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Land degradation and economic conditions of agricultural households in a marginal region of northern Greece

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A B S T R A C T

Land degradation is caused by and has impacts on both the social and natural components of coupled human–environment systems. However, few studies integrate both aspects simultaneously. The main objective of this study is to test a method to evaluate land degradation based on the integration of aggregate metrics of biophysical and socio-economic "degradation". We applied a framework that integrates the biophysical and socio-economic dimensions of land degradation to test the hypothesis that macro-economic policies, and in particular agricultural subsidies, are an important driving force of land degradation in marginal regions of the Mediterranean Europe. We analysed the influence of subsidies on the profitability of each crop and livestock type found in a sample of farms in a region of northern Greece. Spatial and socio-economic data on agricultural households were collected to link remote sensing data and land degradation maps to socio-economic conditions of these households, as measured by the standard gross margin. The results demonstrate that subsidies provide a crucial socio-economic support to maintain the profitability of agricultural activities but may also promote land-use practices with damaging ecological impacts. Different levels of biophysical and socio-economic "degradation" were associated with different land use practices. The integration of the socio-economic and biophysical dimensions of land degradation reveals associations that would not be detectable if indicators along one dimension alone would be used.

1. Introduction

Land degradation in drylands is the result of interactions between human activities and natural ecosystems. It is caused by and has impacts on both the social and natural components of coupled human–environment systems. Yet, most estimates of land degradation are derived solely from either biophysical factors (e.g., soil erosion, loss of plant cover, change in albedo) or socio-economic factors (decreased production, economic loss, population movements, etc), but rarely both types simultaneously (Reynolds et al., 2007). There is thus a need for methods to assess simultaneously the biophysical and socio-economic drivers and consequences of land degradation. Fernandez et al. (2002) proposed a framework that represents the interactions between biophysical processes of desertification at the household level and the capacity of socio-economic systems to cope with these changes. This framework plots trajectories of biophysical and socio-economic variables in a "socio-ecological space" where sustainability thresholds are defined (Fig. 2). These thresholds define four quadrants reflecting non-degraded and degraded states of the human–environment system, and states characterized only by biophysical or socio-economic degradation. The main objective of this study is to test a method to evaluate land degradation based on the integration of aggregated metrics of biophysical and socio-economic "degradation". This method combines remote sensing and socio-economic survey data at the household level, which are increasingly exploited for understanding causes, processes and impacts of land-use/land-cover changes (Rindfuss et al., 2003), including in drylands (Lambin et al., 2008).

The method developed in this study is applied to a marginal region of northern Greece, to evaluate the influence of the Common Agricultural Policy (CAP) on land use. In marginal agricultural regions of the Mediterranean Europe, land degradation is often linked to agriculture (Geist and Lambin, 2004). Land use results from decisions by land managers who respond to constraints and opportunities created by the macroeconomic, policy and natural environment. In these regions, many land managers are agricultural households who derive their income from cropping and/or livestock. In the Member States of the European Union, and since the 1992 CAP reform but before the implementation in 2006 of the 2003 reform, subsidies were allocated to agricultural exploitations per production unit (head of

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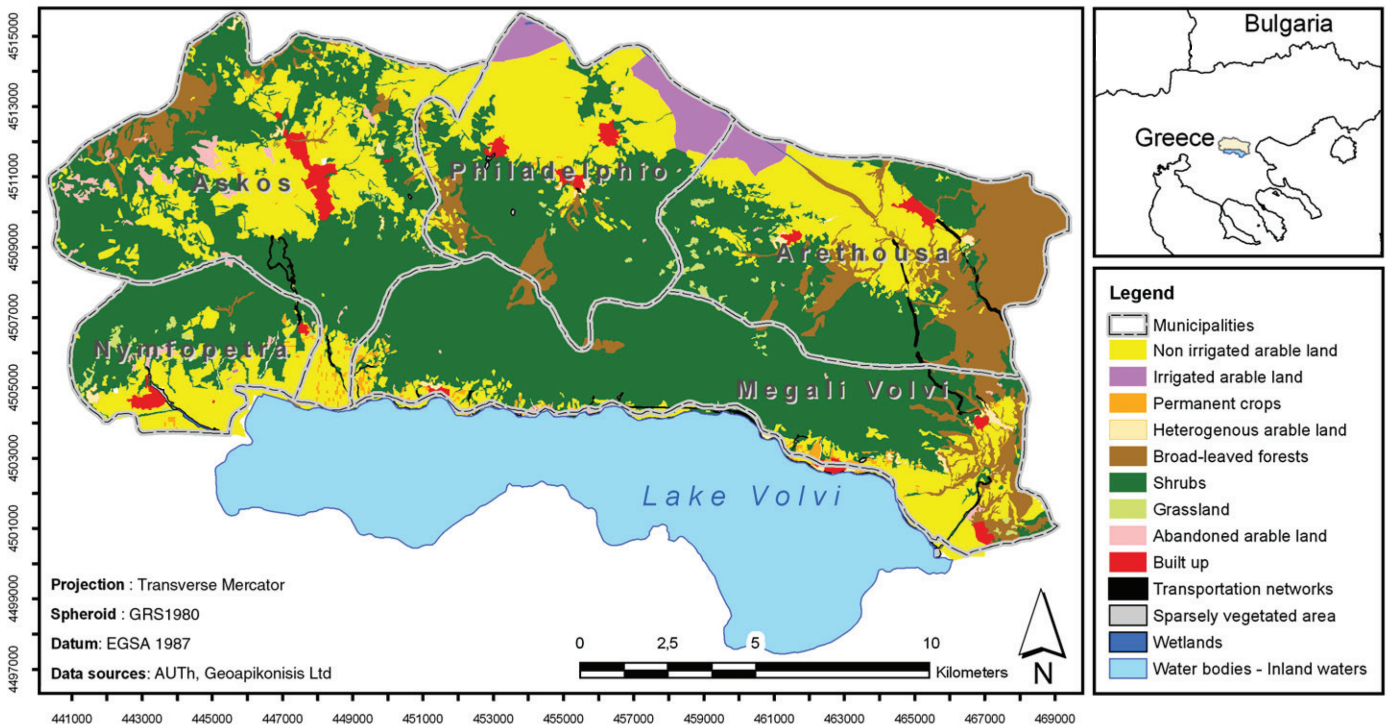

Fig. 1. The 5 municipalities of the study area and their land use in 1993.

livestock or crop area) for certain agricultural products, such as cereals, cattle or small ruminants. Other productions such as olive oil received a price support. Milk and tobacco were submitted to a quota system ensuring relatively high prices. In less favoured areas, defined by the European Union as mountainous areas or regions where the physical landscape results in higher production costs, compensatory allowances linked to fodder production and grazing intensity were also provided to farmers. All these subsidies were defined by the European Union and distributed by Member States. Direct and indirect support for crop and livestock production may represent a significant part of the agricultural household income. Subsidies are thus a critical factor in their decisions on land allocation to certain crop types, for livestock production methods, and for agricultural intensification. This exogenous financial support can stimulate farmers and stock breeders to shift from traditional agricultural practices, local animal breeds or local crop varieties to new zootechnical or phytotechnical methods, such as concentrated feedstuff, irrigation, genetically enhanced livestock or crop types. This in turn may release pressures on the environment. By decoupling agricultural income from environmental constraints and responses, subsidies may also promote land-use decisions that induce land degradation.

In this study, we first linked the socio-economic conditions of a sample of agricultural households with land degradation on their plots. We spatialised both socio-economic and biophysical variables, therefore allowing a linkage of “people to pixels”. We then estimated the standard gross margin (SGM, or profit, Eurostat, 2003) for these households. We applied a framework that integrates the biophysical and socio-economic dimensions of land degradation to test the hypothesis that macro-economic policies, and in particular subsidies, are an important driving force of land degradation in marginal regions. We analysed the importance of subsidies in the profitability of each crop and livestock type found in our sample of farms.

2. The Lagadas study area

Our study area includes five municipalities of the Lagadas county, Central Macedonia, Greece (Fig. 1). It covers 33,301 ha, including the Volvi Lake (6762 ha). Altitude varies between 27 and 1092 m above sea level. Climate is classified as semi-arid to sub-humid (Tsiourlis and Konstantinidis, 2006). Topography is variable, with large flat areas occupied by agriculture and smooth to sharp hills and mountains covered by rangelands and forests. Vegetation cover is dominated by evergreen shrublands mainly composed of kermes oak (*Quercus coccifera*) and interspersed by openings with herbaceous species (grasslands) in the central part of the study area (Volvi hills). These shrublands provide forage to livestock throughout the year, especially in summer when kermes oak stays green while herbaceous vegetation dries out (Platis and Papanastasis, 2003). Balkanic thermophilous oak forests surround the northern and eastern parts of the Mavrouda valley. *Q. coccifera* shrubland is a typical grazing land traditionally used also for fuelwood logging. Kermes oak shrublands are mostly present on steep slopes where agricultural activities are difficult, while grasslands are present in various places (Tsiourlis and Konstantinidis, 2006), with a patchy distribution within shrublands. Major non-submerged land-use/cover types are shrublands (56%), non-irrigated agricultural areas (26%), broad-leaved forests (10%) and irrigated croplands (2%).[1] Agricultural land is situated in the bottom of the Mygdonia valley, North to the Volvi lake, and in the valley of Mavrouda.

In 2005, agricultural land use in the five municipalities was mainly composed of wheat (57%), olive trees (10%), tobacco (7%), fodder maize (5%), grain maize (5%), other cereals (7%) and other fodder crops (4%). About 4237 heads of cattle, 12,922 sheep and 24,939 goats were declared in 2005 (Greek Ministry of Agriculture, Thessaloniki, 2005, personal communication). Nowadays, markets for agricultural input and output are concentrated in the city of Thessaloniki. Cereals and cotton seeds grown in the county of Lagadas are harvested by companies that retain a fraction of the production as payment. Cereals are sold on the few local markets of the city. They are integrated into concentrated feed that is sold to local stock-breeders. Farmers either

[1] Data extracted from land-use classification derived from orthophoto interpretation for 1993, Geoapikinisi Ltd.

buy inputs directly in Thessaloniki or contact one of the few resellers operating in the region. Milk is collected on the farm by one of the two agro-industrial companies that transport it to the local cheese production plant. A very small fraction of the milk production is transformed on the farm and sold directly to consumers. Animals to be slaughtered are picked up by specialized transporters who bring them to the slaughterhouse.

Large rangeland areas have allowed the development of extensive grazing livestock husbandry, which has been present in the region for centuries. During the second half of the XXth century, major socio-economic and land-use changes took place in the region. Municipality-level agricultural censuses reveal that, between 1961 and 2001, the total number of agricultural and livestock-breeding exploitations decreased by 23% (National Statistical Service of Greece, 1966, 1978, 1994b, 2001a,b). Land-use change analysis based on classifications from aerial photographs of 1960 and 1993 showed that the rangeland area decreased by 8%, mainly due to the encroachment of non-irrigated crops. Agricultural encroachment took place on the most accessible rangeland areas—i.e., gentle slopes of rangelands bordering agricultural areas, that increased by 14%.

During the same period, the primary sector (mostly agriculture and livestock husbandry) was by far the most important economic activity of the study area, employing more than half of the workforce (National Statistical Service of Greece, 1962, 1972, 1994a, 2001a,b). Rural exodus towards the city of Thessaloniki caused a population decline (−23%), principally in the younger classes (National Statistical Service of Greece, 1962, 1972, 1994a, 2001a,b). The proportion of non-economically active persons doubled between 1961 and 2001, reaching 46% (National Statistical Service of Greece, 1962, 1972, 1994a, 2001a,b). Between 1971 and 2001, the workforce of the primary sector decreased by 39% (National Statistical Service of Greece, 1972, 1994a, 2001a,b), with the consequence that many heads of agricultural exploitations could not find a successor. This led to the abandonment of traditional management techniques, and to rangeland deterioration, characterized by a dramatic reduction of grasslands. Shrublands and forests expanded and became taller and denser, thus reducing the available grazing biomass (Platis and Papanastasis, 2003; Papanastasis and Chouvardas, 2005). This led farmers to intensify their production methods by using concentrate feed but also to increase grazing pressure on the rangeland area to minimize costs linked to fodder. Grazing pressure was also intensified on the remaining grasslands, mainly grazed by sheep and cattle. Abandoned agricultural areas and some rangelands were converted to artificial grasslands sown with barley, to improve the diet of the flocks. These leys, grazed in April and May, have a low vegetation cover, thus increasing the risk of rainfall-induced erosion. The development of dairy production, resulting from the same socio-economic changes, led to the abandonment of the system of transhumance, which involved the movement of the flocks out of the study area during summers. Nowadays, the flocks stay permanently in the range with the shepherds herding them daily to the area surrounding the sheds for grazing (Yiakoulaki et al., 2002). This leads to overgrazing locally because flocks are concentrated spatially (Röder, 2005).

3. Materials and methods

3.1. Socio-economic data

Estimating the financial status of agricultural households requires standardised records of household's accountancy. Privacy issues restrict the type of information that can be collected, e.g. for indebtedness. Data about farming systems and land use practices of agricultural households for 2005 were collected during a field survey. In September and October 2006, 51 farmers and/or stockbreeders were interviewed in the study area. The selection of interviewees was non-random. It has been made by local administration agents and through informal contacts in the village café. We focused our survey on the means of production of households to assess their socio-economic status related to agricultural activities. Other data on household composition (number of people living in the household, number of family members working in the farm) and social characteristics (age and education of the head of the household) were also collected. Agricultural plots, grazing areas, houses and farms used by each of the interviewed farmers were located on orthophoto maps, either visually with the help of the interviewed person or on the basis of cadastral maps. All these data have been integrated in a geodatabase to analyse the link between socio-economic characteristics of agricultural households and land-cover changes observed on remote sensing data (see Materials and methods section). A geodatabase is an object-oriented data model that represents geographic features and attributes as objects and the relationships between objects, but is hosted inside a relational database management system (ESRI, 2004).

Complementary data on the means of production (crop yields and variable costs) were collected from local administrations. The main data sources were the agricultural indices for 2005, released by the Agricultural Service of the Central Macedonia prefecture. These data include estimates of highest values for prices, subsidies, irrigation, workforce, crop yields and variable costs as measured for typical professional farms in the district of Central Macedonia. Other data were collected at the Central Macedonia Agricultural Service, such as the total production of certain crops or animal husbandry in each municipality, and actual subsidies data distributed to the interviewed households in 2005 as registered by the Agricultural Service. These data contributed to the detection and correction of erroneous values in the agricultural indices.

3.2. Biophysical data

A soil erosion status map at the 1:50,000 scale produced by the Greek Ministry of Agriculture (1993) and vectorised for the Georange Project (Tsiourlis 2007, personal communication;http://www.georange.org/georange/start.html) was used to assess biophysical degradation in crop fields. This soil map includes a soil erosion status classification based on field observations, and gives the level of the main and secondary erosion types found in each spatial unit. As an alternative measure for erosion risk and land quality, the average slope for all plots under cultivation was also computed based on a digital elevation model with a 30 m spatial resolution. The environmental impact of grazing activities was assessed through a time series of remotely sensed vegetation cover data (Röder, 2005). Vegetation cover is one of the most important factors offering protection of the soil against erosion (Vrieling et al., 2007). A high vegetation cover reduces erosion, soil sealing, soil crusting or salinisation by stabilising the soil, slowing down overland flow, reducing splash impact, and preventing capillary rise effects in the soil (Hill and Stellmes, 2006). In Mediterranean rangelands, vegetation cover change can be used as an indicator for slow degradation processes linked to land use, provided that other determinants of erosion are controlled for (Thornes, 1990). We used a degradation status map of the vegetation cover of rangeland at a high spatial resolution (30 m) produced by Röder (2005) for the study area. After geometric and radiometric corrections of a time series of Landsat images, proportional vegetation cover has been extracted by spectral mixture analysis for the period 1984 to 2000. One image per year was acquired where available, with a preference for images at the same phenological stage (mid-summer being considered as the period of maximum photosynthetic activity). A quantitative characterization of the decadal-scale evolution of green vegetation cover was then undertaken by means of linear trend analysis. This led to a degradation index that combines information on the direction and magnitude of the vegetation cover trend and the average vegetation cover during the observation period (Hill and

Stellmes, 2006). It thus encompasses the change and time dimensions (Hostert et al., 2003).

3.3. Linking socio-economic data with land degradation data

We analysed agricultural households in the socio-ecological space defined by Fernandez et al. (2002) (Fig. 2). We used aggregate metrics for the socio-economic and biophysical conditions that define that feature space. The socio-economic condition was represented by the total standard gross margin (SGM) of households, as defined by Eurostat (2003). The biophysical condition was represented by the average soil erosion status and average slope of crop fields for cultivators, and by the average vegetation cover trend of grazing areas for livestock breeders. The position of each household in this socio-ecological space with respect to critical socio-economic and biophysical thresholds was evaluated. Degradation of the human–environment system was identified when both or just one of these two thresholds were exceeded. We then estimated the influence of subsidies on the profit of agricultural households by replacing SGM by the difference between total gross production and total variable costs, excluding thus subsidies from profit.

3.4. Socio-economic condition: Standard gross margin

The standard gross margin is defined as the balance between the standard value of output (including subsidies) and the standard value of some direct costs, i.e. the proportional (variable) costs which can easily be allocated to this output. SGM is expressed in monetary terms, either per hectare of utilised agricultural area in the case of crop enterprises, or per head of livestock in the case of livestock farming (Eurostat, 2003). It estimates the profitability of the means of production. The total SGM, or profit, of an agricultural household is a linear function of the total amount of means of production and the balance between the output and the production costs of these different means. It is computed by multiplying the total amount of each type of production units by its respective SGM. It also allows classification of agricultural holdings by economic size and technical orientation (Eurostat, 2003).

To study ecological impacts of land use, SGM allows directly expressing some of the ecosystem services for agriculture in monetary units, in a spatially-explicit manner. Individual SGM can be calculated for each spatial production unit (agricultural plots). It is thus possible to directly link subsidies for specific crops to land-use change in each unit. Furthermore, spatialisation of production means allows linking households to land-cover change on the plots they use. For animal production units, grazing areas of the flocks are taken as the spatial units to be linked to the total SGM of the flocks.

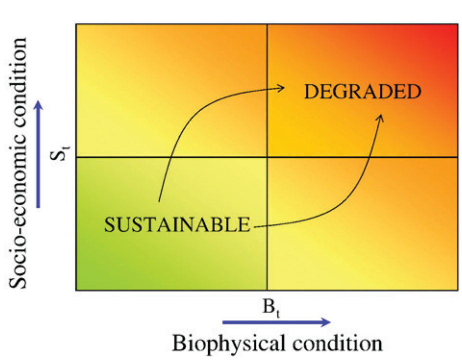

Fig. 2. Conceptual representation of land degradation framework (Fernandez et al., 2002).

As SGM can be calculated for each unit of production, i.e. per hectare of crop or per head of livestock, it has been computed separately for crop and animal production. Furthermore, total SGM permits the classification of farms by the relative contribution of different activities to the total standard gross margin of the farm:

$$\Pi_i = \Pi_i^C + \Pi_i^{LS} \quad (1)$$

i	household index
Π_i	total SGM (or total profit) for household i (€)
Π_i^C	total SGM linked to crop production for household i (€)
Π_i^{LS}	total SGM linked to livestock breeding for household i (€)

Using this method, we distinguished cultivators—defined as deriving more than half of their profit from crop production—from livestock breeders. Based on this classification, we evaluated separately the impact of cultivators and stockbreeders on land degradation.

3.4.1. SGM for crop production

The profitability of each land parcel is expressed by the SGM of the crop it has been allocated to. SGM has been computed for each crop type that has been identified during the field survey. The profitability of each land parcel was then computed as:

$$\mathrm{SGM}_{jk} = Y_{jk}P_k + (s_k^C + Y_{jk}p_k^C) - I_k - F_k - L_j - M_k \quad (2)$$

j	plot index
k	crop index
SGM_{jk}	profitability of crop k under irrigation condition of plot j (€/ha)
Y_{jk}	estimated yield for crop k in the study area under irrigation conditions of plot j (kg/ha)
P_k	price of crop k on the local market (€/kg)
s_k^C	subsidy per hectare for crop k (€/ha)
p_k^C	production subsidy for crop k (€/kg)
I_k	pesticide input for crop k (€/ha)
F_k	fertilizer input for crop k (€/ha)
L_j	land rental value for plot j (€/ha)
M_k	mechanical harvesting cost for crop k (€/ha)

In agreement with European Commission specifications, labour, machinery (repairs, depreciation), fuel and lubricants, buildings, and most contract work (in particular, harvesting) were not included in the variable costs (Eurostat, 2003). The exclusion of workforce costs can result in very high SGM for some labour intensive productions. Fodder crops, like barley or oats cultivated on grazed land parcels or maize harvested as feed, were not included in the SGM for crop production but their variable costs were allocated to livestock production (see below).

The total SGM (profit) of each household for crop production was then calculated as:

$$\Pi_i^C = \sum_j \sum_k \mathrm{SGM}_{jk}.a_{ijk} + O_i \quad (3)$$

i	household index
j	plot index
k	crop index
a_{ijk}	area of plot j, owned by household i and planted with crop k (ha)
O_i	profit from transformed vegetal products (TVP) (€)

3.4.2. SGM for livestock breeding

SGM for livestock husbandry is more complex than for crop production because it is associated with a greater variability in the total amount of means of production. The size and composition of the flocks can quickly change from one year to another, both in terms of animal species and breed. We computed SGM separately for cows, sheep and goats based on data collected in the field for 2005, agricultural indices and specialised literature. SGM and total SGM have been computed for animal production for each household. During the survey, we collected data on the total number of adult sheep and goats. To calculate more realistically fodder costs, the composition of the herd (number of young and adult animals, and of productive and non-productive animals, whose needs vary) was assumed to be proportional to the total number of animals and was based on representative sample data (personal communication of the FADN service, Greek Ministry of Agriculture, Thessalonica, 2006). On this basis, the proportion of non-productive adult sheep or goats (males and non productive females) was assumed to be 0.2 in every herd. The proportion of non-productive young animals for replacement was computed based on the replacement rate provided in the agricultural indices for 2005 (25%). Gross agricultural product, or gross production (GP), was computed based on declared dairy production data and herd size and composition. GP includes sales, benefits in kind and changes in stocks. It relates to both the principal and secondary products. Agricultural indices and survey data on vegetal products consumed inside the farm by animals, also called intermediate consumption, were used to define the variable costs (VC), defined as proportional specific costs that may be readily allocated to the production. We used actual subsidies for the year 2005, as provided by the local agricultural service.

$$\Pi_i^{LS} = \sum_m \left(M_{i,m} + D_{i,m} + Y_{i,m} + Y_{i,m}^{SL} + S_{i,m}^{LS} - F_{i,m} - K_{i,m}^{VC} - K_{i,m}^{FC} \right) \quad (4)$$

m	animal type index
$M_{i,m}$	net profit from meat sales for adult animal type m (€)
$D_{i,m}$	dairy product profit for animal type m for household i (€)
$Y_{i,m}$	value of young animals produced and kept for replacement (€)
$Y_{i,m}^{SL}$	profit from slaughtered young animals of type m (€)
$S_{i,m}^{LS}$	total subsidies for livestock of type m received by household i (€)
$F_{i,m}$	concentrated feedstuff expenses for animal type m (€)
$K_{i,m}^{VC}$	sum of variable costs of household i for production of animal type m (€)
$K_{i,m}^{FC}$	variable costs linked to fodder crops that are consumed internally by animal type m—intermediate consumption (€)

3.5. Biophysical condition associated with households

Concerning crop production, we extracted average erosion status values and mean slope for each crop-cultivating household by overlaying the land parcels used by each household on the erosion status map. Classes of vegetation cover change were aggregated by classifying pixels by trend category (strongly negative, negative, neutral, positive and strongly positive trends), according to the classification defined by Röder (2005) and Röder et al. (2008). This produced a classification of the study area with pixel values indicating the class of the vegetation cover trend (Röder, 2005). To associate data on land degradation with data on grazing activities, vectorised grazing zones were overlaid on the map of vegetation cover trend for rangelands. The average vegetation cover trend was extracted for each livestock-breeding household based on the vectorised grazing zones (Fig. 3). Areas with other land uses were masked.

3.6. Data quality

While georeferencing errors can be estimated for the remote sensing and aerial photograph data, other errors affecting both socio-economic and land degradation data are more difficult to estimate. We defined a quality index based on crosschecks between questionnaire items, a subjective assessment by the interviewers of the quality of answers, and the consistency between spatial data with overlapping information. Only data concerning the household with a high value on the quality index were analysed. Out of the 51 households interviewed, only 38 were retained for the quality of their responses about socio-economic data. Only 33 of these households had spatial data of a sufficient quality and could be projected in the socio-ecological space. The main sources of errors in the household survey data come from the difficulty for some respondents to estimate changes in past production. The delineation of grazing areas may be spatially inaccurate as they sometimes vary through the season. Some land parcels may have been missed on orthophotos, even when cadastral maps were available.

3.7. Thresholds in the socio-ecological space

We defined a critical threshold for the socio-economic and biophysical conditions. These thresholds define four regions in the socio-ecological space (Fig. 2), from sustainable socio-economic and biophysical conditions (A) to a degraded state (D). The other quadrants represent transition states, reflecting a mining of the natural resources for short-term profits (B) and a socio-economic impoverishment that could lead to an overexploitation of natural resources (C) (Fernandez, 2002). For the biophysical condition, the absence of vegetation cover trend (i.e., vegetation cover stability or variability around a stable mean) was used as a threshold (B_t), within a trend value interval of −0.05 to 0.05 (Hostert et al., 2003). For cultivated fields, a soil erosion status with a value of 1, defined as the presence of no or moderate erosion, was used as threshold. For the socio-economic condition, a total SGM of 0 (no profit) was used as threshold. The position of each household in this socio-ecological space reveals the relationship between the profit generated by their agricultural activities and their impacts on land degradation.

3.8. Influence of subsidies on profit

To assess the importance of subsidies on the profit of agricultural households, we compared the SGM for each crop and livestock types (i.e., the profit per hectare or per head with subsidies) to the difference between the standard gross production (GP) and variable costs (VC), or (GP−VC) in euro per hectare. (GP−VC), or gross margin, is defined as the monetary value of the gross agricultural output (or gross agricultural product) based on the farm-gate price, after deduction of proportional specific costs that may readily be allocated (Eurostat, 2003). (GP−VC) thus measures the profitability of crops or livestock per unit. It does not include subsidies. Based on agricultural indices, we calculated the SGM, total GP, subsidies and VC for crop production (in €/ha) for the households that were cultivating crops. SGM and (GP−VC) per head of livestock were calculated differently. Information about secondary production (like dairy products) and integrated feed that was produced and consumed inside the farm, also called intermediate consumption, was collected. First, total SGM and total (GP−VC) per household for livestock production were computed, and then SGM and (GP−VC) per head of livestock were derived.

The values of actual subsidies received by households in 2005 as reported by the Agricultural Service and the values for subsidies computed based on agricultural indices were not strongly correlated (R^2=0.33). The computed values were in average higher than the amounts actually perceived by households. We attribute these differences to two main factors. Firstly, agricultural indices estimate

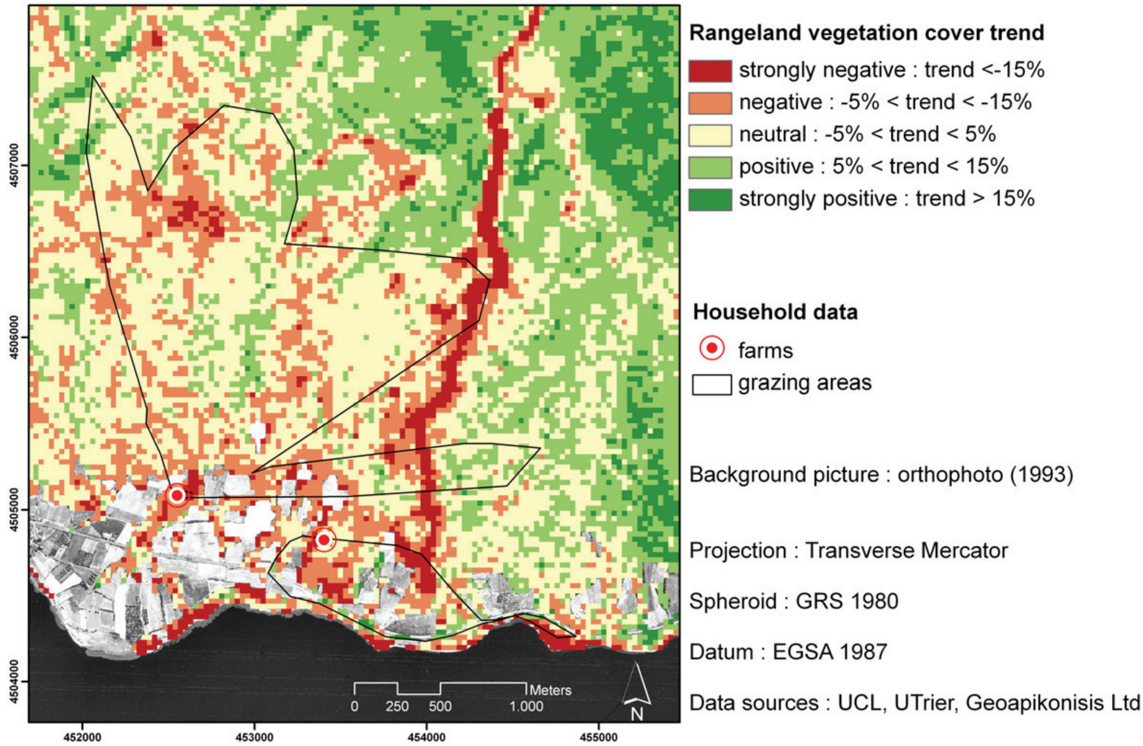

Fig. 3. Extraction of the average index of vegetation cover trend for grazing areas.

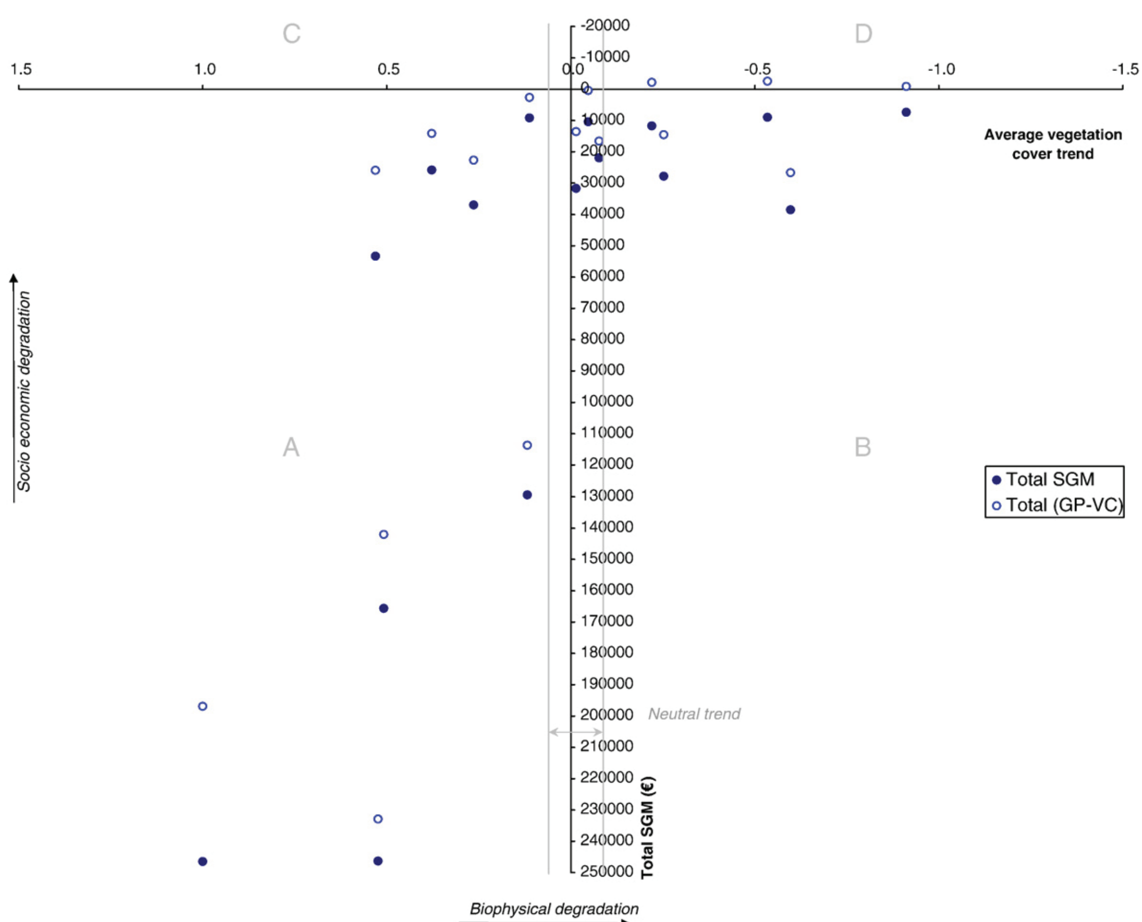

Fig. 4. Socio-ecological space for livestock breeders: household total SGM and non-subsidised profit (GP−VC) as a function of average vegetation cover trend of grazing areas.

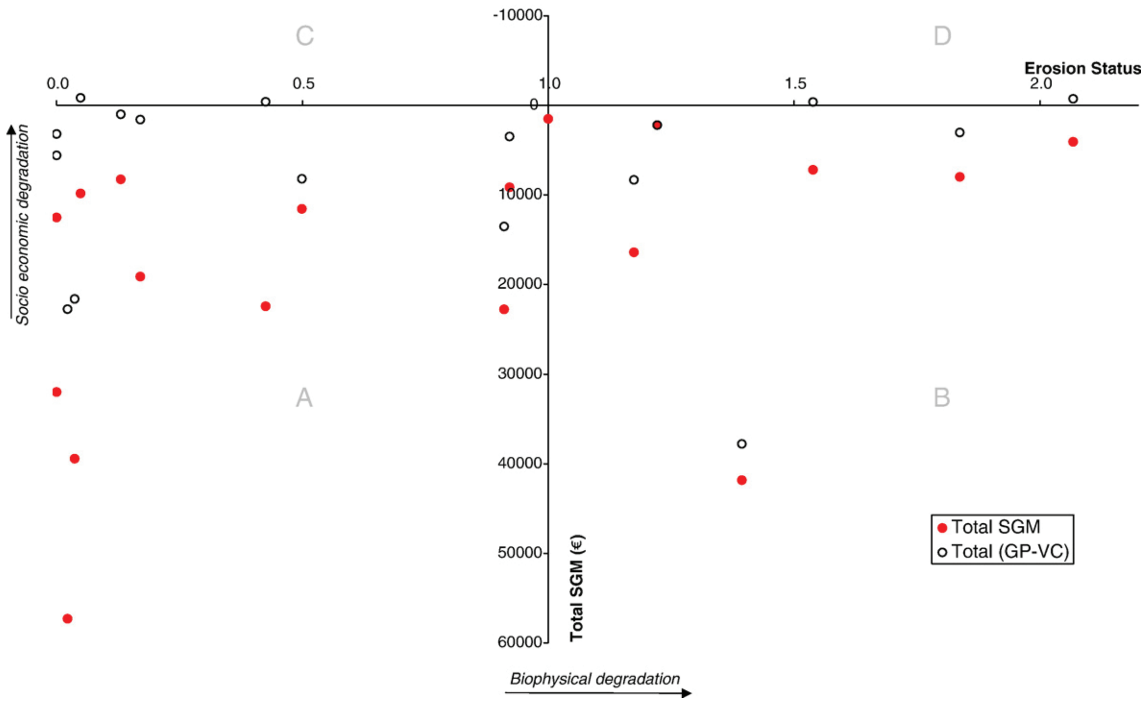

Fig. 5. Socio-ecological space for cultivators: household's total SGM and non-subsidised profit (GP−VC) as a function of average erosion status of agricultural land parcels.

the highest values found in Central Macedonia in 2005, which may lead to an overestimation when applied to all households of our sample. Secondly, many farmers declared that an accountant fill their CAP declarations. Their responses during the interview may thus be biased. Below, we used data on the subsidies from the agricultural services, except for olive oil and tobacco. For these two crops, we used, respectively, computed values based on production data and data collected during the field interviews.

4. Results

4.1. Farmers' profit versus land degradation

The distribution of households in the socio-ecological space for cultivators and livestock-breeders shows a strikingly similar pattern (Figs. 4 and 5). Farms with a low total SGM are distributed along the biophysical axis on both sides of the biophysical threshold. Households

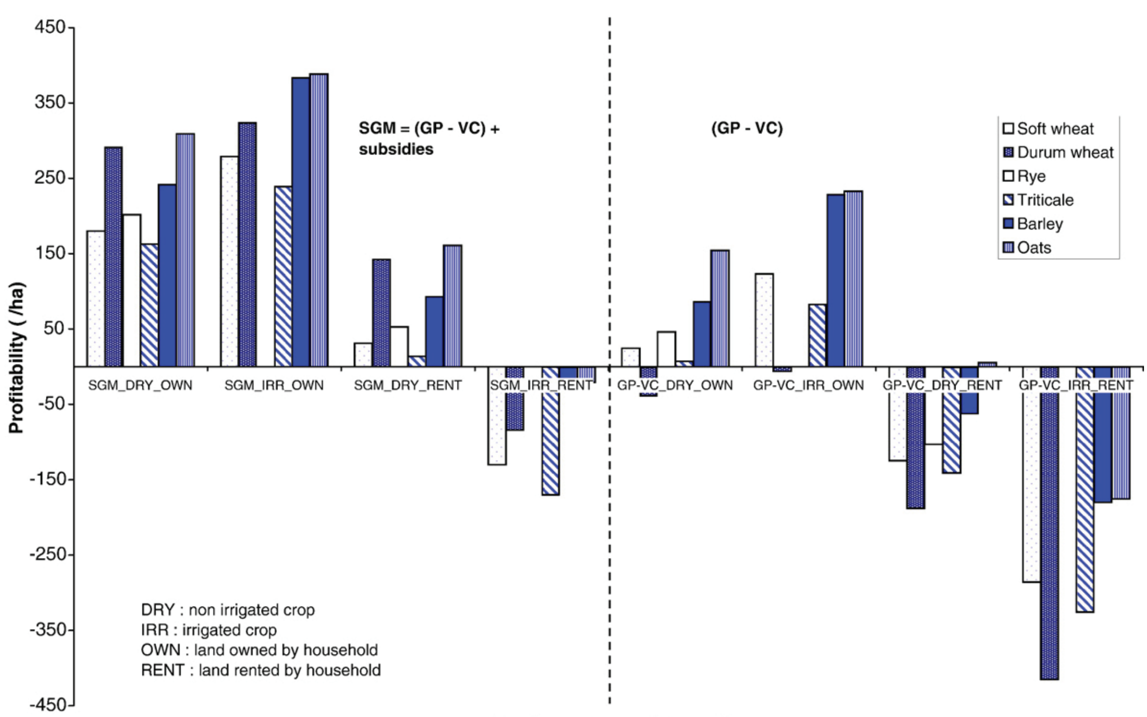

Fig. 6. SGM and (GP−VC) for cereals in the Lagadas study area in 2005 (in €/ha, agricultural indices from Central Macedonia agricultural service).

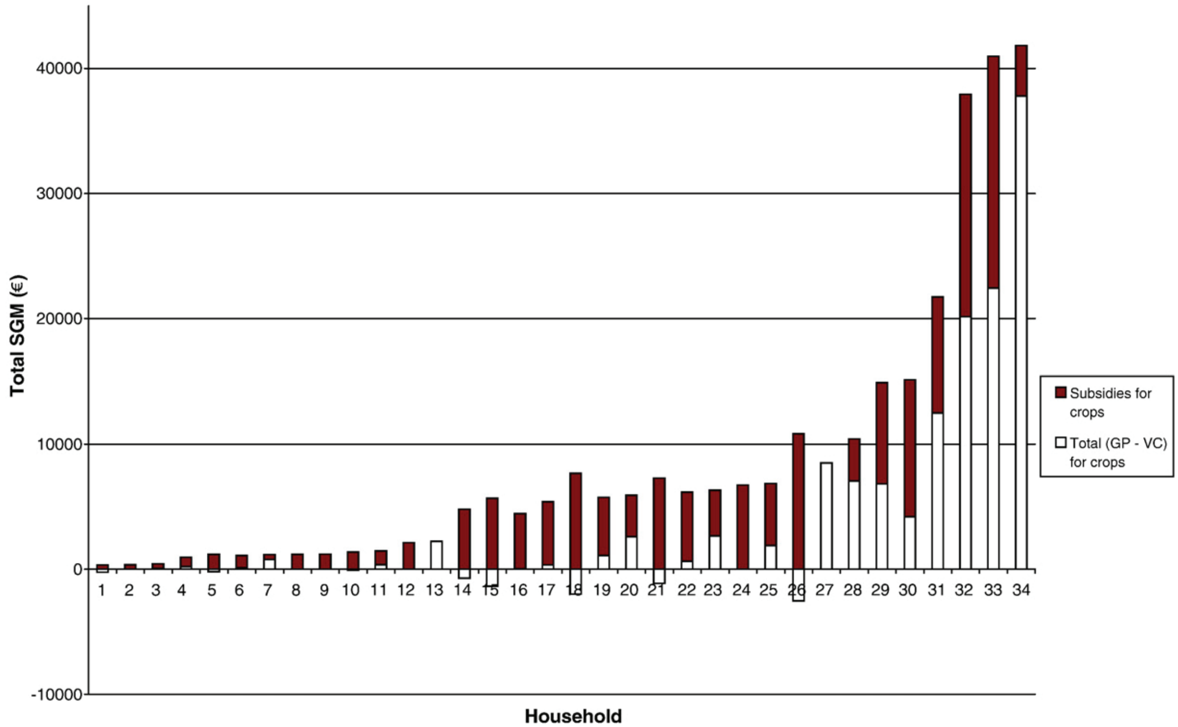

Fig. 7. Total SGM and direct subsidies per household for crop production.

with a high profit are mostly in the region with no (or very little) biophysical degradation. Cultivators with the highest total SGM mostly own plots with low erodibility values, while households with a low total SGM are evenly distributed along the biophysical degradation axis, with low to moderate soil erosion. The same conclusion can be made when average slope of cultivated plots is used as a proxy for erosion instead of average erosion status. Low-profit stockbreeding households show both negative, neutral and positive vegetation cover trend values. Livestock breeders with high SGM are all associated with a positive average vegetation cover trend.

For both cultivators and stockbreeders, the sustainable quadrant (A) includes all levels of total SGM. All households with a high profit are in this quadrant. Households with a medium or low total SGM are found in quadrant B. When subsidies are included in the SGM of households, none has a negative profit (quadrants C and D). The position in this graph of the total SGM values after subtraction of subsidies (total (GP−VC)) is very informative. In the absence of subsidies, 22% of the cultivators and 27% of the stockbreeders, including all the goat breeders, would have a negative profit, i.e. would loose money through their activities (Figs. 4 and 5). Without subsidies, half of these cultivators would shift from quadrants A to C, while the other half would shift from quadrants B to D. All the stockbreeders with negative total (GP−VC) are found in quadrant D, which represents a degraded state.

4.2. Influence of subsidies on crop SGM

Subsidies and land ownership have a significant influence on SGM for cereals (Fig. 6). Most of the cereals have a negative or almost null SGM when they are cultivated on irrigated land that is not owned by the farmer. Actually, the rental price of an irrigated field is much higher (409.3 € ha^{-1} yr^{-1}) than for a non-irrigated field (149 € ha^{-1} yr^{-1}). As a result, land ownership has a greater influence on crops with a low SGM. Without subsidies, cereals are no longer profitable when land is rented. SGM of maize for grain production, which is always irrigated, is also highly influenced by subsidies and land ownership. Tobacco is a highly subsidised crop.

Subsidies have a lower influence on the SGM of olive trees. This production would still generate profits if production subsidies were suppressed. Given the high interannual variability in yields for olive trees, we did not consider the SGM values computed from agricultural indices. Instead, we used the production per household in olive oil and table olive from the survey to compute total SGM for this crop. Unlike for the other crops, subsidies for olive trees are linked to oil production

Table 1
Average gross production (GP), variable costs (VC), subsidies and standard gross margin (SGM) for sheep and goat production (€/head of livestock)

	Mean gross production (€/head)	Mean variable costs (€/head)	Mean subsidies (€/head)	Mean standard gross margin (€/head)
Productive sheep	142.06	67.24	21.53	96.39
	S.D. = 63.81	S.D. = 8.64	S.D. = 8.79	S.D. = 71.70
Productive goats	80.74	64.39	19.97	37.65
	S.D. = 35.16	S.D. = 1.80	S.D. = 8.06	S.D. = 40.99
Non productive adult sheep	1.30	38.56		−37.25
	S.D. = N.A.	S.D. = 4.62		S.D. = 4.62
Non productive adult goats	1.50	36.98		−35.48
	S.D. = N.A.	S.D. = 0.99		S.D. = 0.99
Young sheep				
a. slaughtered animals	54.00	16.00		38.00
	S.D. = N.A.	S.D. = N.A.		S.D. = N.A.
b. replacement animals	1.30	9.55		−8.25
	S.D. = N.A.	S.D. = 0.77		S.D. = 0.77
Young goats				
a. slaughtered animals	57.00	16.00		41.00
	S.D. = N.A.	S.D. = N.A.		S.D. = N.A.
b. replacement animals	1.50	8.70		−7.21
	S.D. = N.A.	S.D. = 0.14		S.D. = 0.14

SGM = GP − VC + subsidies.
S.D.: Standard deviation.
N.A.: data not applicable.
Household exclusively occupied by sheep production: 12.
Household exclusively occupied by goat production: 4.
Mixed sheep/goat production: 1.
Mixed sheep/cow production: 1.
Mixed goat/cow production: 1.

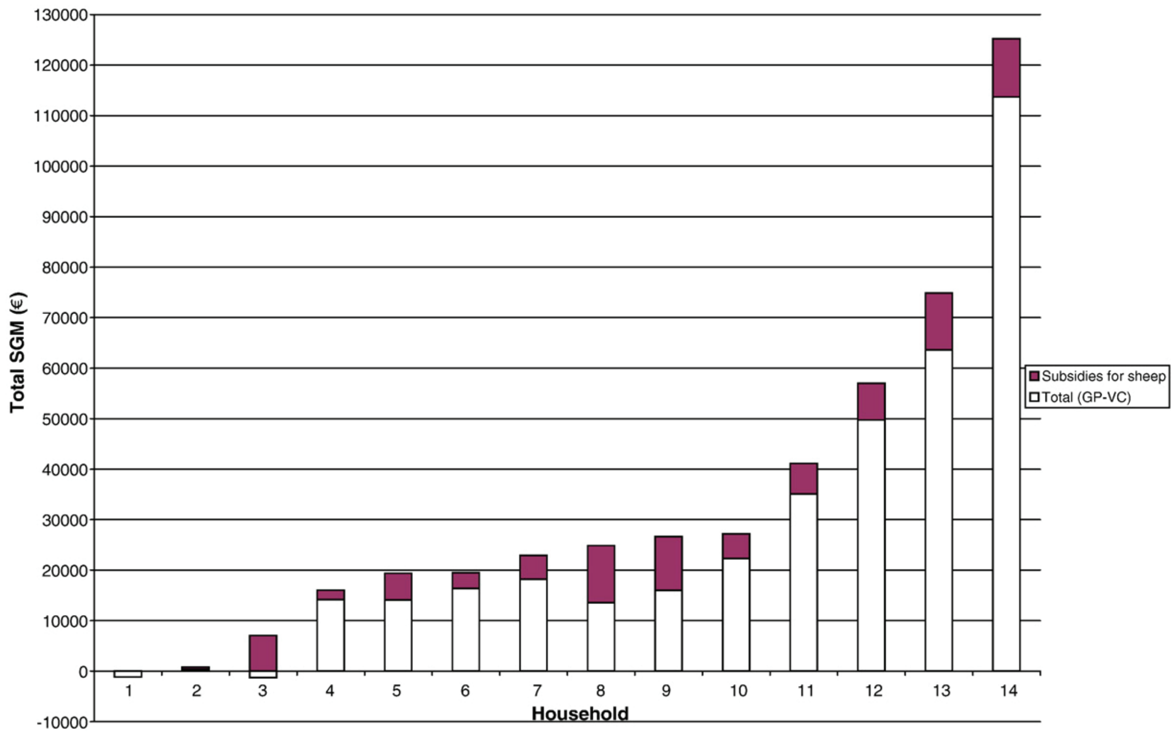

Fig. 8. Total SGM and direct subsidies per household for sheep breeding.

instead of cultivated area. For vegetable and fruit productions that are not subsidised (except for industrial tomatoes), SGM is equal to (GP−VC) and is always positive. The profitability of these productions is generally not much influenced by land ownership. Carrots and pumpkins generate very high profits (up to 20,000 € ha^{-1}). These productions are often exported and the absence of subsidies may have allowed these crops to reach market equilibrium. Note however that these crops are highly labour-intensive, which is not integrated into the SGM as computed under the European Commission recommendations (2003).

The total SGM for crop production in our sample is highly variable between farms, with three levels of profit: up to €2000, from €2000 to €8000, and more than €8000 (Fig. 7), according to Eurostat (2003) farm size typology. This reflects different economic sizes of households (defined as total SGM expressed in European Size Unit or ESU: 1 ESU = 1200 € in 2005). Subsidies represent a very important fraction of the total profit of agricultural households (up to 100% in some cases, and at least 9% of the profit). In a few cases, they allow households to reach a positive profit when variable costs exceed gross production.

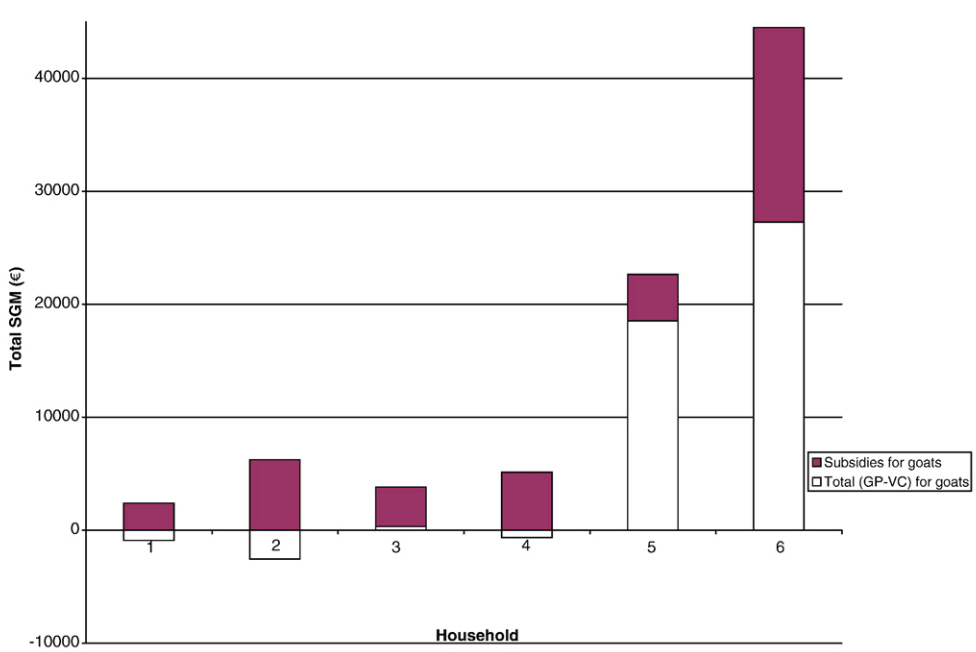

Fig. 9. Total SGM and direct subsidies per household for goat breeding.

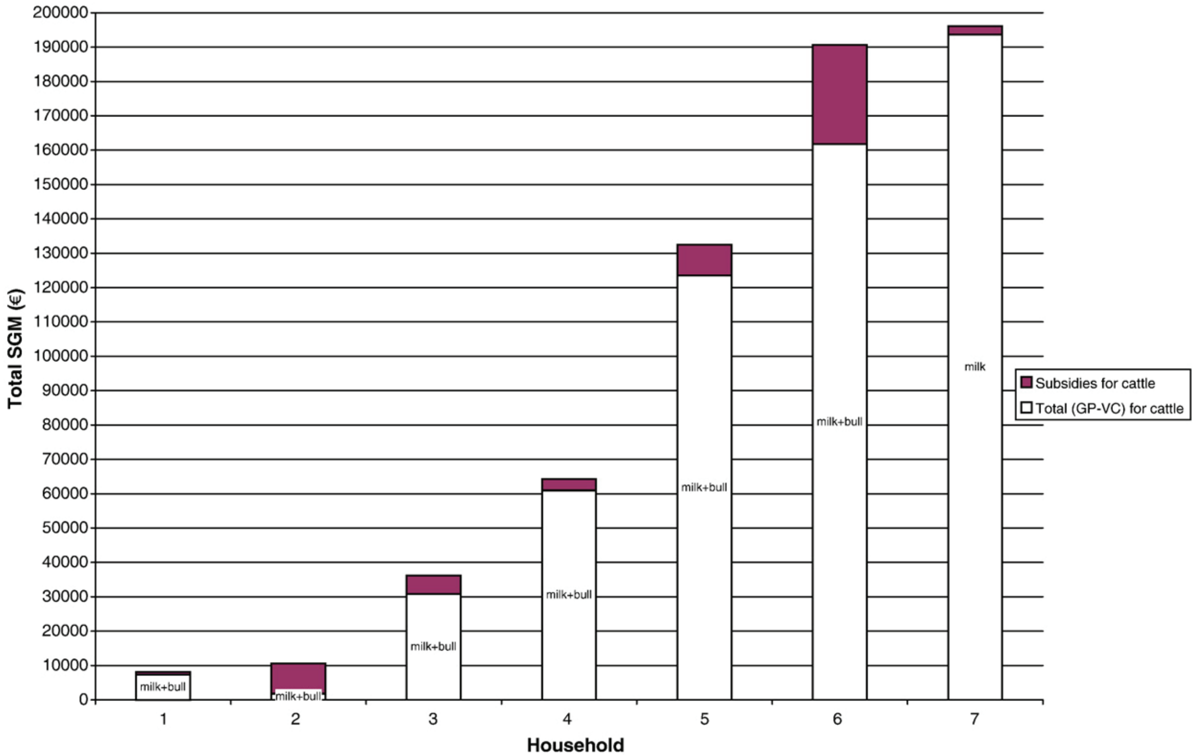

Fig. 10. Total SGM and direct subsidies per household for cattle breeding.

4.3. Influence of subsidies on animal production SGM

In our sample, direct subsidies for sheep and goats represent, respectively, 21% and 53% of the SGM of these animal productions (Table 1). They form a very significant part of the profit of some households (Figs. 8–10). This is especially true for goat production (Fig. 9), which has a much lower gross production than sheep, partially due to a much lower price of goat milk. In our sample, subsidies are proportionally less important for cattle (9% of total SGM, Fig. 10 and Table 2) than for sheep and goats. However, they are much larger for bulls than for dairy cows, whose profitability is high due to high milk production and high milk price guaranteed through the CAP quota system. Furthermore, subsidies for new exploitations can stimulate the start of new cattle farms, with low initial milk production.

5. Discussion

The projection of households in the socio-ecological space suggests two interpretations. Firstly, a low total SGM is not systematically associated with land degradation. The dispersion of low-profit households along the biophysical dimension may be explained by initial farming conditions (e.g., by inheritance of land of a certain quality). Secondly, the low values of the degradation index for households with a high total SGM suggest that higher profits facilitate the adoption of more intensive practices. Data show that these households use land parcels or rangelands with a low slope and thus a low erosion risk. By contrast, households with less profitable agricultural activities are not able to acquire or rent land of higher quality. They would therefore be more likely to exploit marginal land parcels or, in the case of stock-breeders, to let their animals graze on steeper, more fragile or smaller rangelands. The integration of the socio-economic and biophysical dimensions of land degradation reveals these associations that would not be detectable if indicators along one dimension alone would be used. It suggests that “degradation”, as indicated by a position in quadrant D in Fig. 2, is better measured by combining socio-economic and biophysical indicators.

The profitability of most crop and livestock productions is greatly influenced by CAP subsidies, as defined by Greece in 2005 before the implementation of the 2003 reform. Whilst horticultural production receives almost no financial support, grazing livestock, cereals and tobacco benefit from large subsidies. Extensive goat grazing activities, which have a significant environmental impact on rangelands, especially benefit from subsidies and would not be profitable in their absence. While indirect subsidies, linked to the number of heads of animals, increases profitability of grazing livestock, the so-called “compensation subsidy” creates an incentive for stock breeders to

Table 2
Average gross production (GP), variable costs (VC), subsidies and standard gross margin (SGM) for cattle production (€/head of livestock)

	Mean gross production (€/head)	Mean variable costs (€/head)	Mean subsidies (€/head)	Mean standard gross margin (€/head)
Dairy cows	1945.86 S.D. = 709.89	821.04 S.D. = 55.49	19.27 S.D. = 19.52	1144.09 S.D. = 676.88
Calves for replacement	9.6 S.D. = N.A	281.76 S.D. = 20.05	288.06 S.D. = 16.93	−259.19 S.D. = 31.00
Bulls	186.67 S.D. = N.A	687.74 S.D. = 49.70	496.62 S.D. = 749.31	−4.45 S.D. = 749.00
Calves for replacement	186.67 S.D. = N.A	286.98 S.D. = 18.28	21.29 S.D. = 20.56	−79.02 S.D. = 32.75
Heifers	38.4 S.D. = N.A.	326.15 S.D. = 7.39	8.79 6.05	−278.96 S.D. = 13.10
Slaughtered calves	200 S.D. = N.A.	4.00 S.D. = N.A.	4 S.D. = N.A.	196 S.D. = N.A.

Household exclusively occupied by cattle production: 5.
Mixed sheep/cow production: 1.
Mixed goat/cow production: 1.
Suckler cows were not taken into account due to poor quality data.

reach a rather large flock size to maximize the value of this subsidy. The use of concentrated fodder, which started in the late 1970s, helped stock breeders to decouple their production from natural resources on which they were formerly dependent. Nonetheless, concentrated fodder represents the most important cost for farmers. They can minimize this cost by developing leys in shrubland or on formerly abandoned agricultural land, whose area is included in the calculation of compensation subsidies. Restricted access to the market may be another limiting factor for poor households. The concentration of markets in Thessaloniki, and the limited number of input resellers and of opportunities for selling their output, increase the dependency of farmers on these market structures.

SGM measures the profitability of agricultural activities and total SGM gives the profit that farmers get from these activities. The use of total SGM has a few drawbacks. First, a negative total SGM suggests that agricultural households are losing money by farming, not taking into account other possible sources of income. This is unlikely to happen, except in the case of temporary situations such as bankruptcy or new exploitations that are being launched. Secondly, total profit is computed for the whole household or farm and should therefore be related to its labour units. Thirdly, farming activities generate other costs and income (e.g., overhead costs, labour costs, taxes, depreciation, investments and subsidies on investments) that cannot be integrated into SGM. Using family farm income instead of SGM would reflect the global income of each household unit working on the farm, by including variables absent in SGM. It requires however collecting more household-level data.

We aggregated vegetation cover classes in order to use vegetation cover trend only. However, this trend does not have the same ecological meaning in areas with a high versus medium or low vegetation cover (Platis and Papanastasis, 2003). An increase in high and dense vegetation cover areas can be interpreted as a loss of potential forage and biodiversity (Platis and Papanastasis, 2003; Papanastasis and Chouvardas, 2005). Nevertheless, as the grazing areas mapped for stockbreeders covered mainly medium and low vegetation cover classes, this aggregation is unlikely to influence our results on rangeland degradation.

The combined use of georeferenced household-level land-use data, remote sensing products, and standardised socio-economic data has several advantages. It allows linking directly households, which are the main decision units for land-use change, to land degradation. The collection of georeferenced household and land-use data through field surveys is a labour-intensive task, however. Standardised socio-economic databases and agricultural indices make the complete analysis of household profit and income possible. The framework proposed by Fernandez (2002) links explicitly socio-economic and biophysical conditions associated with land degradation. Characterizing households based on quantitative socio-economic and biophysical metrics may be useful for policy-makers and field operators aiming at combating land degradation. This information may contribute to better define target groups for their actions and to design the most suitable ecological and socio-economic remediation actions. A next step for this research would be to apply panel analysis based on longitudinal household-level data to plot temporal trajectories of households in the socio-ecological space. Note that the use of SGM as a socio-economic metric is restricted to market-oriented agricultural economies, where reliable statistical socio-economic data are available.

6. Conclusion

In marginal European regions such as Lagadas, subsidies distributed as part of the Common Agricultural Policy (CAP) ensure the profitability of crop and livestock productions for the majority of farmers. For some of the poor farmers, these subsidies may also create a perverse incentive to degrade land. Actually, subsidies maintain low-profit farmers into extensive farming activities on the most erodible, steep-sloped land. By partially delinking agricultural income from environmental conditions and degradation, they artificially ensure the persistence of land uses poorly adapted to the biophysical conditions of the region. Subsidies buffer farm income from land degradation. Boody et al. (2005) also reported that farm commodity payments in the US encourage low-profit production that increases government costs and environmental damages. In this study, subsidies have most notably stimulated the increase of grazing pressure by goats, one of the most heavily subsidised productions. The results suggest that subsidies did not encourage the rich farmers to overexploit land. To the contrary, richer farmers are most able to intensify by relying on external inputs, e.g. by buying external feed for livestock, but also to acquire the land parcels of higher quality.

The recent reform of the CAP includes a decoupling of subsidies from agricultural production: payments should be based on the past production of the farm and conditioned to the compliance to food safety, animal welfare and environmental constraints. This has been implemented in Greece in 2006–2007, thus after our survey. It is likely to provoke land-use changes by modifying incentives for some productions and management practices. With this new support scheme, also referred to as single farm payment, market signals should have more influence on production decisions by farmers. The impacts of this policy change on land use and land cover, and on poor farmers with a low adaptation capacity to a more competitive context, are difficult to predict.

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