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Socio-ecological and nutritional benefits of traditional mountain sheep grazing

Eneko Garmendia, Aitor Andonegi, Arantza Aldezabal, Gonzalo Gamboa, Iker Etxano, Oihana Garcia, Luis Javier R. Barron

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Abstract

Rural landscapes in Europe are changing due to the globalization of the food system, new policies like the CAP (Common Agriculture Policy) and evolving rural lifestyles, among others. These changes are remarkable in mountain areas where traditional activities that contribute to food sovereignty are threatened by industrial production systems. In this context, it becomes critical to assess the socio-ecological and nutritional benefits of traditional food systems like extensive sheep grazing in order to ensure their contribution to a sustainable food system. Using as a case study Aralar (Basque Country), this article analyzes the contribution of traditional mountain sheep grazing to rural development, the provision of high quality food and biodiversity conservation. With this aim we develop a multi-criteria evaluation system that integrates socio-economic (e.g. employment, added value, profitability) and ecological (e.g. biodiversity conservation, soil quality) indicators. This evaluation system allows the assessment of future scenarios from multiple perspectives and contributes to better understand the performance of this complex socio-ecological system under global and local changing conditions.

Keywords: Sustainability; multi-criteria evaluation; sustainable food system; livestock grazing; mountain areas; rural development; biodiversity; food quality.

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1. Introduction

In the time of globalization, where the link between animal production areas and food producing areas is becoming weaker (Naylor *et al.*, 2005), recent studies highlight the capacity of ruminants to ensure a sustainable food system which could be beneficial, not only for human health, but also for the health of the planet (Eisler *et al.*, 2014). Likewise within the sustainable development agenda efforts to improve social, environmental, ecological conditions in agro-pastoral systems, including initiatives contributing to animal healthcare, are increasing notably.

In this regard a well managed extensive livestock grazing system can encompass an appropriate production system to ensure sustainable food production sustainability. In addition to the benefits associated with the production of high quality food, these systems contribute to the conservation of biodiversity, enhancement of ecosystem services associated with the grazing, the promotion of the local economy and other socio-cultural benefits (Odriozola, 2016).

In terms of environmental benefits, extensive livestock grazing reinforces the spatial heterogeneity of mountain pastures, improving the landscape and botanical diversity (Adler *et al.*, 2011). On the same way, it ensures a stronger ecological stability against climatic changes (Volaire *et al.*, 2014), providing an effective adaptation mechanism (Kreyling *et al.*, 2012). The changes that happen on the upper side of the soil also benefit the subsoil, as grazing has a direct impact on the development of the underground parts of the plants (Wardle, 2005). In this regard, the grazing management is also important for microbial communities and contributes to processes that condition the production of mountain pasture systems, such as decomposition and recycling of nutrients and nitrogen fixation. Moreover, those communities regulate nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) emissions at soil level. In the case of stomach methane, they are also able to regulate it, depending on the botanical composition of pastures (Hopkins and Del Prado, 2007).

Last but not least, in socio-economic terms, the relevance of extensive grazing systems in the primary sector (Malagón, 2009) has been associated with the conservation of traditional heritage and the consolidation of local population in territories that suffer demographic decline (Corbera, 2006).

Despite all these benefits for society and the environment (Bernúes *et al.*, 2011; Godber and Wall, 2014), nowadays extensive livestock grazing is at risk in Europe in general and in Cantabrian Mountains in particular and strongly conditioned by the intensification of the sector (Rounsevell *et al.*, 2006). Just to give an example, in Spain between 2000 and 2007 the number of sheep farms fell by 26%, while the number of sheep fell only by 10,4%, showing the strong intensification of the sector (Bernúes *et al.*, 2011).

The last Common Agriculture Policy (CAP) includes some subsidies for the livestock sector including extensive sheep farming (European Commission, 2013). However, the main challenges that threaten the sustainability of the extensive sheep grazing system in the Cantabrian Mountains and the Basque still persist. Scarce communication channels among the stakeholders and shepherds; lack of social recognition; conflicts with activities like biodiversity conservation or tourism, hard working conditions; infrastructure deficits and a regulatory framework that does not take into account the real needs of the sector, are just some examples (HAZI, 2016). The lack of economic viability and increasing decline of rural areas are also reflected in the abandonment of numerous farms (Bernúes *et al*., 2011; Leizaola, 1999).

In the Atlantic part of the Basque region, sheep farming is also witnessing a similar trend but to a lesser extent. In this territory, the extensive livestock grazing of ruminant animals is still active (mainly sheep production), due to the rugged orography of the Basque Mountains, and has a strong link with territorial identity (Batalla, 2015). An example of this is the local Idiazabal cheese production, awarded worldwide, which is produced with the milk of the local sheep breed, the *Latxa* sheep (Batalla, 2015). 59% of these cheese is still produced by shepherds in farms (EUSTAT, 2013) which still practice the traditional transhumance, connecting the farms used in winter, which are in lower altitudes, with the nearby mountainous areas grazed in an extensive way in summer (Mendizabal, 2009; Odriozola, 2016). In this context, the present article analyses the socio-ecological and nutritional benefits of sheep grazing using as a case study the Community of Enirio-Aralar (Basque Country). More precisely, through a multi-criteria evaluation framework in this study we assess the performance of different livestock systems (e.g dairy and cheese producers), at farm and landscape level based on socio-economic, ecological and nutritional indicators.

2. Material and methods

2.1. Study area

The study area is located in the Aralar Natural Park (Gipuzkoa, Basque Country), a Special Area of Conservation (SAC) part of the European Natura 2000 network. With a surface of 11000 ha and an oceanic climate, it has a mean annual temperature of 12,4ºC and a mean annual precipitation of 1400 mm. The vegetation in the park comprises a mosaic of gorse-heather shrublands and grasslands that supports livestock, mainly 18000 dairy sheep of the *Latxa* breed. The area traditionally used by livestock (dairy sheep, beef cattle and horses) from May to the end of October has a surface of 2077 ha, which encompasses the 18,9% of the park area. This area is dominated by native grasslands included in the Habitat Directive, being the most relevant one the *Jasiono-Danthonietum* grassland (code 6230, subtype a), primarily comprising perennial graminoids such as *Festuca rubra, Agrostis capillaris* L. and *Luzula campestris* (L.)DC and herbaceous dicotyledons such as *Galium saxatile* L., *Trifolium repens* L. and *Cerastium fontanum* Baumg. (Aldezabal *et al*., 2015; Mendizabal, 2009; Odriozola *et al*., 2014). Unlike most of the Atlantic mountain pastures, the livestock load of Aralar has remained almost stable over the past decade (Aldezabal *et al.*, 2014).

2.2 Livestock farms: definition and different typologies

There are two main types of livestock farms in the study area: production and reproduction farms and farms related to pastures. In the first case, animals are fed and maintained with the aim to obtain economic gain or to direct them to familiar consumption. In the second case, livestock is grazed in pastures in order to take advantage of natural or planted productions.

Focusing on the production and reproduction farms, there are 4 different typologies in the Community of Enirio-Aralar (for more information about different typologies see Appendix 1):

- **Cheese-maker shepherds.** They have *Latxa* sheep and their main source of income comes from the sale of cheese, which is sold directly to consumers, in local markets and or in the farm itself. Some of them also sell a share of their cheese production through cooperatives. Under this typology only a little additional income comes from milk, lamb and/or livestock selling.

- **Milk producer shepherds**. They have *Latxa* sheep and their main source of income comes from milk production, which is sold mainly to cooperatives. Other sources of income include: cheese, lamb and livestock selling.

- **Cattle rangers.** There are just a few professional cattle rangers, while most get complementary income from this activity. Meat is sold to slaughters in the region.

- **Horse rangers.** Only obtain small complementary income. They have mainly mares and some horses and the small income they obtain comes from livestock selling.

2.3 Definition of scenarios

Livestock load (sheep, cattle and mare load) is the main feature that has been taken into account in order to design the different scenarios and also to assess current and alternative distributions of that load. In addition, following Massam's (1988) suggestion, we also consider the *Business as Usual*, the ideal and worse scenario as well as other hypothetical situations located between these two extremes to define the scenarios. Following these criteria we designed the following scenarios:

I. *BAU* (*Bussiness As Usual*): this scenario represents the current situation with 17260 sheep, 853 beef cattle and 742 mares distributed along the entire study area . These numbers have been taken from the 2016 pasture census.

II. *BYE-Grazing*: the scenario without livestock, which simulates grazing abandonment.

III. *MIX-Up*: this scenario simulates the grazing abandonment in the higher remote altitudes of the Community. Estimated livestock quantities: 11480 dairy sheep, 817 beef cattle, and 293 mares.

IV. *MIX-Down*: This scenario simulates the grazing abandonment of the lower altitude pastures of the Community. Estimated livestock quantities: 5369 dairy sheep, 36 beef cattle and 385 mares.

In the case of the MIX scenarios, cattle and mare spatial distribution has been taken into account, using the data and the digital cartography obtained by Mendizabal (2009), who studied the habitat use of these animals following them "*in situ*". Based on that data, beef cattle and mare spatial distribution has been obtained by a Kernel density map (see Appendix 2) done with public domain software called *Quantum Gis* 2.12. Once identified the higher density of these animals in the upper and lower areas of the Community, two polygons were built in order to determine the surface of those areas. Finally, the specified number of beef cattle and mares in each polygon was determined. With regard to sheep, there was not accurate information about their habitat use, so the data that has been used is the number of sheep linked to shepherd cabins. With the aim to simulate the spatial distribution of dairy sheep, the digital cartography of pastures has been used.

2.4 Multi-Criteria Evaluation (MCE) frameworks

The aim of the MCE framework is to simplify and structure complex decision-making problems in a systematic way (Proctor and Drechsler, 2006). This framework can be helpful as a decision aid tool to in context characterized by high degrees of complexity where confronted interest and values coexist (Munda, 2004, 2008). The origin of MCE lie in the fields of mathematics and operational research, however in recent years it has been widely used in the context of natural resource management and other sustainability related issues, such as renewable energy (Gamboa and Munda, 2007), hydrological resources (Paneque *et al.*, 2009), coastal management (Garmendia *et al.*, 2010); mining (Walter *et al.*, 2016) or protected area planning (Etxano *et al.*, 2015).

Briefly speaking, when using MCE frameworks, firstly the relevant dimension and indicators need to be identified ideally with the help of all the relevant social actors and then an impact matrix is built to evaluate the scenarios according to these criteria and indicators. In this case, socioeconomic, ecological and nutritional indicators have been considered. Further details of the methodology used in this study can be found in Munda (2004 and 2008).

2.4.1 Socioeconomic indicators

The socioeconomic indicators have been evaluated at farm and landscape level according to the data collected for twelve farms (for five cheese-maker farms, two milk producers and six beef cattle farms) and during three years (2013, 2014 and 2015) by Lurgintza, a livestock farmers' association. Horse rangers are not professional and in this case we have not been able to collect reliable data associated with their activity. Therefore, due to the lack of data and their small contribution in socio-economic terms the contribution of these farmers in socio-economic terms has been omitted from the analysis.

A more detailed description of each socio-economic indicator is provided bellow:

- **Net margin per family Agrarian Work Unit (AWU)** (at farm level): the difference between incomes and costs of the farm per family AWU.

- **Total net margin** (at landscape level): the net margin taking into account the total livestock load of the Community.

- **Added value per Livestock Unit (LSU)** (at farm level): the addition of net margin, including salaries and value-added after tax, per LSU.

- **Total added value** (at landscape level): the added value taking into account the total livestock of the Community.

- **Employment** (at farm level): the number of employees working full time during a year.

- **Total employment** (at landscape level): employment taking into account the total livestock load of the Community.

- **Economic productivity of employment** (at farm level): the division of gross margin and employment (production per employee).

- **Dependency of subsidies** (at farm level): the division of subsidies and net margin.

- **Total dependency of subsidies** (at landscape level): dependency of subsidies taking into account the total livestock load of the Community.

2.4.2 Ecological indicators

Taking into account the scale of these indicators, to obtain the score of this indicators we consider the landscape level. Data was obtained thought a literature review of peer review articles and other relevant scientific sources like PhD. thesis and technical documents elaborated for the corresponding authorities. Building upon this information the scores for each indicator has been calculated using QGIS and the surface of dense grassland.

These are the ecological indicators that have been considered (for more information about the calculus of each indicator see Appendix 3):

- **Plant species diversity in dense grassland (S)**: number of plant species in dense grassland (Odriozola, 2016).

- **Nitrogen content in dense grassland (pasture forage quality)**: Nitrogen tones in dense grassland (Odriozola *et al.*, 2014).

- **Soil microbial metabolic quotient (qCO_2)**: Soil microbial CO_2 emissions per microbial biomass (Aldezabal *et al.*, 2015).

2.4.3 Impact matrixes and spider diagrams

Once indicators have been selected, the next step is to build an impact matrix. The aim of an impact matrix is to evaluate each scenario with the selected indicators. These indicators can be quantitative or qualitative and they can be measured in different units (€, tones, jobs etc.), both important features to deal with sustainability related issues and incommensurability of values (Martinez-Alier *et al.*, 1998).

In this paper two impact-matrixes have been built: (i) one related to private farms (with socioeconomic indicators) and (ii) the other one related to the scenarios simulated for landscape level (integral evaluation).

In this case for the graphical representation of the impact matrix spider diagrams have been used. Each indicator has a different scale, so in order to normalize these differences the values of each indicator have been rescaled to a scale that goes from 0 to 10. The best value in each indicator got 10 points, and the other scores were calculated basing on that relationship. In the case of plant species diversity indicator, the best value obtained 10 points, the worst 0 and 5 the ones that were between the previous two.

In spider diagrams an increase in the areas indicates a positive influence, but there are two indicators in which to get a higher value is considered negative. That is the case of dependency of subsidies and microbial CO_2 quotient. In order to correct that, in the case of dependency of subsidies, it has been done a subtraction of the possible biggest value (1) and the value obtained in each case. Regarding microbial qCO_2, the subtraction has been done between the higher value obtained and the value obtain in each case.

3. Results and discussion

3.1 Farm level evaluation and comparison

The following impact matrix (Table 1) summarizes the scores obtained by each of the farm typologies (CS: Cheese-maker shepherds; MS: Milk producer shepherds; BCR: Beef cattle rangers) according to the selected set of indicators.

Table 1. Impact matrix at farm level.

Dimension	Indicator	Unit	Preferred direction	CS	MS	BCR

Socioeconomic	Net margin per family AWU	€/AWU	Max (↑)	28.390	22.650	12.900
	Added value per LSU	€/LSU	Max (↑)	765	705	600
	Employment	AWU	Max (↑)	2,083	1,417	1,694
	Employment economic productivity	€/AWU	Max (↑)	27.940	26.300	16.990
	Dependency of subsidies	%	Min (↓)	0,502	0,772	1,9

As it can be seen in the spider diagram below (Figure 1), the cheese-makers are the ones getting the best scores in all the selected indicators, mainly due to their profitability and higher contribution to employment.

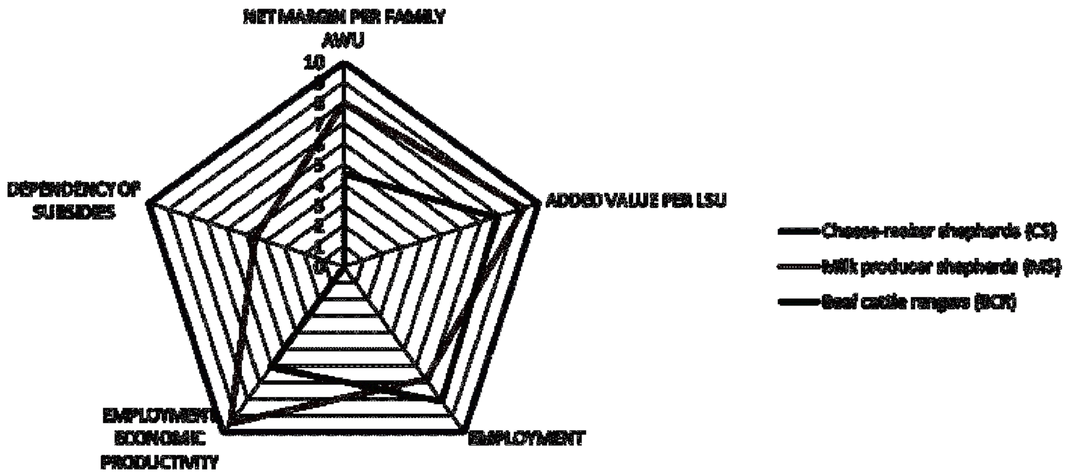

Figure 1. Representation of socio-economic indicators at farm level.

In the case of net margin, the most relevant factors contributing to this indicator are profits and total costs. Focusing on the costs, cheese-maker shepherds are the ones that have higher costs compared to the other typologies (cheese-makers 74.706,42 €; milk producers 43.865,03€ and beef cattle rangers 68.070,64 €), but in terms of profit, the cheese-makers earn more than double compared to the others (cheese-makers 101.383,37€; milk producers 47.209,51€ and beef cattle rangers 44.573,59 €), without counting subsidies. Consequently, cheese-makers get a better value than the rest of farms.

In terms of employment the cheese-makers also obtain the best scores (cheese-maker shepherds 2,083 AWU; milk producer shepherds 1,417 AWU and beef cattle rangers 1,694 AWU) reaching also the highest productivity in terms of income per person employed.

With regard to subsidies dependency, cheese-makers are the ones again getting the best score. In contrast, beef cattle rangers are the ones that have highest dependency, with more than 44.000 € per farm in average. In the case of milk producer shepherds, the amount of money they receive from subsidies is quite similar to cheese-maker shepherds’ on average (cheese-makers receive 25.845,01€ and milk producers 28.745,62€). In relative term, if we compare the subsidies with the net margin of each typology cheese-makers show the best performance (0,502) followed by milk producers (0,772) and beef cattle rangers (1,9).

3.2 Landscape level evaluation and the comparison of scenarios

In this section, landscape level values are presented for all the designed scenarios (BAU, BYE-Grazing, MIX-Up and MIX-Down), which have been summarized using an impact matrix (Table 2). BG: BYE-Grazing; *Score for upper pastures; **Score for lower pastures.

Table 2. Impact matrix at landscape level.

Dimension	Indicator	Unit	BAU	BG	MIX-Up	MIX-Down
Ecological	Plant species diversity	Number of species	32,33	25	25*/32,33**	32,33/25
	Nitrogen content	Tones	106,04	86,69	99,06	98,46
	Microbial qCO_2	$\frac{mg\ CO_2\ h^{-1}}{mg\ mikro\ C\ kg^{-1}\ h}$	$1,38\cdot10^7$	$1,78\cdot10^7$	$1,53\cdot10^7$	$1,54\cdot10^7$
Socioeconomic	Total net margin	€	1.994.096	0	1.261.753,64	551.662,167
	Total employment	AWU	90,28	0	65,84	22,77
	Total added value	€	2.281.301	0	1.615.702,78	619.277,96
	Total dependency of	-	0,660	0	0,778	0,441

	subsidies					

BAU is the scenario that gets the best scores in most of the indicators selected for the evaluation, both in the socioeconomic and ecological indicators (see Figure 2 and Table 2).

Within the ecological dimensions, highlights the fall of plant species diversity that would take place if grazing activity would disappear (7,33 units from BAU scenario to BYE-Grazing scenario). In the case of both MIX scenarios, taking into account that grazing abandonment has been simulated in different areas, each of them shows different values. These results clearly show the negative influence of grazing abandonment in the floristic composition of the pasture. In that sense, Milchunas and Lauenroth (1993) showed that in non-grazing conditions, relative proportion of graminoid species increases and that dicot species decrease, especially those species of Fabaceae family. Similar results have been observed in other studies too (Aldezabal *et al*., 2015; Odriozola, 2016).

That indicator has a direct relationship with nitrogen content indicator. In fact, forbs have a higher nitrogen content compared to graminoids (Semmartin *et al*., 2004), so if the relative proportion of forbs decreases, a fall of nitrogen content can be expected. The results obtained in this study confirm that hypothesis. All non-grazing simulating scenarios suffer a decrease of nitrogen content compared to BAU scenario, with the highest fall in BYE-Grazing scenario.

Regarding microbial qCO_2, all the non-grazing simulating scenarios had an increase in their values compared to BAU scenario: BYE-Grazing increased a 29,10%; MIX-Down a 11,41% and MIX-Up a 10,50%. According to Aldezabal *et al.* (2015), grazing abandonment induced shifts in floristic composition, soil insulation and decrease of soil compaction at 0–10 cm depth are the main reason for the increase of this indicator values. Due to those factors, microbial enzymatic activity and biomass suffer a reduction and CO_2 soil emissions increase.

In terms of socioeconomic indicators, all of them directly related to livestock load, BAU is the scenario that gets the best results according to most indicators. The only exception is the dependency to subsidies. In this case, MIX-Down scenario is the one getting the "best" score, because of the reduction of subsidies induced by the fall of sheep and beef cattle load. The values of the rest of indicators fall remarkably (over 70%) in comparison to the BAU scenario: net margin 72,34%; added value 72,85% and employment 74,78%. With regard to MIX-Up scenario, the values of all the indicators fall, but not so remarkably (surrounding 30%). Regarding the BYE-Grazing scenario, the score of all socioeconomic indicators is 0 due to the abandonment of the activity. Taking into account these results, it can be concluded that the total abandonment of grazing activity, apart from ecological and environmental damages, would suppose the loss of over 90 employments and 2 million € in terms of added value. These results illustrate the importance of grazing activity in the case of some rural areas.

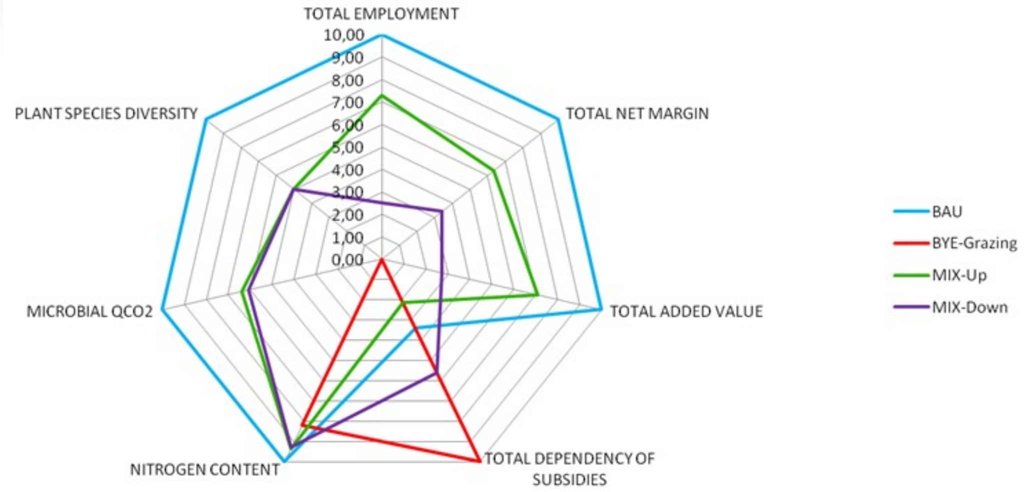

Figure 2. Representation using a spider diagram of the results of the socioeconomic and ecological indicators at landscape level.

4. Nutritional benefits

In term of nutritional benefits, extensive grazing systems provide safe and high quality food (e.g. goat and sheep cheese) which is produced taking into account animal welfare (de Renobales *et al.*, 2012).

The composition of mountain pasture plants are related with the lipid composition of milk and cheese (De Noni & Batelli, 2008; Falchero *et al.*, 2010). In this regard, the scientific evidence shows that fresh pasture intake lowers the saturated FA content of milk fat and increases that of some unsaturated FAs (Abilleira *et al.* 2009, Revello-Chion *et al.* 2010). The most of those unsaturated FAs are associated with potential antiatherogenic, antiobesity and anticarcinogenic properties that are beneficial for human health (Pintus *et al.* 2013). Further details on the nutritional benefits associated with extensive mountain grazing can be found in the recent study developed by Valdivielso *et al.* (2016) in the study area of this article

For all this factors it is not surprising that the milk and cheese obtained from extensive grazing systems provide traditional foods that are perceived by most consumers and producers themselves as high-quality foods.

5. Conclusions

Cheese-makers obtain the best scores in all the indicators selected for the evaluation at farm level and show the best socio-economic performance among all the typologies considered. Hence, without any doubt it can be say that these farmers are the most sustainable ones in economic terms at least in the Community of Enirio-Aralar. However, they show a high dependency of subsidies, even though they are the least dependent farm type of the Community. That factor makes them vulnerable to the decisions, interest and commitments of public institutions (priority changes, sectarianism, political interests etc.). In order to avoid that situation, it would be desirable to promote and support alternative measures and initiatives that can serve to strengthen the autonomy of farms. For example, in order to diversify the sources of income and reduce the dependency to public subsidies it might be worth to explore the possibility to combine the traditional farming activities with new education or leisure activities (e.g. ecotourism) that are implemented in other regions of Europe; to prioritize short-chain sale channels; to make an efficient use of communal lands in order to reduce feed costs, or to diversify the products sold by farmers. Urgent measures are also needed to shepherd cabins to make their work easier and ensure the production of high quality food, to improve the accessibility to the cabins without compromising the environmental values of the area, and to update the regulation to the current situation. The contract of additional people to assist shepherds in the grazing season (e.g. to control the livestock) can be also beneficial both in socio-economic and environmental terms and should be considered by the public administration. All these measures would contribute to improving the quality of life of shepherds and making their work more respectable, what ultimately will determine the sustainability of the activity and the continuity of future generations.

As the landscape level analysis shows the socio-economic and ecological benefit associated with the current grazing systems are multiple. However, the current socio-economic situation threatens the sustainability of the activity. In this regard the study shows the cost associated with the abandonment of the extensive grazing systems (simulated with the MIX-Down and BYE-Grazing scenarios). In addition to socio-economic and nutritional losses the abandonment of traditional mountain grazing activities would derive to reductions in plant species diversity, decreasing pasture forage quality and rise of soil greenhouse emission.

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Nazioarteko Hizketaldia

ELIKADURAREN ETORKIZUNA ETA NEKAZARITZAREN ERRONKAK XXI. MENDERAKO:

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