggest a need to assess their consequences in terms of social and environmental impacts, as well as their implications for climate change.

Additional key words: extensive systems; sheep-cereal systems; productive structure; Mediterranean; census data.

Abbreviations used: CAP (Common Agricultural Policy); EU (European Union); LU (Livestock Unit).

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Introduction

Small ruminant systems of the Mediterranean basin have considerable economic, social and environmental importance. Their current organization and resource endowment are the result of long-term historical, geopolitical and socio-economic changes (de Rancourt *et al.*, 2006; Castel *et al.*, 2011; Ryschawy *et al.*, 2013). Additionally, variable ecosystems and socio-cultural contexts have given rise to highly variable production systems (Robinson *et al.*, 2011).

Spain maintains the largest meat sheep population (13.5 million) of the Mediterranean basin (MAGRAMA, 2012). Meat sheep production is generally located in marginal areas where semi-arid conditions constrain agricultural and animal production. Native grasslands predominate and their use has been mainly restricted to very extensive systems or to limited periods of the year during in which animals have low nutrient requirements (Jouven *et al.*, 2010).

In these economically disadvantaged areas, sheep systems have so far been decisive in maintaining rural livelihoods and in the preservation of rural populations (de Rancourt *et al.*, 2006; de Rancourt & Carrère, 2011). The role of less favored areas has been recognized and valued by the Common Agricultural Policy (CAP) of the European Union (EU), that assigned priority to their consideration in various Council

Regulations (1782/2003, 73/2009 and 1307/201; EC, 2012a) but the purpose as income generator and source of employment has not received an equivalent recognition.

Sheep systems of southwest Spain are located in three main ecosystems, the *Dehesa*, the Mountain Region and the Arid Region. All of them are characterized by extensive grazing on natural pastures, the use of local sheep breeds (mostly Merino and Segureña), low profitability, and production of high quality but highly seasonal products (Riedel *et al.*, 2007; Gaspar *et al.*, 2008; Castel *et al.*, 2011).

The *Dehesa* is a traditional agrosilvopastoral system that combines grasslands under a layer of holm oak (*Quercus ilex*) and cork (*Quercus suber*), where Iberian pigs (*Sus scrofa domestica*) and sheep are fed on acorn and grass during the period of early November to late February (Rodriguez-Estevez *et al.*, 2009). The system's advantages rely on diversified production, low commercial risk and sufficient profitability (Gaspar *et al.*, 2007).

Sheep production is the main source of income for family farms in the Mountain Region, and it contributes to landscape conservation (Milán *et al.*, 2003; Riedel *et al.*, 2007). The sheep population of the Arid Region amounts to 71.2% of Spain's sheep flock (Boza *et al.*, 2008), and it relies on extensive, low-input management, with an average stocking rate of 0.41 LU/ha, and seasonal grazing on cereal stubbles (Robles *et al.*, 2001; Navarro *et al.*, 2006).

The dynamics of sheep systems in the Mediterranean region have been influenced by reforms to the CAP (Patton *et al.*, 2008), and by newer environmental restrictions, sanitary problems and changes in consumer's preferences (Morand-Fehr & Boyazoglu, 1999; Allepuz *et al.*, 2010; Davidova *et al.*, 2010; Toro-Mujica *et al.*, 2012). The EU conducts standardized rural censuses every 10 years, that allow the generation of strategic information, identification of structural changes, and support changes in the allocation of subsidies. Thus, the 2009 census provided information for the 2013 reform of the CAP, centered on food security, competitiveness of European agriculture, good land management, climate change and rural development, which in turn gave rise to the Horizon 2020 proposal (EC, 2012a).

The objectives of the present paper were (i) to examine in depth the evolution of the resource endowment of the semi-arid Mediterranean sheep farming systems based on a farm typology calculated from census data for Andalusia; (ii) the analysis of changes experienced between 1999 and 2009, and (iii) the identification of future implications for the region.

Material and methods

Research context

Using the census data for Europe, CAP-2013 prioritized the development of sustainable farming systems with emphasis on the conservation of natural resources (EC, 2012b). Therefore, farmers face the dual challenge of producing foods while protecting biodiversity and natural resources (EC, 2013). This constitutes in principle to the development of a positive stimulus for extensive livestock systems that may be compatible with both aims and the identification of those systems as High Nature Value Farming Systems (APMM- FECNP, 2013). The study was carried out in the Autonomous Community of Andalusia, in South Spain. The surface area is 87,597 km^2, 65% of which is covered by grazing areas, including non-agricultural lands, shrubs and forests (APMM-FECNP, 2013).

Andalusia houses 2.1 million sheep, equivalent to 12.7% of Spain´s total flock (INE, 2009). Most farms are extensive and carry meat sheep. The farm population analyzed was limited to those with a minimum of 5 ha, and it only included extensive systems, excluding intensive farms (> 2 LU/ha; Caravaca & González, 2011) and non-commercial operations. Farms were identified in the 1999 and 2009 agricultural censuses, and were divided into small (< 30 LU), medium (30 to 100 LU) and large (> 100 LU) sheep farms.

Typological classification

The grouping of farms in homogeneous classes was carried out using multivariate analyses (Gaspar *et al.*, 2011; Guillem *et al.*, 2012; Toro-Mujica *et al.*, 2012). The analysis was performed in three stages, as follows: review and selection of variables, factor analysis, and cluster analysis. Principal component analysis was used as the base of factor analyses applied to the 2009 data, and yielded a number of farm types as well as the corresponding classification equations. The latter were used to allocate the farms surveyed in 1999 to the above farm types.

Quantitative variables included farm dimension, land use and tenure, and the composition of the crop and livestock resources. In an initial descriptive analysis the variables with a coefficient of variation <60% were removed due to their low contribution to the split of factors. This was followed by calculation of the correlation matrix amongst variables, to remove those highly correlated among each other (r>90%), and those totally uncorrelated. The remaining variables were subjected to a factor analysis to reduce the number of factors. Prior to this stage, Bartlett's chi-square test was used to ensure adequate correlations, and the Kaiser-Meyer-Olgin index was calculated to determine sampling adequacy (Uriel & Aldás, 2005). All variables were standardized (Hair *et al.*, 1999; Picón *et al.*, 2003). Factors with an eigenvalue >1 were kept, as suggested by Uriel & Aldás (2005). The varimax rotation was applied to these factors to facilitate interpretation (Guillem *et al.*, 2012).

Farm groups were identified through a hierarchical cluster analysis using the Ward and centroid methods to delimit groups (Álvarez-López *et al.*, 2008; Riveiro *et al.*, 2013). The Euclidean, square Euclidean and Manhattan distances were calculated for each of these methods. The selection of the number of groups was based on the observation of the respective dendograms and variation in the cluster coefficients in successive stages (Caballero & Fernandez-Santos, 2009). Thus, the solutions obtained were tested with discriminate analyses and analysis of variance. The selection of the final solution was based on the discriminate function that correctly classified the majority of farms and that generated significant differences in the largest number of original variables.

Comparison of typological groups

Typological groups defined for 2009 were compared using the original variables by means of analyses of variance or the Welch test, as appropriate, after testing for equality of variances using the Levene test. Means comparisons were carried out using Duncan's multiple test, or with Dunnett's T3 test in case that the variances were unequal (Pérez, 2005).

Chi-square and contingency tests were used to determine associations between typology, flock size, and geographical location (Caballero, 2001).

Trends in the productive structure

Factor analysis applied to the 2009 data yielded equations that were used to group the farms selected in the 1999 census so that the two census groups were consistent with each other. The 1999 classified data were thus subjected to a discriminate analysis, and the 1999 farms were therefore grouped as for the typological groups defined for 2009. Changes in the value of the variables within the groups were tested with analysis of variance or the Welch test. All statistical analyses were performed with SPSS 11.5 (Pérez, 2005).

Results

Extensive sheep systems

Extensive sheep farms in Andalusia showed large variations in surface area, grasslands, crops and flock size (Table 1). Geographical distribution of farms within the Community, is also variable. Pastoral sheep systems in the Provinces of Córdoba, Sevilla, Huelva and the mountain areas in Cádiz (Fig. 1) are located in the *Dehesa* region (Rodero & Valera, 2008) and are known as the western model. Those located in Granada and Almería, in the highlands, are called the eastern model.

Farm typology – 2009 Census

Analysis of the coefficients of variation of the variables available in the 2009 Census, and of the respective correlation matrix led to selection of 12 variables (Table 2) that were used in the subsequent factor analysis, and their analytical adequacy was confirmed with the KMO test (0.64) and the Bartlett sphericity test (p<0.05). Four factors accounted for 72% of the variance (Table 2). The first factor (PC-1) was called *Dimension*, accounted for 28.4% of the variance and it is positively related to flock size, area of natural grasslands, farm size, and farm area occupied by sheep; the second factor (PC-2), *Land Use*, is closely related to cereal cropping, and is responsible for 19.3% of the variance; PC-3 or *Livestock Diversity*, accounted for 13.8% of the variance and represents the trade-offs between sheep and hogs competing for land; in this case, sheep and pigs show equivalent correlations with the factor, but differing in sign; lastly, the fourth factor PC-4, *Land Use*, represents 11.4% of the variance, and is related to the use of the farms' grassland resources; high values in this factor indicate the use of improved pastures, in contrast to natural grasslands, therefore supporting higher stocking rates.

Multivariate analysis led to the identification of four farm groups (Table 3). A subsequent discriminate analysis correctly classified 90% of the farms. A chi-square test suggested that flock size and group membership were associated, since farms with smaller flocks (< 30 LU) were concentrated in Groups I, II and IV, whereas those with larger sheep numbers were mostly located in Group III. These variables, together with the geographical location of the farms, were used to characterize groups.

Group I: Cereal-sheep mixed systems

This group includes 37% of the farms, located mainly in the Provinces of Córdoba (31.7%) and Gra-

Table 1. Comparison of census data for Andalusia, 1999 *vs* 2009

Variables	1999	2009	*p* value
Farms (n)	5,208	3,003	
Structural			
Total farm surface (ha)	299.3 ± 659.4	136.4 ± 201.7	<0.01
Sheep flock size[1]	94.8 ± 157	52.2 ± 62.7	<0.01
Total stocking rate (LU/ha)	0.6 ± 0.5	0.6 ± 0.4	0.20
Sheep stocking rate (LU/ha)	0.57 ± 0.44	0.6 ± 0.4	0.80
Cereals area (ha)	40.9 ± 125.6	16 ± 41.2	<0.01
Natural pastures area (ha)	101.7 ± 336.3	46 ± 129.2	<0.01
Usable agricultural area owned (ha)	184.4 ± 597.3	49.9 ± 106	<0.01
Livestock (% LU)			
Sheep	91.5 ± 14.9	89.2 ± 16.2	<0.01
Pig	0.7 ± 5.2	5 ± 12.8	<0.01
Goat	4.9 ± 10.3	4.2 ± 9.9	<0.01
Land use (% area)			
Cereals	15.5 ± 21.7	12.9 ± 21.3	<0.01
Wheat	4.6 ± 12.1	3.2 ± 10.2	<0.01
Natural pastures	27.5 ± 35.6	19.7 ± 31.9	<0.01
Cultivated pastures	5.7 ± 20.1	20 ± 28	<0.01
Forest	10 ± 21.4	18.4 ± 23.1	<0.01
Provinces (% column total)			
Almería	9.0*	6.7*	<0.01
Cádiz	4.9*	3.7*	
Córdoba	29.0*	31.4*	
Granada	15.5*	18.0*	
Huelva	14.5*	12.1*	
Jaén	6.7*	8.9*	
Málaga	7.8	8.0	
Sevilla	12.7	11.3	
Groups (% column total)			
I	50.5*	36.9*	<0.01
II	20.0*	28.3*	
III	21.9*	22.2*	
IV	7.6*	12.5*	
Sheep flock size (LU)			
Small (5-30)	39.7*	44.9*	<0.01
Medium (30-100)	32.8*	41.8*	
Large (>100)	27.4*	13.4*	

[1] Unit animal; adult sheep = 0.15 LU (EC, 2007). *There is no independence between province and group (Chi-square test).

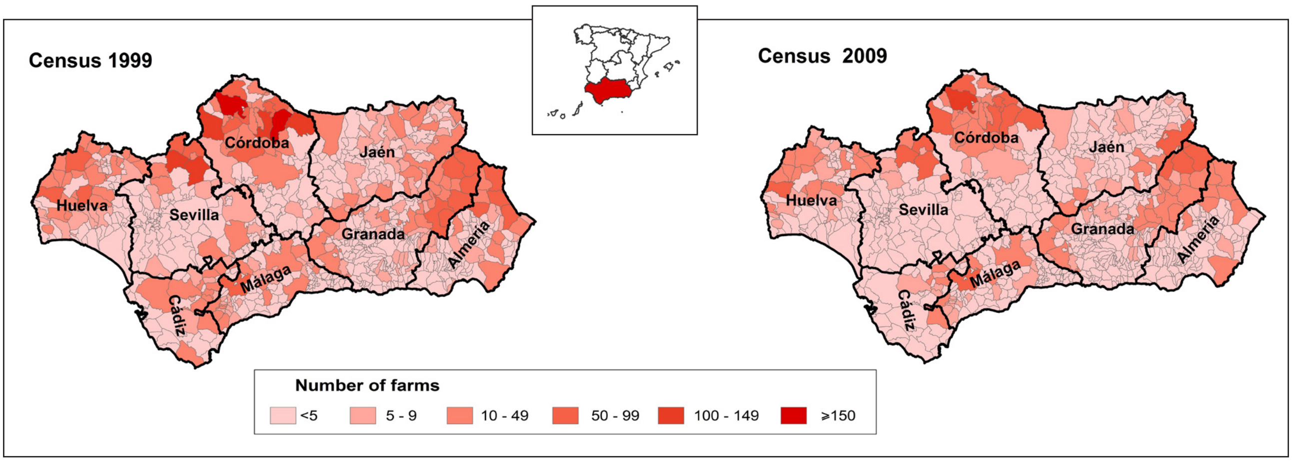

Figure 1. Geographical location of Andalusia sheep farms (Census 1999 and 2009).

Table 2. Selected principal components (PC), eigenvalues, variance explained and accumulated, and correlation coefficients of the variables with each PC

PC	Eigenvalue % variance explained (% variance accumulated)	Variable	Correlation with the PC
1. Dimension	3.4	Total farm surface (ha)	0.925
	28.4	Sheep flock size (LU)	0.821
	(28.4)	Natural pastures area (ha)	0.751
		Usable agricultural area owned (ha)	0.766
2. Land Use	2.3	Cereals area (ha)	0.649
	19.3	Cereals area (%)	0.885
	(47.7)	Wheat area (%)	0.744
3. Livestock Diversity	1.6	Sheep (% LU)	–0.905
	13.8	Pig (% LU)	0.923
	(61.6)		
4. Land Use	1.3	Cultivated pastures (%)	0.796
	10.5	Natural pastures (%)	–0.751
	(72.1)	Forest (%)	–0.446

Table 3. Comparison of groups obtained in the cluster analysis (2009 Census)

Variables	Groups I	Groups II	Groups III	Groups IV	*p*
Physical and intensification variables[1]					
Total farm surface (ha)	87.2 ± 106.6^{a}	97.0 ± 124.8^{a}	268.3 ± 322.2^{c}	136.4 ± 174.5^{b}	<0.01
Sheep flock size	41.2 ± 44.9^{a}	38.2 ± 37.2^{a}	92.6 ± 94.6^{b}	44.5 ± 51.4^{a}	<0.01
Total stocking rate (LU/ha)	0.7 ± 0.5^{c}	0.6 ± 0.4^{b}	0.5 ± 0.3^{a}	0.8 ± 0.4^{c}	<0.01
Sheep stocking rate (LU/ha)	0.7 ± 0.5^{c}	0.6 ± 0.4^{b}	0.5 ± 0.3^{a}	0.4 ± 0.3^{a}	<0.01
Livestock (% LU)[1]					
Sheep	93.5 ± 10.9^{b}	94.4 ± 9.6^{b}	93.4 ± 11.4^{b}	57.3 ± 11.9^{a}	<0.01
Pig	0.9 ± 3.6^{a}	0.7 ± 2.7^{a}	1.3 ± 4.6^{a}	33.5 ± 17.3^{b}	<0.01
Goat	3.8 ± 8.2^{ab}	3.6 ± 8.4^{a}	4.7 ± 10.5^{b}	6.2 ± 14.8^{c}	<0.01
Land use (% area)[1]					
Cereals	28.6 ± 26.7^{c}	2.3 ± 6.3^{a}	5.0 ± 8.4^{b}	4.4 ± 11.9^{ab}	<0.01
Wheat	7.7 ± 15.4^{b}	0.3 ± 1.8^{a}	0.8 ± 3.1^{a}	0.9 ± 4.1^{a}	<0.01
Olive tree	19.1 ± 32.6^{c}	6. 8 ± 14.3^{b}	1.8 ± 5.9^{b}	8.1 ± 19.1^{a}	<0.01
Natural pastures	5.5 ± 13.1^{b}	0.7 ± 4.0 ^{a}	70.8 ± 22.4^{d}	13.4 ± 24.3^{c}	<0.01
Cultivated pastures	5.2 ± 10.9^{b}	52.7 ± 26.1^{d}	0.5 ± 3.3^{a}	24.5 ± 24.2^{c}	<0.01
Forest	3.9 ± 8.9^{a}	31.4 ± 24.4^{c}	13.8 ± 17.8^{b}	39.8 ± 25.1^{d}	<0.01
Provinces (Column %)[2,3]					
Almería	10.7*	1.5*	9.2*	1.3*	<0.05
Cádiz	4.4*	4.5	1.0*	2.6	
Córdoba	31.7	26.9*	36.8*	29.4	
Granada	26.0*	9.0*	27.7*	1.0*	
Huelva	6.5*	12.3	8.6*	36.3*	
Jaén	5.9*	19.6*	3.9*	2.3*	
Málaga	7.4	12.6*	4.8*	3.7*	
Sevilla	7.4*	13.6*	7.8*	23.5*	
Sheep flock size (LU)[2,3]					
Small (5-30)	53.1*	53.4*	17.0*	50.6*	<0.01
Medium (30-100)	37.8*	40.4	51.0*	39.9	
Large (>100)	9.1*	6.2*	31.9*	9.4*	

[1] Values are in mean ± standard deviation. [2]Values are in percentages. [3]: There is no independence between province and group (Chi-square test).*(p<0.05).

nada (26%). They are generally small farms that combine cereals, olives, and sheep. Goats and pigs make up less than 5% of the total LU. Sheep are grazed on natural and permanent grasslands, whose areas are generally small, requiring supplementation with cereal stubbles in Granada, and grazing under olive trees in Córdoba. Irrigation is generally associated with olive plantations. Farm ownership is 58%, somewhat larger than for the rest of the groups.

Group II: Subsistence systems

It contains 28.3% of the farms, with sizes slightly larger than the previous group. They are mostly located in the Central Subbaetic System of the Jaen province, in Eastern Sierra Morena of the high Gualdaquivir, and in the Western Subbaetic System of Cádiz and Málaga. Over 80% of the area is covered with grasslands and grazed forested areas. Sheep flocks tend to be small (5-30 LU), and the areas under cereals are the smallest of all groups. Goats and pigs are absent in 75% and 90% of the farms respectively.

Group III: Extensive commercial systems

This group includes 22.2% of the farms, with a geographical distribution similar to that of Group I. Córdoba and Granada account for 37% and 27% of the group's farms respectively. Sheep numbers are high (72% of the farms run over 300 sheep), and natural grasslands represent 70% of the surface area, associated with lower stocking rates. Given the low cropping aptitude of soils, crops and olives are unimportant. Twenty-five percent of the farms located in the highlands of Granada and Almería include forested areas, whereas the *Dehesa* zones of Córdoba, Sevilla and Huelva are present in 67% of the farms and 21% of the surface area.

Group IV: Mixed sheep-hog systems

This group had the smallest number of farms (12.5% of the total) and it is localized mostly in the provinces of Huelva (35%), Córdoba (29%) and Sevilla (24%). The main distinguishing trait of this group is the abundance of pigs (Table 3), present in 90% of the farms. The sheep stocking rate is lower than in the other groups, but the overall livestock stocking rate is higher than in groups I and II. Permanent grasslands and forested areas constitute the only grazing resources, where *Dehesa* systems under holm oak (*Quercus ilex*) and cork (*Quercus suber*) predominate in Cádiz, whereas those of Córdoba are mainly *Dehesa* dominated by holm oak. Farms combining cereals and sheep constitute less than 20% of the total.

Table 4 compares the typological groups in years 1999 and 2009. Changes in the groups' membership were uneven; farms in Groups I, II and III decreased a 20%, whereas there was a 200% increase in the farms belonging to the Group IV. The main modifications experienced by the cereal-sheep Group I were a reduction in farm size, agricultural area ($p<0.01$) and goats numbers ($p<0.01$) and a significant substitution of grasslands with orchards ($p<0.001$), vineyards ($p<0.05$) and cereals ($p<0.01$),

In groups I (cereal-sheep system) and III (commercial), the total farm area decreased 75% and 49% ($p<0.01$) respectively, with parallel decreases in land with agricultural potential of 69 and 90% respectively. The total livestock and sheep stocking rate increased nearly 20% ($p<0.01$) as a consequence of the diminishing areas and increasing hog numbers. Sown permanent pastures increased at the expense of native rangelands ($p<0.01$) and a decrease of land under olives took place too. There was also a relative increase of areas under cereals in Group III ($p<0.01$).

Group IV farms (hog-sheep system) experienced a very large increase in numbers between 1999 and 2009, due to shifts towards pig production among small farms (5-30 LU; Table 4), that were probably located initially in Group II. These changes were associated with decreasing farm and cropping areas, and increased sheep stocking rates, although overall livestock stocking rates did not vary. Cereal cropping decreased ($p<0.05$), whereas olives ($p<0.05$), orchards and sown forages increased ($p<0.01$).

Discussion

The large between-farms heterogeneity in surface areas, grasslands, crops and flock size (Table 1) coincides with others found elsewhere in Spain as the Ripollesa sheep system of Catalonia (Milán *et al.*, 2003), meat sheep in Aragón (Pardos *et al.*, 2008) and dairy sheep in Castilla-La Mancha (Rivas *et al.*, 2014). Meat sheep systems are characterized by low stocking rates, scarce inclusion of cattle and low irrigated areas. Native and improved grasslands, forested areas, cereal crops and olives plantation occupy over 80% of the farms' area. The sheep stocking rates, though low, are higher than those reported by Gaspar *et al.* (2008) for *Dehesa* in Extremadura, for the sheep-cereal systems of Castilla-La Mancha (Caballero, 2001), and for mixed systems of NE Spain

Table 4. Comparison of groups obtained in the cluster analysis between censuses

Variables	Group I		Group II		Group III		Group IV	
	1999	2009	1999	2009	1999	2009	1999	2009
Farms (n)	2,825	1,134	1,104	867	1,152	682	127	383
Physical and intensification variables[1]								
Total farm surface (ha)	167 ± 263.8	87.2 ± 106.6**	389.3 ± 791.6	97 ± 124.8**	526.5 ± 1032.5	268.3 ± 322.2**	397.3 ± 491.5	136.4 ± 174.5**
Sheep flock size (LU)	66.7 ± 88.9	41.2 ± 44.9**	109.6 ± 189.2	38.2 ± 37.2**	148.1 ± 223.9	92.6 ± 94.6**	106.2 ± 157.6	44.5 ± 51.4**
Total flock size (LU)	72.5 ± 98.5	43.6 ± 46.9**	123.1 ± 224.6	41 ± 42.2**	171.6 ± 270	100.1 ± 103.8**	216.3 ± 361.3	81.8 ± 102.8**
Total stocking rate (LU/ha)	0.71 ± 0.54	0.73 ± 0.48	0.5 ± 0.4	0.6 ± 0.4**	0.6 ± 0.4	0.5 ± 0.3**	0.7 ± 0.5	0.8 ± 0.4
Sheep stocking rate (LU/ha)	0.65 ± 0.47	0.67 ± 0.45	0.48 ± 0.38	0.58 ± 0.38**	0.5 ± 0.38	0.46 ± 0.31*	0.34 ± 0.25	0.43 ± 0.26**
Cereals area (ha)	49.3 ± 95.9	28.7 ± 45.3**	24.3 ± 122.5	2.6 ± 11.3**	36.3 ± 181	16.4 ± 55.8**	39.7 ± 104.3	7.8 ± 27.3**
Natural pastures area (ha)	19.5 ± 57.4	8.6 ± 25.7**	26.4 ± 67.8	1.9 ± 14.4**	370.5 ± 630.9	170.5 ± 223**	146.9 ± 244.6	35 ± 80.4**
Cultivated pastures (ha)	0.9 ± 11.7	4.1 ± 13.4**	124.2 ± 462.2	46.9 ± 66.9**	0.9 ± 13.7	1.3 ± 13.6	6.6 ± 52.3	17.9 ± 26.8**
Usable agricultural area owned (ha)	94.9 ± 194	40.9 ± 64.7**	266.1 ± 717.5	24.9 ± 47.3**	319 ± 980.2	98.8 ± 182.1**	244.2 ± 456.3	45.9 ± 86.8**
Livestock (%)[1]								
Sheep	93 ± 12.8	93.5 ± 10.9	93 ± 12.9	94.4 ± 9.6*	90.6 ± 15.6	93.4 ± 11.4**	51.7 ± 9	57.3 ± 11.9**
Pig	0 ± 0.9	0.9 ± 3.6**	0 ± 0.4	0.7 ± 2.7**	0.4 ± 2.9	1.3 ± 4.6**	22.6 ± 22.9	33.5 ± 17.3**
Goat	5.3 ± 10.6	3.8 ± 8.2**	4.3 ± 9.6	3.6 ± 8.4	4 ± 9	4.7 ± 10.5	10.2 ± 17.5	6.2 ± 14.8*
Land use (% area) [1]								
Cereals	25.3 ± 24.6	28.6 ± 26.7**	3.9 ± 8.6	2.3 ± 6.3**	3.4 ± 6.3	5 ± 8.4**	6.9 ± 10.8	4.4 ± 11.9*
Wheat	7.7 ± 15.4	7.7 ± 15.4	1 ± 3.8	0.3 ± 1.8**	1 ± 3.2	0.8 ± 3.1	1.8 ± 6.1	0.9 ± 4.1
Olive trees	19.1 ± 30	19.1 ± 32.6	9.8 ± 18.1	6.8 ± 14.3**	3 ± 7.2	1.8 ± 5.9**	5 ± 10.8	8.1 ± 19.1*
Vineyards	0 ± 0	0.1 ± 1.6*	0 ± 0	0 ± 0.8	0 ± 0	0 ± 0.7	0 ± 0	0 ± 0.2
Fruit trees	0.3 ± 0.4	4.8 ± 15.3**	0.1 ± 0.3	1 ± 5.9**	0.1 ± 0.2	1 ± 4.8**	0 ± 0.2	1.3 ± 8.9**
Natural pastures	10.7 ± 19.3	5.5 ± 13.1**	10.8 ± 16.7	0.7 ± 4**	83.6 ± 17.9	70.8 ± 22.4**	37.1 ± 32.3	13.4 ± 24.3**
Cultivated pastures	0.3 ± 2.2	5.2 ± 10.9**	26 ± 36.9	52.7 ± 26.1**	0.1 ± 1.3	0.5 ± 3.3**	1.7 ± 9.3	24.5 ± 24.2**
Forests	2 ± 6.6	3.9 ± 8.9**	34.5 ± 31.5	31.4 ± 24.4*	3.3 ± 8.3	13.8 ± 17.8**	34.7 ± 28.3	39.8 ± 25.1
Sheep flock size (LU) (% column)[2,3]								
Smalls (5-30)	45.2	53.1**	38.7	53.4**	24.2	17.0**	23.6	50.7**
Medium (30-100)	33.8	37.8**	30.3	40.4**	31.9	51.0**	43.3	40.0**
Larges (>100)	21.0	9.1**	31.1	6.2**	43.8	32.0**	33.1	9.4**

[1] Values are in mean ± standard deviation. [2]Values are in percentages. [3]There is no independence between province and group (Chi-square test). *(p<0.05); **(p< 0.01).

(Ripoll-Bosch *et al.*, 2012). According to Riedel *et al.* (2007) low stocking rates and reliance on grasslands characterize these systems.

The number of farms decreased a 42% between 1999 and 2009 (Table 1), which differs considerably from the 14% decrease predicted by Tranter *et al.* (2007) for extensive sheep and cattle farming in UK, Germany and Portugal. The general changes in the number of farms and in the portfolio of agricultural activities, mostly represented in changes in the composition of the livestock component and in land use, were associated with decreased farm profitability, largely explained by the uncoupling of sheep subsidies than started in 2006 and became permanent in 2010.

According to Rivas *et al.* (2014) this change in policies slowed down the adoption of new technologies in Manchega sheep systems. During the period under consideration there was also an increase in the costs of inputs and a reduction in lamb consumption that further hurt the sheep sector (Atance, 2001; Gürsoy, 2006; García-Brenes, 2009; Chamorro *et al.*, 2012), whereas the increase in Iberian pig production signals a change in the farm systems and in the structure of their income (Gaspar *et al.*, 2008). There was also a simultaneous replacement of native rangelands with improved pastures, stimulated by changed policies (EC Nº 1257/1999; EC, 2009), with loss of traditional pastoral activities (Bouju, 2000) and the development of "false grazing systems" (Castel *et al.*, 2011), which leads to loss of valuable pastoral species, and an increase in undesirable species (Riedel *et al.*, 2007; Jouven *et al.*, 2010). The observed changes in technologies, livestock production and traditional pastoral activities need to be assessed against the background of highly valuable but fragile land resources, with the attending risks of soils and vegetation degradation. In this context it would be important to focus research on the appropriate seasonal and year-long management of multiple species stocking rates (Koen, 1987; Bai *et al.*, 2011; Teague *et al.*, 2011).

Sheep are deemed of very high ecological importance for these habitats, since they contribute to the conservation, and even propagation, of some Mediterranean shrubs and trees (Manzano *et al.*, 2005) given that their grazing habits do not affect the higher layers of trees, a critical component of the *Dehesa* ecosystem (APMM- FECNP, 2013). Sheep production can play a pivotal role in the management of natural resources, while at the same time, continuing to produce high-quality food and fiber. When they are correctly managed, small ruminants have proved to be effective tools in the control of noxious weeds, enhance rangelands and reforestation projects. It improves wildlife habitat and accomplishes riparian and watershed management objectives. Additionally, they can do all of this in a manner that is not only sustainable, but can be profitable in today's environment of shrinking profit margins in agriculture (Kim-Chapman & Reid, 2004).

The comparison of the 1999 and 2009 census data showed large and significant changes in the characteristics of the Andalusia sheep farms, while maintaining considerable heterogeneity. Most notable among these changes were a nearly halving of the farms' surface area and the number of sheep carried, without alteration of the stocking rates. The large percent wise decrease in native pastures and smaller decreases in cereals, with a quadrupling of the percentage of areas sown to permanent pastures and nearly a doubling of grazed forested areas implied big changes too. Farm sizes decreased in all four groups between 1999 and 2009, with a corresponding decrease in the number of sheep; however sheep stocking rates remained fairly stable with the exception of the subsistence group that experienced a modest increase. Sheep represented 93% of the livestock stock in the first three groups, whereas these species represented 52 and 57% of the total livestock units respectively in the mixed sheep-swine group. Despite the changes that occurred between 1999 and 2009, sheep continued to constitute over 90% of the animal units carried in 87% of the farms. These results are comparable to those reported by Bernard de Raymond (2013) in Côte d'Or, France, where the cessation of sheep production seems to be a concern given its role in terms of labor generation, societal values and lifestyle, as well as for economic profitability, a phenomenon that has been termed "innovation by withdrawal". In effect, discontinuation of extensive sheep production in these high value ecosystems is inherently risky due to potential loss of the quality of the environment (Kim-Chapman & Reid, 2004) and various other benefits (Milan *et al.*, 2003). The value of their environmental services should be complemented with estimates of lost income, voluntary coupling subsidies, and the value of local breeds (EC, 2013). Similarly, there is a need for policies aimed at supporting research, innovation, transfer, education, micro credits, direct sales organization and development (Gilg & Battershill, 1998; Dubeuf, 2011). In view of the current evolution of the driving forces, maximizing autonomy and diversification seem to be suitable paths to deal with the challenge of maintaining extensive sheep as well as mixed crop-livestock systems in the Mediterranean basin and more generally, in much of Europe (Ryschawy *et al.*, 2013).

As indicated above, the number of sheep farms and the sheep population decreased considerably between 1999 and 2009, including the disappearance of the sheep subsystem in a number of farms. These changes seem to have been driven by a search for more profitable activities such as the raising of Iberian pigs in *Dehesa* rangelands (López-Bote, 1998; MAGRAMA, 2014), and the intensification of land use in irrigated areas via the establishment of olive trees and orchards at the expense of native rangelands (Civantos, 2008).

The production of value-added products and direct selling possibly associated with the use of local sheep breeds may be a path towards preservation of sheep production. Nevertheless, current prices are not high enough to support these systems by themselves. It is suggested that valorization of the social and environmental services may contribute to improved economic performance. The increasing preoccupation in the EU for the preservation of biodiversity, minimization of production of greenhouse gases, reduction of risks due to wildfires, and the uncertainties related to climate change may lead to policies that would stabilize these old, traditional, sheep farming systems. In the context of EU policies, a definitive agreement on the controversy between what constitutes permanent pastures versus permanent grasslands will surely influence the dynamics of sheep systems in some regions.

Lastly, changes in CAP policies drove modifications of sheep farming systems in the study region. Recent changes in policies regarding the valorization of environmentally friendly agricultural practices, retention of younger generations in the farms, promotion of rural employment and innovation, and prevention of desertification should stimulate the continued existence of sheep farming in a region with limited farming alternatives.

In summary, the analysis of existing data showed that the typology of sheep production systems in Andalusia was determined by variables related to the sheep subsystem itself, agricultural activities such as olive crops, other orchards, cereals, and swine, as well as by land tenure and degree of intensification. Changes in national and international market conditions drove changes in Andalusia's sheep systems, including a reduction in the number of sheep farms, farm's area and number of animals, together with diminished cereals and natural grassland areas. As a consequence of these circumstances, a resulting reduction in the integral, holistic, use of land resources has taken place. Given the historical importance of the sheep-cereal system, the observed changes suggest the need for an evaluation of the environmental and social benefits that may have been lost, including the appropriate management of land resources, changes in the management of biodiversity and their consequences for environmental protection and implications for climate change.

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