Available online: www.notulaebotanicae.ro

Print ISSN 0255-965X; Electronic 1842-4309

Not Bot Horti Agrobo, 2017, 45(2):589-596. DOI:10.15835/nbha45210933

AcademicPres

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

Original Article

The Role of Transhumance on Land Use/Cover Changes in Mountain Vermio, Northern Greece: A GIS Based Approach

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Abstract

Transhumant flocks graze the vegetation of medium and high elevation rangelands during late spring to autumn depending on the geographical area and climatic conditions. This study aimed to assess and interpret the impacts of transhumance decline on the land use/cover on Mountain Vermio, for the period 1985-2009. For many years, this area has received high stocking rates from transhumant livestock. However, during the last 30 years transhumance has been dramatically decreased. Land cover changes have been identified using a post classification comparison approach within a Geographical Information Systems environment. Moreover, the rate and the spatial differentiation of land use/cover were determined by means of the Dynamic Degree Index. According to the results, the acreage of grasslands and grazed open forests has decreased during the study period (3% and 83% respectively), while shrublands demonstrated an opposite trend with an increase of 25%. Furthermore, based on the Dynamic Degree Index, the greatest changes occurred in the conversion of grazed open forests and shrublands, compared to other land use/cover categories. This can be attributed to changes in sheep and goats populations grazing in the area, also related to the dispersion of flocks in local rangelands. Moreover, this article presents the results of a questionnaire survey on transhumant herders. These results, combined with the assessment of changes in the Dynamic Degree Index, reflect the difficulties that farmers face in terms of access to rangelands and their increased awareness regarding the environmental role of transhumance.

Keywords: dynamic degree index, spatio-temporal changes, extensive systems, encroachment, grazing, small ruminants

Abbreviations: Dynamic Degree Index (DDI); Geographical Information Systems (GIS)

Introduction

Transhumance is a common practice of seasonal movement of livestock between two specific areas repeated each year (Nyssen *et al.*, 2009) in order to cope with the seasonality of grazing in Mediterranean areas (Galanopoulos *et al.*, 2011). The system is still alive in most countries of the Mediterranean basin, maintained mainly by flocks of small ruminants (Ispikoudis *et al.,* 2004; Hadjigeorgiou, 2011; Pardini and Nori, 2011; Thevenin, 2011). Additionally, the transhumant sheep and goats livestock system has a dynamic character, which is been manifested through its social, economic and environmental impact in the areas involved (Ragkos *et al.*, 2015). Transhumant flocks graze in mountainous rangelands and thus provide a variety of ecosystem services (Bernués *et al.*, 2011), while they contribute especially to maintaining biodiversity in fragile ecosystems, as well as the diversity of local ruminant breeds. The system also constitutes a particularly suitable activity for the development of less-favoured areas (Laga *et al.*, 2012) especially in terms of production of high quality typical products. It also contributes to the establishment of cultural linkages among winter and summer residences. Elements of agricultural cultural heritage are currently recognized as intangible cultural heritage and efforts are made throughout the Mediterranean to inscribe transhumance in UNESCO

Received: 14 Apr 2017. Received in revised form: 10 Aug 2017. Accepted: 10 Aug 2017. Published online: 15 Sep 2017.

catalogues. Similar husbandry systems have been reported in countries of Central Europe (Luick, 2004; Wolff and Fabre, 2004) and Northern Europe (Jordal, 2004; Eriksson, 2011).

Despite its numerous contributions, sheep and goat transhumance in Greece, as well as in many Mediterranean countries (Oteros-Rozas *et al*., 2013) has presented a decreasing trend during the last 30 years. Nowadays, according to the Greek Payment and Control Agency for Guidance and Guarantee Community Aid (PCAGGCA, 2011) there are about one million transhumant small ruminants' heads. On the contrary, according to Chatzimichali (2007) around 1960, there were about two million transhumant sheep and goats. Transhumant flocks actually use the natural vegetation of intermediate and high elevation rangelands from late spring to autumn (4-6 months) (Zervas, 1998) to graze the lush forage that grows on these areas. The perceptions and livelihood of people poses differential utilization of natural resources, facilitating general ecosystem and vegetation changes, as well as land use/cover change (Wondie *et al*., 2011; Aryal *et al*., 2014). Thus, the decline of transhumance and the subsequent decrease in the utilization of mountainous rangelands drive these areas towards late successional stages, and consequently shrub encroachment, decrease of available forage production, and modification of biodiversity and landscape (O'Flanagan *et al*., 2011; Oteros-Rozas *et al*., 2013). Hence, the identification of the conversion in vegetation types and the land use/cover changes is necessary in order to understand the multi temporal dynamics of the ecosystems.

Landscapes as maquis, dehesas, montados has been formed under grazing pressure (Gómez Sal and Lorente, 2004) and the transhumance has an important role in this landscape shaping (Gómez Sal, 2000; Sklavou *et al*., 2014). Recently remote sensing and Geographical Information Systems (GIS) applications have been reported for the analysis and quantification of spatio-temporal land use /cover dynamics, worldwide e.g. in China (Li *et al*., 2003; Quan *et al*., 2006; Peng *et al*., 2008; Zhoo *et al*., 2008; Deng *et al.,* 2009; Liu *et al*., 2010; Wang *et al*., 2014; Gao *et al*., 2015), Italy (Salvati *et al*., 2012), Ethiophia (Wondie *et al*., 2011; Belay *et al*., 2015*),* and Greece (Ispikoudis and Houvardas, 2005; Sidiropoulou *et al*., 2015).

Moreover, the Dynamic degree Index (DDI) (Liu and Buhe, 2000; Li *et al*., 2003; Chunxiao *et al*., 2008) which refers to the conversion rate of a land use/cover category to another during a certain period, has been used to quantify the changes of land use/cover. However, in Greece there is limited research concerning the conversion rate of a land use/cover change expressed by DDI, although this index is sufficient to represent all land use changes.

Mount Vermio is one of the mountainous areas that for many years have received high stocking rates during late spring and summer, from transhumant sheep and goats flocks especially from Thessaly (Central Greece) (Sidiropoulou *et al*., 2015). In the 1950s there were about 200,000 sheep and goats grazing in the study area (Chatzimichali, 2007), but over the last decades this pressure seems to be reduced. Indeed, although 225,000 transhumant small ruminants were reported in 1957 (Chatzimichali, 2007) nowadays only 27,000 heads (PCAGGCA, 2011) graze in the area (Sklavou *et al.,* 2014). An ethnic group named "Sarakatsanoi" mainly used the whole area as summer grazing rangelands for their flocks. Sarakatsanoi had established a particular form of social organization called "Tseligata", within which a number of small-scale transhumant families would unite and collaborate. In the past, 27 Tseligkata were located in the area, the majority of which established in altitude zones of approximately 1,500 m, with the lowest being at 1,100 m (Sklavou *et al*., 2014; Sidiropoulou *et al*., 2015). Today, only seven Tseligkata exist in Mount Vermio (Sklavou *et al.,* 2014) following the same trend as the number of transhumant animals and farms.

This study aimed to record the spatio-temporal land use/cover changes, in Mount Vermio, Northern Greece using spatial orientation analysis of GIS. The specific objectives of this study were: a) To evaluate the land use /cover changes of Mount Vermio for 1985 and 2009, b) To estimate the characteristics of land use/cover changes using a DDI between 1985 and 2009, in order to evaluate the effects of transhumance decline, and c) To assess and interpret the impact of transhumance decline on the land use/cover changes.

Materials and Methods

Description of the study site

The study was conducted in Mount Vermio, which is located at the Regional Units of Pella, Imathia and Kozani in Northern Greece. The survey has covered an area of 94,406 ha in an altitude range between 700 m to 2,065 m a.s.l.

The areas with high altitudes of Mount Vermio (above 1,500 m), according to classification of Emberger *et al.* (1963) belong to the sub-Mediterranean zone, while the lower ones belong to the meso-Mediterranean zone (Mavromatis, 1978). The mean annual precipitation is approximately 699.83 mm and the mean annual air temperature is 15 °C. The main land covers in the study area are forests and rangelands (which differentiate in grasslands, shrublands and grazed open forests). Forests and shrublands are dominated by plant species such as *Pinus nigra* Arn., *Abies borisii-regis* Mattf., *Castanea sativa* Miller., *Quercus* sp., *Salix* sp., *Populus* sp., *Platanus* sp, *Acer* sp., *Ilex aquifolium* L., *Juniperus* sp., *Fraxinus* sp., *Buxus sempervirens* L., *Cornus* sp., and *Prunus* sp. (Zianis and Mencuccini, 2003). The rangelands in the lowlands are grazed by ruminants and in the upper land are mainly grazed by transhumant sheep and goats from Thessaly (Sidiropoulou *et al*., 2015).

Data sources and land use/cover classification system

Land cover information for 1985 was extracted by the map of Forest Vegetation and Land Cover by the Ministry of Productive Reconstruction, Environment and Energy (Former Ministry of Rural Development) (year of publication 1986-1987). The land use/cover categories of this map were indicative of the classification scheme designed and they were merged to a six land cover categorization scheme to suit the purposes of this study (Table 1).

Land cover information for 2009 was collected through photointerpretation and digitization on a true colour orthomosaic of the National Cadastre Agency, with spatial resolution of 0.5 m and scale of 1:5,000. Altitude stratification of the land cover changes was based on the ASTER GDEM V2 digital elevation model, which was generated using stereo-pair images collected by the ASTER instrument onboard Terra Satellite, and is freely distributed by NASA.

For the land cover change detection the post classification comparison approach was implemented, within a GIS environment. The two maps 1985 and 2009 were combined through their intersection, which resulted in a polygon layer that preserved all the boundaries found in the two original layers. This way, each polygon in the new layer carries information of the land cover of each time, therefore change information can be extracted and further analysed. This layer was combined with the digital elevation model, in order to address land cover changes in different elevation zones. The study area was divided into four elevation zones, namely 700-800 m, 800-1,200 m, 1,200-1,500 m, and 1,500-2,000 m. Nowadays, in the first two zones, ruminants reared under extensive husbandry systems graze alongside with transhumant flocks (PCAGGCA, 2011). Moreover, in the other two zones only transhumant flocks graze.

Finally, a map with the following four land use/cover change types was produced: a) woody species encroachment: where there was a change from open to more dense vegetation cover consisting of: grasslands (G)/ grazed open forests (GOF)/shrublands (S)/ forests (F) , b) thinning: where there was a change from dense to less dense/open vegetation cover consisting of: Forests (F)/ shrublands (S) / grazed open forests (GOF)/ grasslands (G), c) no change and, d) change to other use (none of the above).

Dynamic degree of land use /cover

The spatial differences of land use/cover changes rate were represented by the dynamic degree index. The dynamic degree index was calculated by a simple formula as follows (Liu and Buhe, 2000; Li *et al.*, 2003; Liu *et al.*, 2003):

$$S=\left[\sum_{i,j}^{n}\left(\frac{\Delta S_{i-j}}{S_i}\right)\cdot\left(\frac{1}{t}\right)\cdot 100\%\right] \quad (i,j=1,2,\ldots n)$$

Where: S is the land use change rate, S_i is the area of the initial land use category i, at the beginning of the study period, $\Delta S_{i\text{-}j}$ is the overall area of land use category i changed to j at the time of scale of t (24 years). When we set t as year, the S represented annual change rate of a certain type of land use in the study area (Chunxiao *et al.*, 2008).

Table 1. Land use/cover categories used in the classification scheme

Land use /cover	Characterization features
Grasslands	Areas dominated by herbaceous plants, with ground cover of woody vegetation less than 10%
Grazed Open Forests	Areas dominate by herbaceous plants, with ground cover of woody vegetation between 10% and 40%
Shrublands	Areas dominated by evergreen woody shrubs with sclerophyllous leaves
Forests	Areas with relative tree cover higher than 40%
Agricultural lands	Fields with permanent or temporary crops
Other Areas	Areas with manmade features, including villages, mining fields etc.

Results and Discussion

The change of the land use/cover

According to the results reported in Table 2, there was a significant differentiation in the land use/cover in Mount Vermio for the period 1985 to 2009. Rangelands accounted for 59.1% and 55.6% of the study area, in 1985 and 2009 respectively (Table 2), while all other covers, including forests, agricultural lands and other areas represented in total 40.8% and 44.4% respectively.

Concerning rangelands, grasslands and grazed open forests they were decreased by 3% and 83% respectively, while shrublands had a different trend with an increase of 25% (Fig. 1). The category "other areas" exhibited an overall increase of 142%, due to the establishment of a mining field in the south-western part of the study area.

Throughout the period of 24 years (1985-2009), land use/cover were diversified. Among the increased land uses, shrublands contributed by 42.6% and forests by 16.7% (Fig. 2). These increases were probably due to the gradual decline of transhumance grazing in the study area that leads to higher encroachment (Spatz and Papachristou, 1999). More specifically, the substantially decreased population of small ruminants grazing in the area, which represent only 10% of those grazing during the 50s, is very low to exploit the whole area. The decrease of grazing pressure has led to shrub encroachment, which was been intensified by the reduction of grazed open forests by 76.6% and grasslands by 18.6% (Fig. 2). Moreover, the decrease of local populations and the decline in logging contributed to the reduction in grazed open forests. Furthermore, a decrease of 4.8% in agricultural lands was recorded which is probably due to increase of abandoned fields.

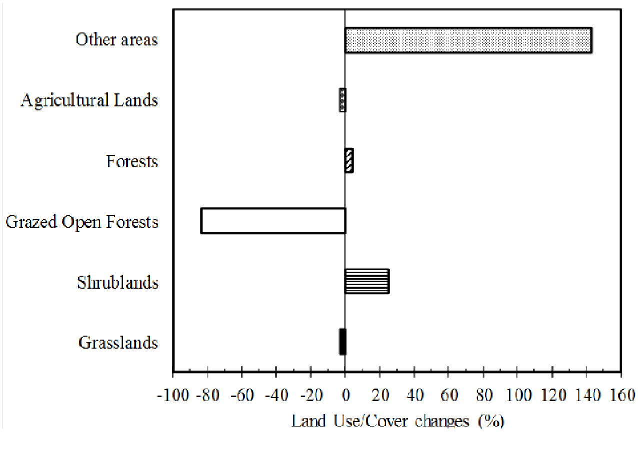

Fig. 1. Land use/cover changes (%) of Mount Vermio in the period 1985-2009

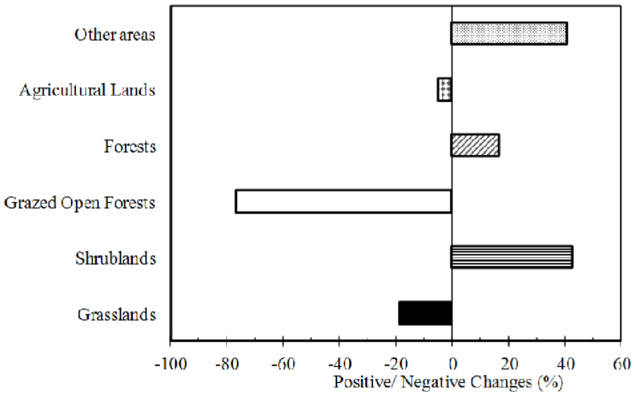

Fig. 2. Land use /cover changes (positive and negative) (%) in Mount Vermio in the period 1985-2009

The dynamic degree and the conversions of land use/cover

The values of the dynamic degree index for grazed open forests and shrublands were obviously higher than that of other land use categories (Table 3). Grazed open forests and shrublands with dynamic degree 3.969% and 2.216% respectively suggested higher changes of land use cover. The cause of higher value of dynamic degree of grazed open forests was that their total area was the smaller between all types (Table 2). The main reason for that probably lies on the gradual reduction of grazing pressure of transhumant flocks, which has led to woody species encroachment. Moreover, this finding is in line with what Kerckhof *et al.* (2016) reported for 14 rural Montenegrin settlements. According to Kyriazopoulos *et al.* (2012) the expansion of shrub species could affect biodiversity as well as socio-economic values, goods and services provided by grasslands (Camarero *et al.* 2015).

Additionally, the high value of the DDI for shrublands was probably due to selective abandonment of tree-line grazing. As the number of animals decreased, the remaining animals covered their requirements in more accessible areas of lower altitude. Kyriazopoulos *et al.* (2017) have reported similar results, especially for the Pindos Mountain treeline ecotones, where *Juniperus* spp. encroachment has been witnessed in formerly grazed rangelands. In the last decades, there is an upward increase of treelines as anthropogenic activities have been decreased (Ameztegui *et al.*, 2016; Kyriazopoulos *et al.*, 2017).

Agricultural lands and other areas have relatively similar values of the dynamic degree index (1.345% and 1.498% respectively) (Table 3). The higher value of DDI for other lands was due to the fact that the total area was smaller in relation to agricultural lands. The change of the dynamic degree for grasslands was similar to the one for forests. These values of dynamic degree near 1% indicate high changes on grasslands and forests as well (Chunxiao *et al.*, 2008). Probably, both of them have been affected more by the transhumance decline, as the ecological role of grazing has stopped via secondary succession (Papanastasis, 2009) and the positive pressure of grazing has been limited (Potthoff, 2009).

Through the study period, the conversion of land use/cover could be probed into. About 60% of the changed grasslands converted to shrublands, grazed open forests and forests (Table 3). The 75% of changed forests converted to grazed open forests and shrublands.

Table 2. Land use/cover (ha) in Mount Vermio, Northern Greece in 1985 and 2009

Land use/cover categories	Years	
	1985	2009
Grasslands	39,152.40	37,956.03
Grazed open forests	5,912.34	1,002.14
Shrublands	10,775.62	13,512.80
Forests	27,440.63	28,509.27
Agricultural lands	9,296.47	8,984.61
Other areas	1,829.97	4,441.58
Total	94,406.43	94,406.43

The elevation differentiation of land use /cover

In order to obtain better understanding of land use/cover changes from 1985 to 2009 through transhumance decline it is useful to examine them in relation to the elevation zone where they occurred (Fig. 3). In the 1st zone (700-800 m) which occupied the 16.25% of the total area, the land use /cover changes from dense to less dense/ open vegetation cover contributed by 10.3%. Additionally, in the 2nd zone (800-1,200 m) woody species encroachment occupied 13.8%, while the opposite trajectory change to less dense or open vegetation cover occupied 15.2%.

Similarly, changes were observed on 3rd zone (1,200-1,500m) where the higher percentage (13.9%) of woody species encroachment was presented, while the total thinning of forest to shrubland, to grazed open forest and grassland occupied 10.1%. On the 4th zone (>1,500 m) which occupied 18.5% of the total area the percentage of woody species encroachment was the highest compared to the other changes (9.6%).

As it is obvious on second and third zone which occupied the 65% of the total area the higher land use / cover changes referring to woody species encroachment and thinning were observed. This is probably due to different spatial grazing pressure, decreased stocking rate from transhumant flocks, as well as the herder's selection of grazing lands. A number of factors in mountainous Mediterranean areas affect in different ways land use/cover changes (Kerckhof *et al.*, 2016).

The dynamic degree index in the four zones followed the same trend (Table 4) as that of the total study area (Table 3). The DDI for grasslands and forests on 1st and 2nd zone (700-800 m and 800-1,200 m) were greater than that of upper zones (1,200-1,500 m and >1,500 m). Moreover, grazed open forests and shrublands had the highest value of DDI on all elevation zones. These results indicate a high land use/cover change due to the decrease of anthropogenic activities as transhumance. These findings are in agreement with other studies in mountainous areas (Palombo *et al.*, 2013; Ainalis *et al.*, 2015).

Economic implications in the study area

The vulnerability of local farms to land use changes can be seen in the Table 5, where economic performance indicators of local farms are reported. The primary data were gathered through a small-scale questionnaire survey of 7 farms, which rear about 35% of the total animals grazing in Mount Vermio during summer. On average farms rear about 600 sheep and 94 goats which achieve relatively low

Table 3. The Dynamic Degree Index (DDI, %) and the conversions of land use / cover (ha) in Mount Vermio in the period 1985-2009

	G*	GOF	S	F	AL	OA	Changed Area	DDI
G	0.00	350.35	1831.82	2387.95	1873.81	1075.72	7519.65	0.800
GOF	780.13	0.00	2188.85	2559.82	80.51	23.67	5632.98	3.969
S	3351.16	119.44	0.00	2024.46	139.10	98.22	5732.38	2.216
F	1277.29	231.17	4299.90	0.00	183.07	87.97	6079.40	0.923
AL	770.81	14.50	132.06	99.40	0.00	1984.69	3001.46	1.345
OA	143.88	7.34	16.91	76.42	413.11	0.00	657.66	1.498
Total	6323.27	722.80	8469.54	7148.05	2689.60	3270.27	28623.53	

*G= Grasslands, GOF= Grazed Open Forests, S= Shrublands, F= Forests, AL= Agricultural Lands, OA=Other Areas

Table 4. The Dynamic Degree Index (%) in four elevation zones in Mount Vermio in the period 1985-2009

Elevation Zones	G*	GOF	S	F	AL	OA
700-800 m	1.952	4.126	2.399	1.750	1.225	1.395
800-1,200 m	1.110	4.025	2.015	1.187	1.538	1.417
1,200-1,500 m	0.724	3.861	2.733	0.582	1.248	2.196
1,500-2,000 m	0.319	4.011	1.433	0.443	3.117	2.645

*G= Grasslands, GOF= Grazed Open Forests, S= Shrublands, F= Forests, AL= Agricultural Lands, OA=Other Areas

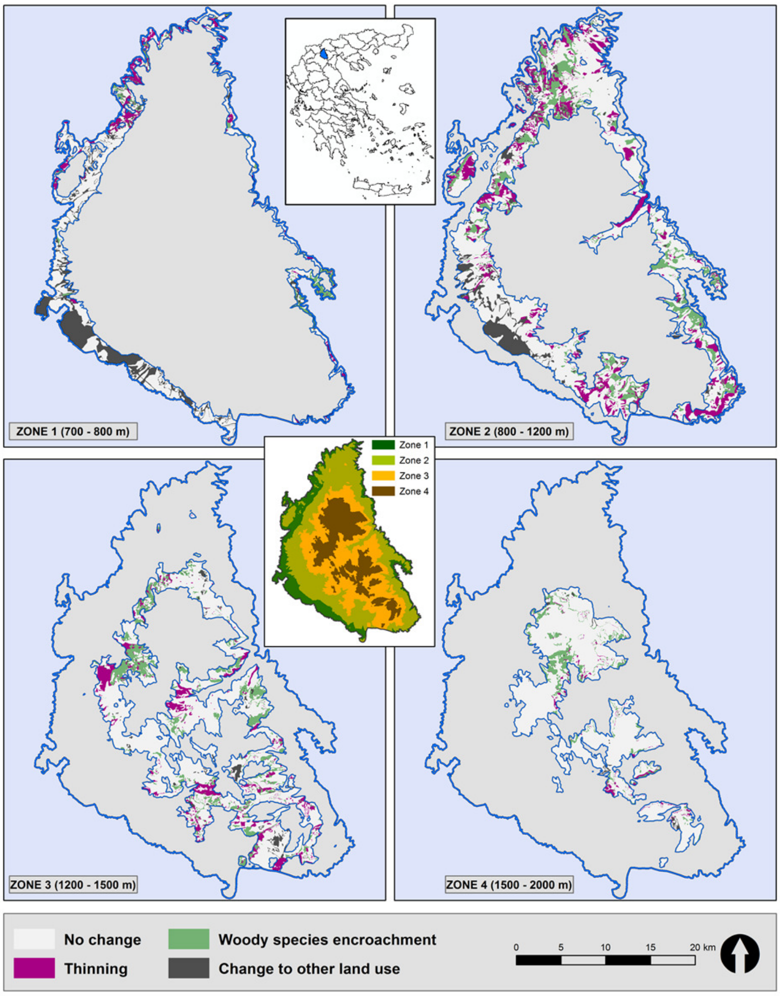

Fig. 3. Land use /cover changes in four elevation zones in Mount Vermio in 1985 and 2009

milk yields (92.6 kg/ewe and 94.5 kg/dam respectively). Nonetheless, this drawback is more than counterbalanced by the low expenses that transhumance incurs. As can be seen, total expenses are 163.1 €/ewe(dam) of which 47% stand for feeding expenses (47 €/ewe(dam)) during the winter period spent in the lowlands. Ragkos *et al.* (2014) reported that the total feeding expenses for transhumant farms in Thessaly Central Greece were higher (73.7 €/ewe/dam) while in intensive systems feeding costs ranged between 157 and 182 €/ewe (Roustemis, 2012). Hence, the financial results of transhumant farms in the study area are quite satisfactory (Table 5). Therefore, the utilization of

Table 5. Technical and economic indicators, production expenses and financial results of transhumant farms in Mount Vermio

Indicator	Ewes	Dams
Flock size	599.2	94.5
Average milk yield	92.6 kg/ewe	85.4 kg/dam
Labor requirements	12.1h/ewe (dam)	
Farm expenses	**€/ewe (dam)**	**%**
Land rent	4.7	2.9
Labor costs	40.9	25.1
Capital costs	117.5	72.0
Variable capital	*96.0*	*58.9*
Purchased feedstuff	73.5	45.1
Animal production variable costs	19.2	11.8
Crop production (for feedstuff)	3.3	2.1
Fixed capital	*21.5*	*13.2*
TOTAL FARM EXPENSES	163.1	100
Gross output per product (source) (€/ewe (dam))	**183.4**	**100**
Milk	101.4	55.4
Cheese/Wool	5.5	3.0
Meat	51.2	27.9
Income support (subsidies)	25.1	13.7
Financial results (€/ewe (dam))		
Net profit	20.2	
Labor wage (€/h)	5.05	
Farm Income	79.9	
Gross profit	87.3	

local natural rangelands is the main source of flexibility of these farms and largely defines their viability. The land use/cover changes pointed out through the calculation of the DDI demonstrate that the danger of encroachment and the expansion of shrublands can threaten the economic performance of farms, as this phenomenon would reduce the availability of grazing material, therefore pointing towards the need for more purchased feedstuff.

Conclusions

Transhumance decline is the main driving force of land use/cover changes in the study area of Mountain Vermio. During a 24-year period the major changes of land use/cover in Mount Vermio concerned grazed open forests and shrublands. These changes not only have important environmental implications but also affect the potential of the transhumance system. The main land use substitution dynamics that occurred in the area due to the constant decrease of the grazing pressure have been revealed through the calculation of the dynamic degree. Therefore, was found that human activities - even in terms of semi-extensive practices - not only affect the natural environment, but were also the cause of changes, which affected the dynamics and future prospects of these activities themselves. In addition, the study of land use/cover changes is imperative for the coming years in order to maintain transhumance system in the region of Mount Vermio in Northern Greece.

Acknowledgements

This paper is part of the project "The dynamics of the transhumant sheep and goat farming system in Greece. Influences on biodiversity" which is co-funded by the European Union (European Social Fund) through the Action "THALIS".

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