Pastoralism and ecosystem conservation

Proceedings of the 17th Meeting of the FAO-CIHEAM Mountain Pasture Network

5-7 June 2013, Trivero, Italy

http://fao13.adcf.ch/

Edited by
DISAFA – Department of Agricultural, Forest and Food Sciences
University of Turin, Italy

ISBN 978-88-908636-2-2
ISBN Editor: Department of Agricultural, Forest and Food Sciences,
University of Turin, Italy

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Suggest citation
Authors, 2013. *Paper title.* In: Lombardi G., Mosimann E., Gorlier A., Iussig G., Lonati M., Pittarello M., Probo M. (Eds). Proceedings of the 17th Meeting of the FAO-CIHEAM Mountain Pasture Network - Pastoralism and ecosystem conservation, 5-7 June 2013, Trivero, Italy, pp. *nn-nn.*

With the support of the following organizations

Oasi Zegna

Università degli Studi di Torino
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Foreword

This book contains the Proceedings of the of the 17th Meeting of the FAO-CIHEAM Mountain Pasture Network - *Pastoralism and ecosystem conservation*, 5-7 June 2013, , Italy, held in Trivero (Biella district) from June, 5th to June, 7th 2013.
The Meeting was jointly organised by the Department of Agricultural, Forest and Food Sciences of the University of Turin, Oasi Zegna, FAO-CIHEAM Mountain Pasture Network, and Agroscope Changins Wädenswil Research Station ACW .

Here we publish 50 contributions, produced by approximately 70 authors. Eleven different countries from four out of five continents are represented. All contributions to this report have been reviewed by the members of the Scientific Committee.

The presentation is organised into two separate parts, one containg the papers presented orally, and one with the papers presented as posters. For each part the papers are sorted according to the program of the Meeting, i.e. into the following sessions:

- Opening session
- Session 1 - Ecosystem services of mountain pastures, including quality products
- Session 2 - Management of pastoral areas
- Session 3 - Agro-pastoral practices for environmental conservation
- Session 4 - Grazing behaviour and GPS tracking.

Publishing these proceedings would not have been possible without the time and dedication of the members of the Scientific Committee. We are indebted to all these colleagues.

We express our appreciation to the participants of this Meeting and their effort to share information, skills, curiosity and scientific inspiration for this meeting. We hope this will be the occasion for creating new fruitful collaborations.

The Editors

Table of contents

ORAL PRESENTATIONS

OPENING SESSION

California Mediterranean Rangelands and Ecosystem Conservation

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Abstract

Transhumance, irrigated pasture, supplements, and feeds complement rangelands of introduced Mediterranean species. In this changed ecosystem, grazing and pastoral practices can benefit native wildlife and plants. Conservationists and pastoralists work together to combat landscape fragmentation. We visit an oak woodland ranch to see the impacts of land use change, conservation policies, rancher goals, and land, livestock, and ecosystem service markets.

Keywords: conservation policy, ecosystem services, transhumance, oak woodlands, working landscapes

Introduction: California Mediterranean rangelands

In the 1930s, Ermenegildo Zegna reforested an Italian mountain with a history of grazing dating to Classical times. In California, we are changing rangelands that were once the sole domain of indigenous Californians who managed for hunting and plant harvest. Over fewer than 300 years, the landscape has been "engineered" by livestock grazing, cultivation, fire suppression, and the introduction of exotic species. Rangeland researchers strive to understand this dynamic situation.

About 4.3 million ha of annual grasslands and 2.1 m ha of oak woodlands offer forage for grazing animals (CDF-FRAP 2003). Grasses are mostly Mediterranean annuals. Highly variable rainfall patterns mean forage production varies by orders of magnitude. Forage dry weight varies temporally from 500 to 3000 kg/ha (Huntsinger and Starrs 2006). It is drier and warmer in the south; northern or higher elevation areas are colder and wetter. The cold Pacific Ocean results in a moderated, cooler and moister, climate near the coast. Heterogeneous soils cause high spatial variation in forage production (Jackson and Bartolome 2002.)

Grazing is California's most extensive land use. Calving and lambing is timed to take advantage of spring growth (George et al. 2001a; George et al. 2001b). Supplemental feeds, selling of calves, transhumance, irrigated pasture, leased pastures, and stock movements help cope with unpredictability and the summer dry period, which is longer than southern Europe's (Huntsinger et al. 2010a). Transhumance began in the mid-19th century, to the Sierra Nevada and northern mountains.

An oak canopy, common throughout the state, creates a moister microclimate and litter that can increase production, influence species composition, improve forage quality, and extend the period of green forage (Frost and McDougald 1989; Frost et al. 1991; Frost et al.1997). Trees may be thinned to prevent suppression of forage production, however, the canopy is often naturally open. Canopy cover of 50% or less does not tend to suppress forage. There is much research on overstory-understory relationships, afforestation, and factors influencing oak regeneration and recruitment, including grazing. (McClaran and Bartolome 1989; Jackson et al. 1990; Marañón and Bartolome 1993; Marañón and Bartolome 1994; Hatch et al. 1999; McCreary 2001; Tyler et al. 2006; McCreary et al. 2011).

Livestock production

Ranchers are encouraged to manage using residue management: leaving behind a certain amount of ungrazed plant material, or residual dry matter (RDM) at the end of the grazing season to protect the soils and encourage the growth of useful forage species by influencing germination conditions. Recommendations call for leaving 110–960 kg/ha depending on canopy cover of oaks and slope (Bartolome et al. 2002; Bartolome et al. 2007). Management practices vary, including year-long, rotational, seasonal, and targeted grazing (Huntsinger et al. 2007).

Livestock have been in California since 1769, with dramatic shifts in numbers through time (Fig 1.). A history of livestock in California shows huge increases following 1849 Gold Rush when prospectors and associated industries departed, reducing demand for the animals once brought in to feed them, and during WW I. Leasing of government and private land is common, with government land usually around a third to half on average of the rangeland portfolio (Liffmann et al. 2000; Sulak and Huntsinger 2007; Roche, 2013; Huntsinger et al. 2010a). Replacement heifers from California's large dairy industry now compete for grazing lands. Mountain meadows are frequently in federal ownership and some ranchers have summer permits, though few spend summer in the mountains anymore (Sulak and Huntsinger 2002; Huntsinger et al. 2010a). The use of these pastures is shifting to recreation and nature preservation. Rangeland calves or yearlings are sold to feedlots where they are fed agricultural by-products, hay, grain, and other rations for 100 to 150 days and slaughtered at 18 to 24 months of age and 475 to 520 kg. The largest feedlots are near the grain production centres in the middle of the country, though there are a few in California where cattle are fed agricultural resides and some locally-produced grains (Huntsinger and Starrs 2006).

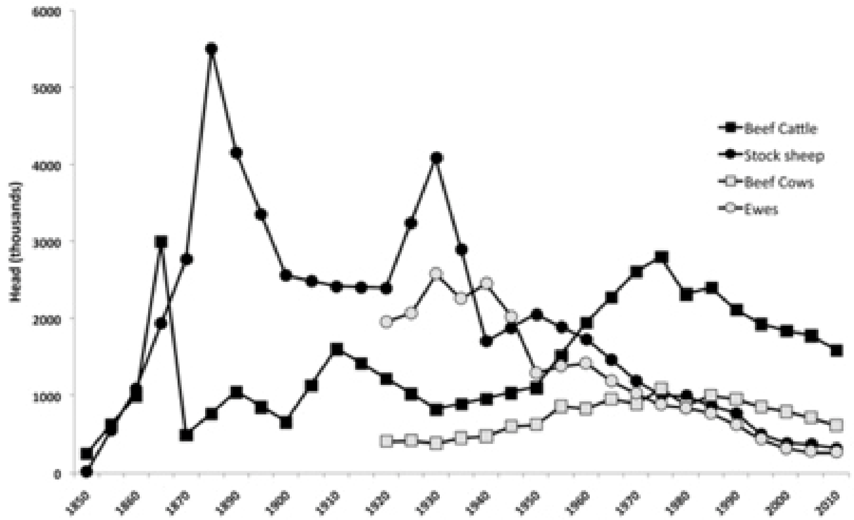

Figure 1: Range cattle and sheep in California, 1850-2010. Beef cows are brood cows, ewes are meat breed brood ewes, and both are often on rangeland. The gap between the number of beef cows and beef cattle indicates the presence of yearlings (stockers) on rangelands or in feedlots. Separate data for cows and ewes was not provided until 1920 (Data recompiled from Burcham 1982, USDA-NASS 2011a and b).

California and Texas have the most sheep in the United States. In 2010, California had 263,000 ewes, down from 770,000 in 1985 (USDA-NASS 2011b). The drop is attributed to low profits stemming from competition from imported lamb, high labour costs, and a decline in lamb consumption. In oak woodlands, with wildlife protections predators have increased (Neale et al. 1998; Conner et al. 1998), and with development, domestic dogs are a growing problem. Lambing is in late fall and spring.

About 140,000 goats resided in California in 2011, including 38,000 dairy animals (USDA NASS 2011b). Goats are used for meat, dairy, and vegetation management. Goats may be herded to control weeds and reduce fire hazard, often on steep hills where other brush control methods would be expensive and difficult. Free-ranging pigs are rare, but the practice has undergone a recent revival for the gourmet market, with at least two producers trying acorn-fed pigs (O'Rourke 2012; Reed 2010).

Ranchers and land use change

More than three-fourths of ranchers live on their properties and manage the land themselves, and have owned their properties for an average of 39 years. In 2005, 25% of oak woodland ranchers reported that the majority of household income came from ranching. About 22% cited off-ranch wages as a major income source, and another 22% earned most of their income from other forms of self-employment, including investments, pensions, and the like (Huntsinger et al. 2010b). Livestock producers may earn income through marketing

oak trees as firewood and selling access to their land for hunting, but most work off-ranch to support the property (Smith and Martin 1972; Torell and Kincaid 1996; Huntsinger et al. 2010b).
Ranchers readily agree that “income maximization” in the conventional sense is not their goal (Liffmann et al. 2000). Instead, a financially sustainable operation that maximizes landowner autonomy in decision-making, provides a good place to raise a family, allows enjoyment of the natural environment, and is based on work with animals is more important to most ranchers (Liffmann et al. 2000; Huntsinger et al. 2010b). For the most part, ranchers are enthusiastic about the amenities produced from the management of their properties, and aware that society values them, but at the same time, they strongly seek to maintain control over management decisions and practices on their land (Huntsinger et al. 2004). Land prices are consistently above those that can be justified by commercial production value, reflecting the high profits to be earned from development and conversion, but also substantial landowner consumption of non-market benefits from the land (Campos et al. 2009; Torell et al. 2005).

Rangeland Ecosystem Services

Efforts to conserve and enhance rangeland ecosystem services are at two scales: landscape and pasture, with a constellation of policies, practices, and research for each. The “wide open spaces” of ranch landscapes are important aesthetically, and many other ecosystem services depend upon the extensive and undeveloped land. At the pasture scale, a number of studies have shown that livestock grazing has become a valuable tool for conserving native species. Programs that motivate landowners to manage for the joint production of livestock and increased and multiple ecosystem services can be a powerful approach to ecosystem conservation.
At the landscape scale, zoning is weak in response to the financial power of development interests. For many ranchers land appreciation is a long-term financial asset (Ferranto et al. 2011), planned for retirement and inheritance. Cash-short ranchers sell land to raise capital. Ranchers strongly defend their right to market their land as they see fit. The constant attrition and fragmentation of the resource base undercuts the long-term sustainability of ranching. There is strong competition for available grazing leases (Sulak and Huntsinger 2002), augmented by the administrative withdrawal of millions of acres of federal lands from grazing, and the continued decline in numbers of stock allowed on federal lands (CDF-FRAP 2003; Sulak and Huntsinger 2007). A study in the Sierra Nevada foothills showed that transhumant ranchers have been ranching for a longer time, and are more affected by land use change, than ranchers not practicing transhumance. Most have owned their land for a long time by U.S. standards: 63% of transhumant foothill oak woodland ranchers reported that their families have owned their ranch for more than 100 years (Huntsinger et al. 2010a). Loss of a permit to graze in the mountains can make associate private lands more vulnerable to development due to reduction in grazing land (Sulak and Huntsinger 2002).
Conservation easements are a private sector response to fragmentation and are now the most widely used private sector land conservation method in the United States (Gustanski and Squires 2000). The amount of California land under conservation easements increased by 34% since 2005, and doubled since 2000 (Land Trust Alliance 2010). In exchange for tax benefits or outright payment, a landowner voluntarily agrees to a permanent deed restriction on the property title that prohibits development (Merenlender et al. 2004; Reiner and Craig 2011). Easements allow ranchers to continue ranching, while extracting some of the capital value of the land by voluntarily donating or selling the right to develop (Sulak et al. 2004). Surveys of range and forest landowners in 2005 and 2008 found that approximately 6% had a conservation easement (Huntsinger et al. 2010; Ferranto et al. 2011). California programs spent approximately $103 million in cash on easements for conservation or mitigation in 2002, much of it public funds, and mostly on oak woodland grazing lands (Rilla and Sokolow 2000).
At the pasture scale the role of pastoralists as providers of ecosystem services that support biodiversity is now recognized (Barry 2011, Huntsinger et al. 2007). In the San Francisco Bay region, half of the available habitat for the endangered California tiger salamander (*Ambystoma californiense*) is provided by stockponds and improved with grazing (DiDonato 2007). In a more complex case, more than half of the foothill habitat for the rare California black rail comes from the leaky irrigation works associated with ranching (Richmond et al. 2010), yet grazing must be carefully managed during the breeding season (Richmond et al. 2012). Trade-offs are typical: grazing reduced methane emissions from oak woodland seeps and springs, but was associated with a decline in insect species richness (Allen-Diaz et al. 2004). Other examples of species that benefit from grazing are endangered bay checkerspot butterflies (*Euphydryas editha bayensis*) (Weiss 1999),

burrowing owls (*Athene cunicularia*) (Nuzum 2005), insects (Dennis et al. 1997), kit fox (*Vulpes macrotis mutica*) (USDA-FWS 2010), kangaroo rats (*Dipodomys stephensi*) (USDA-FWS 1997, Kelt et al. 2005, Germano et al. 2012), wildflowers (Barry 2011), and a host of rare flora and fauna associated with vernal pools (Marty 2005, Pyke and Marty 2005). In some cases grazing exclusion has caused the species being "protected" by the exclusion to leave or disappear (Weiss 1999).

One way to conserve the pasture and landscape is to increase ranch profits. Labelling programs are not well developed, although consumer interest is on the increase. Non-governmental certification programs play a growing role in informing consumers of the ecosystem services associated with buying various products or brands. There are markets for some ecosystem services provided directly by livestock. One example is grazing for control of fire hazard and invasive weeds. Goat companies charge up to $1300 per ha for this service. Cattle can also be used for fire hazard management (Byrd et al. 2009). On some public lands, lease costs are reduced for habitat improvement and detailed and highly constrained grazing prescriptions have emerged (Germano et al 2012; Huntsinger 2012).

More than two-thirds of ranchers surveyed were receptive to the idea of being rewarded monetarily "to improve the quantity and/or quality of environmental benefits that their land provides to society," even though many were unfamiliar with the specific term "ecosystem services". The duration of their commitment, and the payment amount, were important factors in rancher willingness to participate in such payment for ecosystem services programs, with preference for shorter contracts and higher payments (Cheatum et al. 2011). The kind of entity that would offer the payments was important to prospective sellers, with non-profit organizations or private firms strongly preferred over state and federal agencies with regulatory or administrative authority over ranchers (Ferranto et al. 2012).

Federal cost-share programs, a form of payment for ecosystem services including habitat and environmental quality improvements include the Wildlife Habitat Incentives Program (WHIP), the Environmental Quality Incentives Program (EQIP), and the Grassland Reserve Program (GRP). In 2011, EQIP provided $74 million to California farmers and ranchers for carrying out projects to improve "environmental quality" while WHIP paid out $3.6 million (USDA-NRCS-EQIP 2011; USDA-NRCS-WHIP 2011). The Conservation Reserve Program (CRP) paid farmers 89.2 million dollars to keep land out of cultivation, though grazing is not allowed on reserved lands (Environmental Working Group 2011). Altogether the USDA Natural Resource Conservation Service spent another $5.4 million on conservation practices in California between 2005 and 2009, including brush management, prescribed grazing, and upland wildlife habitat (Tanaka et al. 2011).

Provision of wildlife habitat was the service that ranchers in California would prefer to market or be rewarded for producing, and they already report such management, but there was considerable willingness to restore native plants, improve water quality, and increase carbon storage (Cheatum et al. 2011; Ferranto et al. 2011). Ranchers were slightly less interested in increasing oak numbers, perhaps because most are familiar with the difficulties involved and may feel too many oaks will interfere with forage production (Huntsinger et al. 2010). Increasing woody plants is one possible way to increase carbon storage but it increases water consumption and fire risk (Booker et al. 2013).

Many non-market ecosystem service values can be satisfied with a property of a few hundred acres (Oviedo et al. 2012). On the other hand, commercial values from livestock production and other natural resource products continue to increase with property size. Combining these two "valuations" is the basis of the "working landscapes" effort in California to encourage joint production of commercial and non-commercial ecosystem goods and services in order to create sustainable rangeland enterprises.

Conclusions

I invite you, in my presentation, to join me on a visit to a California ranch, to see the on-the-ground effects of conservation policies, rancher goals, and land, livestock, and ecosystem service markets.

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SESSION 1- Ecosystem services of mountain pastures, including quality products

A qualitative research on Spanish farmers and citizens perceptions of ecosystem services provided by mountain livestock farming

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Abstract
There is a strong debate nowadays on the public goods derived from certain agro-ecosystems and their valuation for establishing payments for ecosystem services (ES). In this context, we carried out a qualitative research on the spontaneous knowledge of ecosystem services and the perceptions of farmers and citizens on relationships between mountain farming and the environment. Five focus groups (2 with farmers and 3 with citizens; n=33) were organized in north-eastern Spain. Discussions were guided according to 5 general questions on links between pasture-based mountain livestock and the environment, lasted around 1.5 hours, were video recorded and transcripts were written for text analysis. Ideas or items from discussions were interpreted and organized according to the type of ES participants referred to (provisioning, regulating, habitat, cultural).
The ES that were mentioned and discussed a greater number of times were (in descending order): aesthetic (landscape/ vegetation); gene pool protection (biodiversity maintenance); disturbance prevention (forest fires); lifecycle maintenance (nutrient cycling, photosynthesis); raw materials (firewood, forage); water purification/ waste management; spiritual experience; recreation/ tourism; soil fertility/ erosion prevention; and culture/ art. Differences between farmers and citizens were observed: farmers gave more importance to regulating (in particular, prevention of forest fires and soil fertility) and provisioning (raw materials) ES, mainly related to their own farming activity or local circumstances; whereas citizens gave more importance to cultural (aesthetic landscape/ vegetation, spiritual experience, recreation/ tourism and culture/art) ES, showing in general more global concerns.
This study constitutes the base for a quantitative research on valuation (including monetary valuation) of ES derived from mountain farming systems in Mediterranean and North-Alpine areas.
Keywords: public goods, sustainability, valuation, focus groups.

Introduction
Mountain agriculture supplies private goods (e.g. animal products of differentiated quality), but also multiple public goods and services, which by definition are non-excludable (if the good is available to one person, others cannot be excluded from the benefits it confers), non-rival (if the good is consumed by one person it does not reduce the amount available to others) and non-marketable (the good does not have a known market price) and, therefore, people do not contribute to covering the costs associated with their provision. Among these, the conservation of biodiversity, the maintenance of cultural landscape and the prevention of environmental hazards, such as forest fires, are inherently linked to agricultural activities (Cooper *et al.*, 2009). For these reasons, there is nowadays a strong debate on the public goods derived from diverse agro-ecosystems (e.g. greening of the CAP) and their valuation for establishing payments for ecosystem services (ES).
Ecosystem services are defined as the direct or indirect benefits that humans get from nature and the concept is considered a good link between ecosystems, including agro-ecosystems, and human wellbeing (Kumar, 2010). The concept is becoming widely adopted by scientist and managers (Chan *et al.*, 2011), however, there are few studies on the understanding of ES by society, their demand or relative importance (Lamarque *et al.*, 2011).

In this context, the objective of this research was to gain information on the spontaneous knowledge and perceptions of farmers and citizens about ES provided by mountain agriculture.

Material and methods

We organized five Focus Groups (FG) (2 with livestock farmers, n=11, and 3 with citizens, n=22) to generically discuss about relationships between pasture-based mountain livestock and the environment in North-East Spain. FGs lasted approximately 1.5 hours and were conducted by a moderator according to 5 general questions. 1. Do you know the term "ecosystem services"? 2. How do you think livestock production affects the environment and vice versa? 3. How these relationships between livestock production and the environment affect you? 4. What geographical areas/ places can you identify that show the effect of livestock on the environment? 5. Should society pay for the delivery of environmental services? Who? In what way? Participants were asked to reflect individually on the questions for about 10 minutes previous to the discussion and to write in their own words the responses or give examples. The sessions were video recorded and transcripts written for text analysis.

Items of information appearing in texts were divided in mentioned and discussed (when a particular item originated substantial debate among participants) and were counted to facilitate the presentation of results. The items corresponding to ES were classified in *provisioning* (products obtained from ecosystems); *regulating* (benefits obtained from the regulation of ecosystem processes); *habitat* (necessary for the production of all other ecosystem services); and *cultural* (nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences), following the definitions by the Millennium Ecosystem Assessment (2005) and the classification proposed by TEEB (The Economics of Ecosystems and Biodiversity) (Kumar, 2010). Other items of information about mountain farming and agriculture in general were classified in *farm economics*, *social issues* at the farm level, *socio-economic context* and *policy/ legal context*, but are not presented in this paper.

Results and discussion

Not a single participant in the FG discussions affirmed to know the term "ecosystem services". A number of them showed a good intuitive understanding of the concept; for example "*goods that nature provide to society*", "*utility of diverse natural environments*" or "*economic benefits from nature*". However, others interpreted the term as the responsibility of humans to preserve nature.

Figure 1 shows the relative frequency of number of times that ES were mentioned grouped per type (provisioning, regulating, habitat and cultural). Farmers tended to speak more often about regulating and habitat ES, followed by provisioning services. However, citizens spoke predominantly about cultural ES (around 50% of items mentioned), being the other types equal in relative importance.

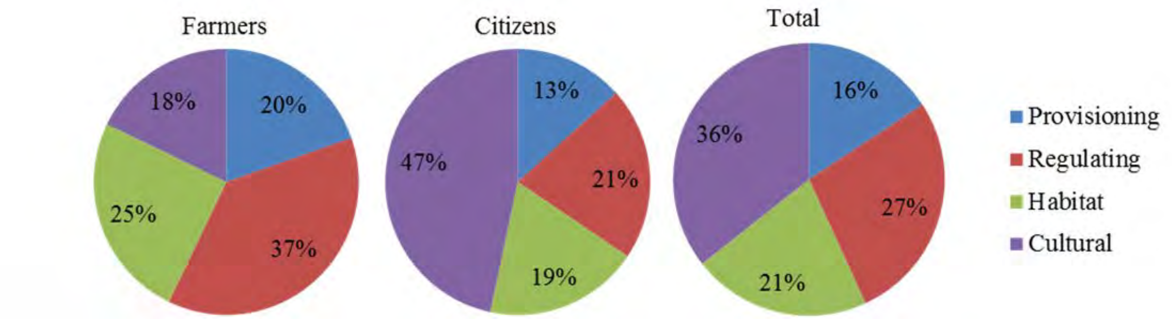

Figure 1: Relative importance of types of ecosystem services (% of times mentioned)

Figure 2 shows the number of times that individual ES were mentioned. Globally, the more frequent were (in descending order): aesthetic (landscape/ vegetation), gene pool protection (biodiversity maintenance), lifecycle maintenance (nutrient cycling, photosynthesis), provision of raw materials (firewood, forage), disturbance prevention (forest fires), water purification/ waste management, soil fertility/ erosion prevention, and other cultural ES such as spiritual experience, recreation and culture.

However, there were some differences between the perception of farmers and citizens. Farmers gave more importance (mentioned a larger number of times) to regulating ES such as disturbance prevention (forest fires) and soil fertility/ erosion prevention, and provisioning ES such as raw materials (mainly forage for animals and firewood). Citizens gave more importance to all cultural ES, in particular the aesthetic value (landscape/ vegetation).

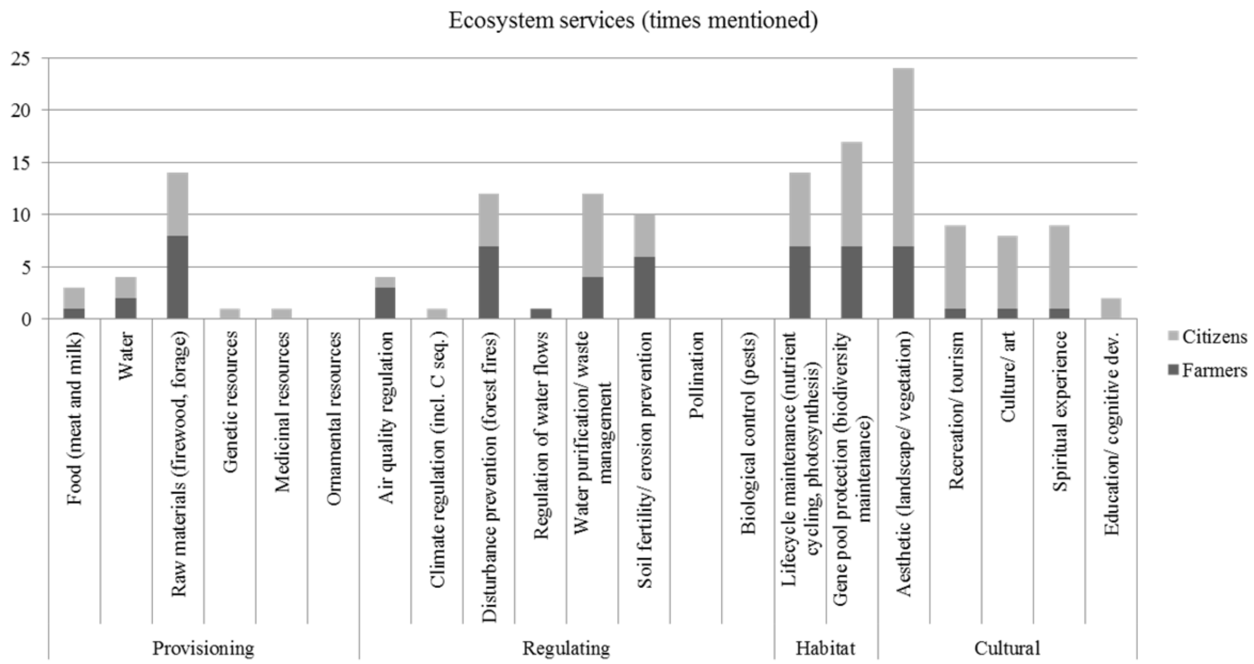

Figure 2: Number of times that different ecosystem services were mentioned in the FG

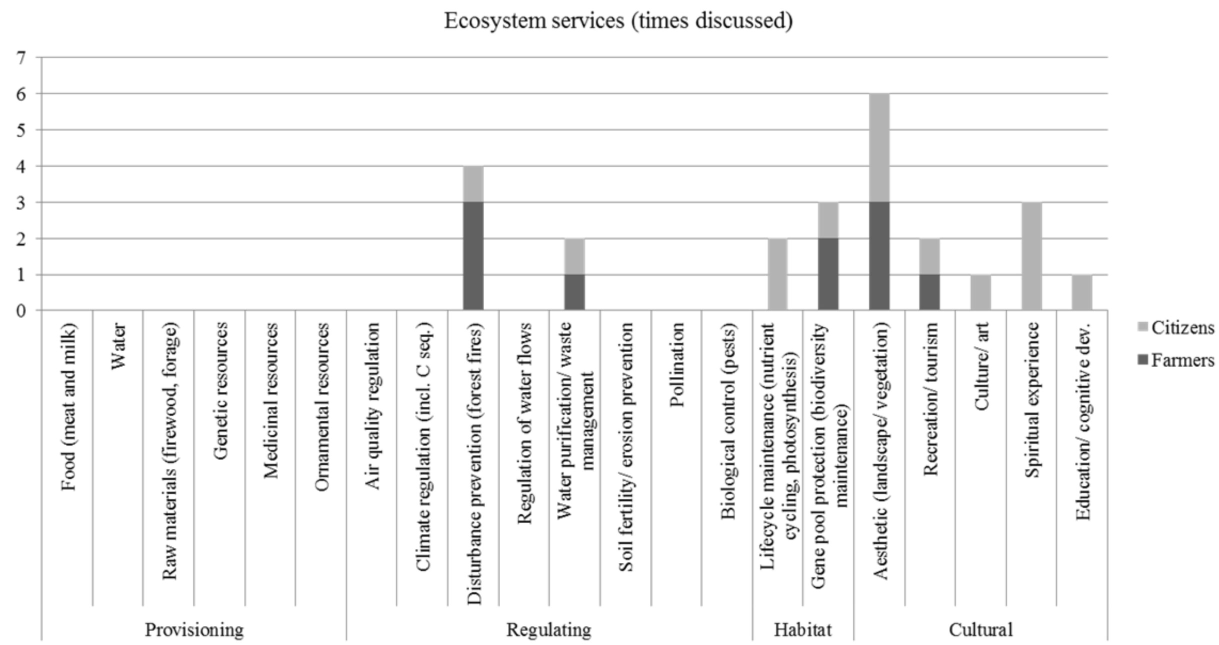

Figure 3: Number of times that different ecosystem services were discussed in the FG

Figure 3 shows the number of times that different ES originated discussions among FG participants. Two issues originated a large share of the discussions among participants; these were the maintenance of cultural landscape and natural vegetation and the prevention and control of forest fires (especially among farmers). The loss of cultural landscapes, the encroachment of vegetation and the risk of wildfires are often pointed out as major concerns when discussing agriculture-environment interactions in Mediterranean conditions, for example Ruiz-Mirazo *et al.* (2011) and Riedel *et al.* (2013). All cultural ES originated a stronger debate among citizens, especially on issues related to spiritual experience (see Daniel *et al.* (2012) for a review on the importance of cultural services).

It is noteworthy the case of habitat ES. These basic ES were identified by participants but expressed in different manner to the formal terminology. For example, for lifecycle maintenance participants used other more familiar terms like "balance" and "equilibrium" of different components of nature. For gene pool protection, terms like diversity of wild species, flora and fauna, and biodiversity were used, but there were contrary opinions between farmers and citizens on the positive or negative effect of mountain farming of wild species and vice versa, as also pointed out by Ripoll-Bosch *et al.* (2012).

In general, the results indicate that farmers gave more importance to ES directly related to their own farming activity or local circumstances; whereas citizens showed in general more global concerns. These results are in agreement with Lamarque *et al.* (2011) that also found that ES that are more visible or familiar to humans, such as cultural landscape, are more easily identified and valued. Moreover, farmers and citizens valued differently some ES derived from mountain farming according to their capacity to satisfy individual needs or interests (Martín-López *et al*., 2012).

A good understanding of the social demands in terms of ES should be required when designing agri-environmental policies. These policies should take into account the views of stakeholders with different roles and interests. However, although land use managers (farmers) and tax payers (citizens) have some divergent views, they also share a large number of concerns on the relationships between mountain farming and the environment and other sustainability issues not discussed here.

There is a need to establish concrete policy targets for the provision of public goods and objectively value (also in monetary terms) the positive externalities of pasture-based mountain agriculture, so we can compensate farmers in an equitable way for the public goods they deliver (Bernués *et al.*, 2011).

This study constitutes the base for a quantitative research on valuation (including monetary valuation) of ES derived from mountain farming systems in the Mediterranean and Northern Europe.

Acknowledgements

Projects: Marie Curie IEF Contract no. 299794 and INIA RTA2011-00133-C02-02. The second author has a pre-doctoral fellowship from INIA.

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Developing tools to conciliate grasslands services in order to ensure the sustainability of farming systems – the case of PDO areas in Massif central

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Abstract

The wide range of services and goods provided by grassland ecosystems allow to conciliate environmental benefits and production services but necessitate a better evaluation of grasslands potentialities. We present i) a typology-tool, allowing characterizing vegetation types services and ii) a complementary and innovative diagnostic tool on dairy forage systems (DIAM) which makes a multi-criteria diagnosis that focuses on forage autonomy, system coherence and the services provided by grasslands.
Keywords: PDO cheese union, multifunctionality, ecosystem services, multidisciplinarity, dairy production, permanent grasslands

Introduction

The emergence of new societal expectations combined with challenges linked to global change force to reconsider livestock farming systems. The wide range of services and goods provided by grassland ecosystems offers a considerable opportunity. Adopting a multifunctional approach makes it possible to conciliate environmental benefits and production services.

In upland area like Massif central (France), grasslands exhibit a great diversity due to the diversity of pedo-climatic conditions and management practices. They influence botanical composition and also agricultural or environmental performances of the grasslands. If this ecosystems diversity is a great opportunity for biodiversity, it could be difficult to deal with it for farmers.

Moreover, rules on PDO cheeses production of the Massif central set grasslands as a key point of the forage system (cutting and grazing). Previous results have shown that in this area permanent grasslands are frequently under-used (Theau *et al.*, 2009). Theau *et al.* (2009) have shown that their management could be improved with better knowledge of their potential and with coherent practices regarding the functioning of vegetation. The stake is to promote and improve the use of grasslands to guarantee the economic durability of farms, the biodiversity of grasslands and the quality of cheeses. To achieve this goal, the R&D "Prairies AOP" project (Hulin *et al.*, 2012), involving 14 research, extension and education partners had developed an innovative and prospective "tool box" including a typology to characterize grasslands diversity and potentials (Carrère *et al.*, 2012) and a diagnosis tool on dairy forage systems (Farruggia *et al.*, 2012). This paper aims to present these two tools and to discuss perspectives of their utilization.

The Grassland Multifunctional Typology: the keystone of the diagnosis

In upland areas, semi-natural grasslands assure a link between products and territory. They provide specific qualities for animal products, supply environmental services and open landscapes. Rules on PDO cheeses of

Massif central set grasslands at a key point of the forage system for farms involved in the labeling process. Local stakeholders are also interested in the characterization of the services provided by grasslands: forage production, biodiversity, other environmental services and organoleptic and nutritional properties of cheeses. The "Prairies AOP" program have combined a botanical and an agronomic approach (Carrère *et al.*, 2012) to construct a typology-tool allowing to characterize at the same time the vegetation (botany), the production potentials and their evolution, the management and environmental conditions and the quality of cheeses expected.
The data set came from a network of 75 plots from 15 dairy farms chosen to cover a wide range of environmental and management conditions (Piquet *et al.*, 2011). Surveys identifying farmer practices, agronomic and phytosociological measurements were carried out. The agronomic samples were realized in the dominant vegetation community of each plot four times during the grazing season. The phytosociological samples were realized in all communities and then organized using phytosociology taxonomy (Braun-Blanquet, 1932). The combination of these ecological data with agronomic (biomass production and quality) ones designed the typology.
A multidisciplinary expertise was used to characterize services like biodiversity, C-Storage, cheese quality. Sixty vegetation types were considered, characterized by their botanic composition and organized in general framework considering interactions between environment and management. From them, twenty three vegetation types (VT) - well informed by agronomic data - were organized by hierarchical approach considering altitude, practice, moisture and fertility. An identification key was established using those different factors in order to facilitate the determination of the VT in the field. The several data available for the 23 VT were used to describe each type and were synthesized in index cards. These cards present seven main parts: (i) code, name and photo of the type, (ii) agro-ecological conditions, (iii) vegetation composition, (iv) agricultural and environmental potentials, (v) agricultural and environmental services and quality of cheeses (Figure 1), (vi) dynamics of VT under perturbations and (vii) a synthesis with strengths and weaknesses. The typology includes also attached documents describing the calculation methodology, supplying additional data and instructions for use. This typology shows the multifunctional aspects of grasslands and constitutes therefore a useful tool (free access on http://www.prairies-aoc.net/) for stakeholders to develop the future of livestock farming in upland areas.

The multi-functional diagnosis: DIAM

DIAM is an innovative diagnosis declining compromise between production, environment and quality of cheese in the forage systems. It was designed for the PDO areas in Massif central. For the implementation of DIAM, agricultural advisor first requires collecting global data (farmer survey) on the forage system (areas, livestock inventory, annual purchases of forage or concentrates and mineral fertilizers) as well as monthly milk yield (production, quality).
In a second step, he must establish the plot profile of the farm, using the Grassland Multifunctional Typology, to identify with the farmer the VT of each plot. The management over the season was also described. This second step allows a diffusion of knowledge on grassland potentiality between the farmer and the advisor. Finally, a field visit confirms the attribution of VT for each of the farm plots.
The collected data feed the diagnosis tool which is organized into four modules: a forage module, an environmental module, a quality of dairy products module and a module analyzing the resource valorization considering PDO cheese production rules (Farruggia *et al*., 2012). As an example, the forage module includes a forage feed balance achieved by comparing the annual needs of livestock in dry matter to the total potential forage dry matter produced by the plots. This production potential uses data provided by the Typology, for each VT. It also includes indicators of practices (acres per cow in spring, % of first cut, g concentrate per liter of milk, mineral nitrogen units per hectare, etc.).

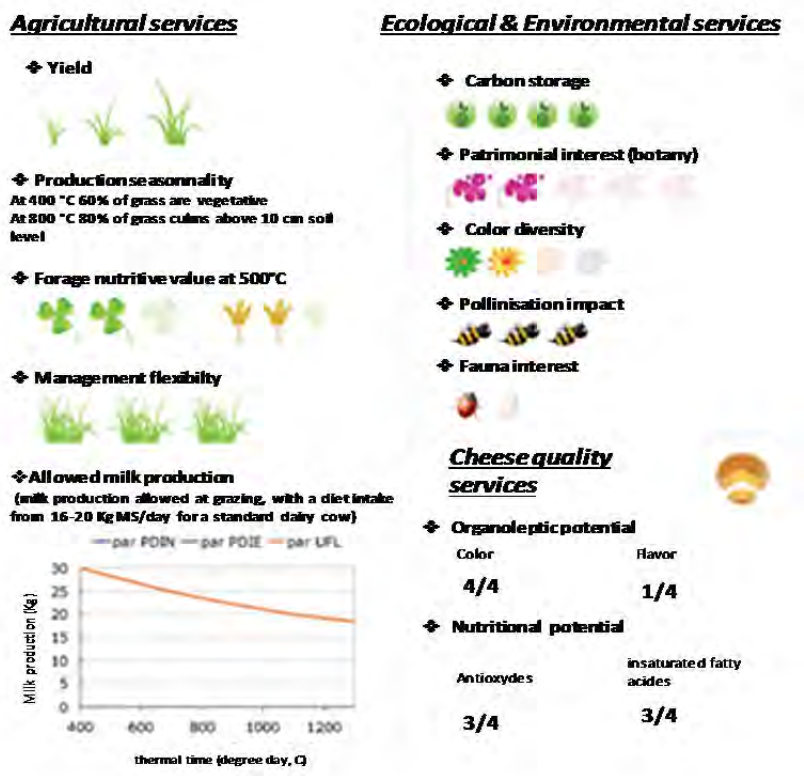

Figure 1: Example of services produced by a vegetation type shows in the Grassland Multifunctionnal Typology. Services were evaluated on the basis of pictograms with traduce class values for each criteria. i.e. Carbon storage was estimated on a 4 points scale, patrimonial interest (botany) on a 5 points scale.

To detect inconsistencies in the forage system, the indicator of practice estimated on the farm were compared to regional references obtained from a long term regional survey (Forage reference networks 2012for Auvergne, Lozère, Aveyron). Each farm is positioned according to its regional forage reference (i.e. all grass-volcanic, volcanic-plowed, etc…) and its practices (harvest management, stocking rate, etc…). Moreover, a table of regional coherence, based on the consumption of concentrates according to milk production, is used to evaluate the quality of the average feeding ration on an annual basis.

DIAM allows showing strong differences between farming systems.

Three farms were selected to illustrate DIAM' outputs (Table 2). A moderately productive farm for the area in term of Kg milk/cow but autonomous for its forage (PROD-A), a very productive – non autonomous farm (PROD+-nA) and a an efficient farm (productive, autonomous, farm with a low stocking rate) (EFF-A).

Table 2: technical characteristics of three farm types used to illustrate the multi-functional diagnosis DIAM.

Farm type	Surface Ha	Stocking rate (average dairy cow/ha)	Milk / dairy cow	% temporary grassland	Kg N/ha	Number of VT in the farm
PROD-A	57	0.92	6300	0%	20	6
PROD+-nA	71	1.02	9000	0%	28	10
EFF-A	59	0.77	7500	40%	30	10

PROD+-nA shows the best results from the environmental criteria point of view (Figure 2), whereas the EFF-A is far behind. The main explanation of this result is due to the VT presents in the different farms. Although a high number of VT (10), EFF-A has a large proportion of productive grasslands including temporary grasslands that have few assets vis-à-vis environmental services compared to permanent grasslands (Farruggia *et al.*, 2012). Moreover, PROD+-nA has a great number of VT with interest for ecological point of view, including summer pastures. Finally, the 3 farms differ widely on the balance of their forage system. PROD-A appears to be very balanced on all components studied: system consistency, fodder services, environmental services and cheeses quality; and present a very good valorization of natural farm resources. Many inconsistencies were however detected in the forage system developed by PROD +-nA, mainly due to a low utilization of herbage resource and large concentrate inputs, and thus despite a good potential for forage services of its grasslands (large number of VT allowing high flexibility). The EFF-A shows a very consistent feeding system, a very good valorization of its resources, but a quite low contribution from environmental point of view (Figure 2).

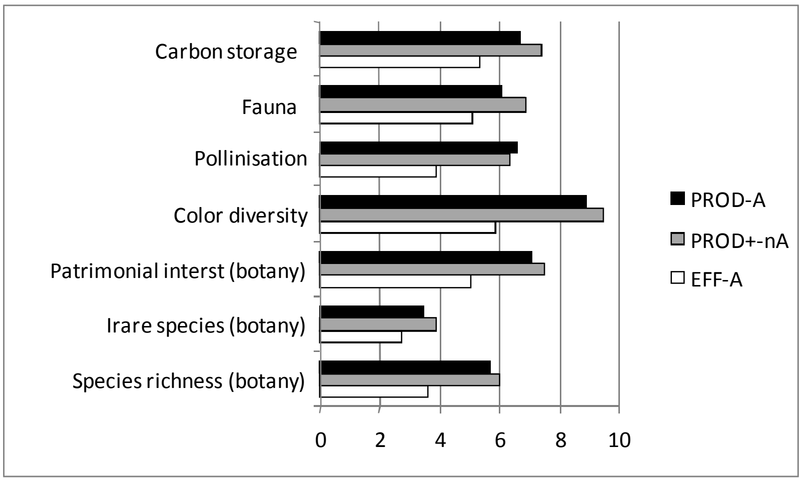

Figure 2: Evaluation of environmental services of the three farms type (see text).

DIAM is a multifunctional approach of the farm feeding system. It brings to the farmer thoughts on the balance he has developed within its farm between the production, environment and the product quality. It positions grasslands as a strong element in the construction of cheeses quality, and provides some very innovative information on environmental index (carbon storage, variety of plant colors, etc..). It allows professionals to anticipate future demands of agricultural policies, such as biodiversity, carbon storage, preservation and development of agricultural systems incorporating permanent grasslands in the service of quality food production. The three farms show very contrasting and unexpected balances between the different kinds of services. It shows that DIAM could discriminate forage systems. However, DIAM still has a number of limitations. Assigning a vegetation type (VT) to each grassland of the farm, what determines greatly the diagnosis' result, is sometimes not so easy despite a quite simple identification key. Knowledge of plant species could be useful to validate "intermediate grassland", which share characteristics intermediate to two VT. After one year of training, we have also identified that some relatively frequent VT are lacking.
Moreover, the diagnosis is based on an "additive method" to provide an integrative approach per kind of services. This method is not totally satisfactory and must be adapted in the future to deal with stakeholders expectations. Finally, DIAM is well suited for the diagnosis of specialized dairy systems but is a little trickier to apply to mixed systems. Currently, the tool is in the process of being computerized (software development) and should be used on a larger scale in order to assess the diversity of farms in these PDO cheese areas. It will identify and question the balances and tradeoffs within a farm and between farms within a territory.

Acknowledgements to peoples from Chambres d'Agriculture, EDE of Cantal, Puy-de-Dôme and Aveyron, CBNMC, VetAgro Sup and Idele for their contribution in this work. This work was funded by the French Ministry of Agriculture (CASDAR program).

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Design of low-input dairy farming systems in mountain areas: animal performances and cheese sensory properties

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Abstract

Two experimental dairy farming systems were designed with the objectives of limiting the inputs and reinforcing the link to terroir in PDO cheese mountain areas. After 2 years, the functioning of the systems is not yet stabilized but they both produced interesting quantities of milk, although its composition was sometime not optimal for cheese manufacturing. Nevertheless, the poor reproduction results of the two systems must be corrected to ensure the renewal of the herds and their sustainability.
Keywords: low-input farming system, dairy cow, PDO cheese

Introduction

Milk produced in the French mountains is mainly transformed into PDO cheeses. PDO specifications aim at reinforcing the link to terroir, in particular by maximizing the use of local forages. In this context, two "contrasting" innovative dairy farming systems were designed with the objectives of limiting the inputs thanks to an optimal use of grasslands, and being sustainable.
This type of long term farming system research seems indeed the most adapted to improve our understanding of the interactions between management practices and animal performances at farm level, as suggested by Gibon et al. (1999).

Material and methods

The two systems are tested for 5 years, from April 2011, in an experimental farm of INRA located in an upland area of central France (1 100 m asl). Herd and lands were divided in two farmlets:
- **Bota** (French acronym for Biodiversity, Sensory, Work, Autonomy), 59.6 ha of diversified grasslands, with low stocking rate (0.66 LU/ha the 1st year), spring calving of 3-year-old cows, no mineral fertilization, no concentrates, long grassland rotation duration and long dry period for cows,
- **Pépi** (for Production, Efficiency, Planet, Innovation), 29.2 ha of permanent and old temporary grasslands, with moderate stocking rate (1.1 LU/ha the 1st year, which is slightly higher than average in the surrounding area), spring calving with 2-year-old cows, sharp adjustment of mineral fertilization and concentrates (4 kg/d at pasture), rotational grazing and early cutting.

Two groups of 24 similar cows and heifers have been paired at the beginning of the experiment and put on each system. The characteristics of the two herds are summarized in Table 1.
Strategies and decision rules for managing animals and land were established for each system, with the aim of producing most of the milk from pasture. A breeding season of 70 d (42 d for artificial insemination followed by 28 d for natural mating with a Limousin bull) has been scheduled for a very short calving period around the end of April, the time at which cows are usually put out to pasture. The renewal of each herd is made only of female calves born from it.
Measurements include forage production, inputs (fertilization and concentrates for Pépi), floristic diversity (in 2011) and animal performances. Animal performances are calculated from individual data: milk production at each milking, fat and protein contents two days a week on 4 consecutive milkings, live weight

at calving and twice a month, body condition score (**BCS**) at calving and every month, health events (mastitis, lameness, etc.) and reproduction data (heat, insemination, calving).
In 2012, cheeses have been manufactured with the milk produced by the not extended lactation cows of each system (see Results). Twelve Cantal cheeses have been made in controlled conditions with unskimmed raw and pasteurized milk in July when cows were on pasture. The sensory characteristics of the 5 months ripened cheeses were assessed by a trained panel.

Table 1: Characteristics of Bota and Pépi herds at the beginning of the experiment (spring 2011)

	Bota		**Pépi**	
Breed	Holstein	Montbéliarde	Holstein	Montbéliarde
Number of cows	12	12	12	12
% of primiparous	16.7	25.0	25.0	25.0
Rank of lactation at calving	2.9 ± 1.7	2.9 ± 1.8	2.7 ± 1.4	3.0 ± 1.8
Two-year-old heifers	4	5	-	-
One-year-old heifer	5	4	5	4

Results and discussion

Health
The main problems encountered the 1st year were calving fever and grass tetany on cows in April-May, when cows were turned out to pasture just after calving. They were linked to a nutritional deficit in Mg and they were resolved the 2nd year by a supplementation of MgCl powder put on the hay during April (100 g/d), plus a bolus of Mg for cows that had to calve at pasture. Lameness was also an important health problem (Table 2), especially at the end of summer when cows grazed far from the milking parlor. In 2012, for the Bota system, we reduced walking by grazing 2 plots each day: a distant one during the day and a closer one at night. On average, 26% of the cows had at least one mastitis, but Montbéliarde cows from the Bota system were very little subject to mastitis.

Table 2: Number of dairy cows from Bota and Pépi herds affected by lameness or mastitis

		Bota		**Pépi**	
Breed		Holstein	Montbéliarde	Holstein	Montbéliarde
Lameness	2011/2012	4	7	2	5
	2012/2013	6	5	2	4
Mastitis	2011/2012	6	0	3	5
	2012/2013	4	1	4	2

Reproduction and renewal
The 1st year, the performances of reproduction of the cows from the two farmlets were poor, especially for the Bota system (Table 3). In order to maintain 24 lactating cows in each system the following year, we extended the lactation of 9 cows from Bota and 7 from Pépi to about 20 months. In addition, this improved the reproductive performances during the 2nd year, because cows with long lactations reproduced better. Nevertheless, for the 3rd year, we will still have to prolong the lactation of 2 cows from Bota and 5 from Pépi. In the future we also have to use a methodology to improve reproductive performance, such as that described by Gouttenoire et al. (2010) for close experimental systems.

Table 3: Percentage of pregnant females in Bota and Pépi herds, at the end of the breeding season (confirmed by echography)

		Bota		Pépi	
Breed		Holstein	Montbéliarde	Holstein	Montbéliarde
2011	cows	33%	25%	50%	42%
	heifers	100%	80%	60%	75%
2012	cows after calving	38%	71%	44%	13%
	extended lactation cows	75%	80%	67%	75%
	heifers	100%	75%	80%	100%

Milk production and composition
During the first year (from 1st April 2011 to 31 March 2012), the cows from the Bota and Pépi farmlets produced 115 800 and 125 400 kg milk, the difference between the two systems being essentially due to Holstein cows (Table 4). During the 2nd year (from 1st April 2012 to 31 March 2013), the overall milk production of the two farmlets decreased by 22% (-16% in Pépi and -28% in Bota). This decrease is primarily related to the high percentage of cows in extended lactation (33% on average), that contributed to only 24% of the bulk milk. Over the two years, the difference between Pépi and Bota systems was about 375 kg/yr for Montbéliarde cows and 883 kg/yr for Holstein cows. This suggests that the Holstein breed is better adapted than the Montbéliarde one to produce milk in the Pépi system. But, as pointed out by Blanc et al. (2006), this ability to maintain a good production level can be antagonistic with the reproductive efficiency and the sustainability of the system.

Table 4: Milk production of Bota and Pépi herds, by year (1st April to 31 March) and by breed

		Bota		Pépi	
	(in kg)	Holstein	Montbéliarde	Holstein	Montbéliarde
2011	primiparous	9 950	13 210	15 070	14 160
	multiparous	51 900	40 740	53 340	42 790
2012	extended lactation cows	8 970	13 220	16 190	9 510
	primiparous	17 360	12 590	32 760	21 920
	multiparous	19 600	11 490	11 510	11 710
	2013 advanced calvings	-	130	100	280
Two years		107 780	91 380	128 970	100 370

The average milk fat and protein contents from the Bota and Pépi systems over the 2 years are presented in Table 5. As expected, the fat content is lower and the protein content higher in Pépi, linked to the concentrate supplementation. In 2012, fat and protein contents would have been lower than in 2011 if extended lactation cows which produced a very "concentrated" milk were excluded. For the Bota system, milk of the latter cows particularly helped to avoid the protein content to fall below 30 g/kg from mid-June to end of August, as in 2011.

Table 5: Milk composition of Bota and Pépi herds, by year (1st April to 31 March)

		Bota		Pépi	
Contents	*(in g/kg)*	Fat	Protein	Fat	Protein
2011	total herd	39.7	31.2	38.5	32.5
2012	total herd	41.8	32.9	37.7	33.3
	without extended lactation cows	40.2	30.7	37.0	31.9
	extended lactation cows	45.4	38.5	39.8	38.1
Two years		40.6	31.9	38.1	32.8

Concentrate feeding

The main difference between the two systems is that cows from Bota received no concentrate during the 2 years meanwhile, in accordance with the protocol, cows from Pépi received on average 4 kg/d of concentrate from calving to the end of the pasture season. This corresponded to 879 kg/yr of concentrate (1/3 wheat, 1/3 barley, 1/3 maize), with no difference between primiparous/multiparous or years. However, the Holstein cows received significantly more concentrate than the Montbéliarde cows (+102 kg/yr; $P<0.01$), due to their lower BCS and higher milk production. Holstein cows seem to have used more efficiently the concentrate in relation to the quantity of milk produced (175 *vs.* 212 g concentrates/kg milk; $P<0.05$). This result confirms that the Holstein breed seems to be better adapted than the Montbéliarde one to produce milk in the Pépi system.

Cheeses characteristics

Bota milk yielded in average +0.2 kg ripened cheese /100 kg milk in comparison to Pépi milk (Table 6). This slightly higher yield is linked to the higher fat content of Bota milk compared to Pépi milk (38.0 *vs.* 34.2 g/kg) which offsets its lower protein content (28.0 *vs.* 29.3 g/kg). In comparison to Bota cheeses, Pépi cheeses had a yellower coloration certainly linked to the leafy grass grazed in Pépi that could lead to a higher β-carotene content of grass and cheeses. Bota cheeses were characterized by a less firm and more melting texture certainly related to the higher fat in dry matter consecutive to the higher fat to protein ratio of Bota milk. In comparison to Pépi cheeses, the odour of Bota cheeses made with raw milk was described as more intense and characterized as more "fermented cream" and "yeast". The odour differences between Bota and Pépi cheeses were much lower and non significant when milk was pasteurized prior to cheesemaking. Similar interactions have already been reported in the literature (Martin et al., 2005) but, in this case, further chemical and microbial analyzes are required to understand the origin of the odour differences.

Table 6: Chemical and sensory characteristics of the 5 month ripened Cantal cheeses made in July 2012 with the bulk milk from the Bota and Pépi cows (extended lactation cows excluded)

	Bota		**Pépi**	
Milk treatment	Raw milk	Pasteurized milk	Raw milk	Pasteurized milk
Cheese yield (%)	8.6 ± *0.16*	8.4 ± *0.16*	8.3 ± *0.44*	7.9 ± *0.30*
Dry Matter (%)	63.6 ± *0.97*	63.6 ± *0.31*	63.6 ± *0.49*	64.4 ± *0.85*
Fat in Dry (%)	55.7 ± *1.35*	54.0 ± *0.80*	51.0 ± *1.04*	50.0 ± *0.78*
pH	5.56 ± *0.08*	5.36 ± *0.10*	5.60 ± *0.01*	5.47 ± *0.10*
Sensory descriptors (0-10)				
Yellow color	5.6 ± *1.00*	6.4 ± *1.12*	6.2 ± *1.08*	6.7 ± *0.97*
Firm Texture	4.6 ± *1.14*	5.8 ± *0.99*	5.0 ± *1.08*	5.8 ± *1.05*
Melting Texture	5.1 ± *1.47*	4.7 ± *1.17*	4.8 ± *1.24*	4.2 ± *1.38*
Intense Odour	6.2 ± *1.06*	5.1 ± *1.25*	5.6 ± *1.45*	4.9 ± *1.30*
Fermented Cream Odour	1.7 ± *1.50*	0.8 ± *1.02*	1.4 ± *1.37*	0.9 ± *1.11*

In conclusion, these first results show the feasibility of low input farming systems in mountain areas, where the milk produced is devoted to the manufacture of high quality cheeses. The sustainability of these systems shall nevertheless be assessed taking into account the low reproductive performances of the cows during the first experimental year. Other solutions to improve reproduction and renewal will be implemented: the advancement of the calving period, the use of sexed semen and the practice of once-a-day milking at calving for selected cows. In addition, these results confirm that the pasteurisation of the milk prior cheese making disrupt partly the link to terroir.

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Effects of pasture characteristics and farming practices on fatty acid profile of pasture-derived milk

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Abstract

This work aimed to evaluate the effect of herbage nutritional value, phenology and botanical composition, and of farming practices on fatty acid (FA) profile of pasture derived-milk. Thirty-six bulk milk derived from 36 dairy herds were sampled for FA analysis during the grazing season 2011 form herds grazing on lowland, mountain, and highland pastures. Grazed vegetation was sampled and analyzed for nutritive value and divided into botanical groups (grasses, legumes, and forbs). Herbage phenological stage was determined following BBCH scale. High concentrations of milk saturated FA were associated to mature herbage, and low herbage proportion in cow diet. The C18:1cis9 showed high concentrations in milk when herbage non-structural carbohydrate content was high and neutral detergent fiber (NDF) content was low. Milk branched chain FA were positively related to herbage NDF content. Increasing concentrations of CLAcis9trans11 in milk were associated with increasing herbage proportion in cow diet, and increasing concentration in C18:3n-3 and polyunsaturated FA (PUFA) to high herbage proportion in cow diet, high forb proportions and early phenological stage. Promising prediction models were developed for C18:3n-3, basing on herbage DM content, phenological stage and proportion of forbs; and for PUFA, basing on herbage proportion in cow diet, phenological stage and forbs proportion. The work highlights the greater importance of herbage phenology and nutritive value compared to altitude on FA profile of pasture-derived milk.
Keywords: milk fatty acids, upland pasture, herbage phenology.

Introduction

The effect of pasture feeding on milk FA composition compared to conserved forages-based diets is well known (Chilliard et al., 2007). Several research have been carried out to understand the effect of herbage characteristics on milk FA composition, mainly focusing on botanical composition (Leiber et al., 2005). Only few research projects studied the effect of herbage phenology (Coppa et al., 2011; Tornambé et al., 2010). These studies have been conducted in controlled condition, thus, little is known about the relative effects of herbage characteristics on FA composition of milk derived from commercial farms. This work aimed to evaluate the effect of herbage nutritive value, phenology, botanical composition, and of farming practices on FA profile of pasture derived-milk from commercial farms.

Material and methods

Thirty-six bulk milk derived from 6, 13, and 17 herds, grazing on lowland (<500 m a.s.l.), mountain (500-1200 m a.s.l.), and highland (>1200 m a.s.l.) pastures, respectively, were sampled during the grazing season 2011 in north-western Italy. Farming practices were recorded thought on farm surveys. Grazed vegetation was sampled and analyzed for nutritive value, as described by Revello Chion et al. (2010). A sub-sample was also divided in three botanical groups (grasses, legumes, and forbs) and oven-dried to constant weight. Herbage phenological stage was also determined by following BBCH scale (FBRCAF, 2001). Milk samples were analyzed for fat and protein contents by infrared spectroscopy (MilkoScan FT6000, Foss System, Hillerød, Denmark) and for FA composition by gas-chromatography (GC) according to Revello Chion et al. (2010) for sample preparation, and Coppa et al. (2011) for GC analysis. A principal component analysis (PCA) was performed on the farming practices and milk FA composition data, using SPSS-17 (SPSS Inc., Chicago, IL – USA). Prediction model based on farming practices were developed for C18:3n-3 and PUFA using Minitab 14.1 (Minitab.inc - State College, PA - USA).

Results and discussion

Farming practices, characteristics of grazed herbage, and the bulk milk FA composition according to the altitude of grazed pasture are reported in Table 1.

Table 1: farming practices, fresh herbage characteristics, and bulk milk FA composition according to the altitude of grazed pasture. SD = standard deviation; De novo FA = Σ C4 to C14 even chain FA; SFA-EC = Σ all even chain saturated FA; OCFA = Σ odd chain FA; BCFA = Σ branched chain FA; MUFA = Σ monounsaturated FA; PUFA = Σ polyunsaturated FA.

Item	Highland				Mountain				Lowland			
	Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD
Farming practices												
Dairy cows (n/farm)	28	5	70	20	20	6	50	17	27	18	43	11
Milk yield (L/cow per day)	7.4	5.0	15.0	3.1	8.5	4.9	15.0	3.7	5.6	4.0	9.0	1.7
Milk fat (g/100 g milk)	4.25	3.46	6.41	0.70	3.70	3.33	4.37	0.34	3.82	3.67	3.96	0.12
Milk protein (g/100 g milk)	3.53	3.21	4.34	0.26	3.31	2.93	3.87	0.25	3.59	3.33	3.98	0.26
Fresh herbage (% DM intake)	100	93	100	2	75	45	100	19	71	55	100	17
Hay (% DM intake)	0	0	0	0	14	0	41	18	23	0	45	19
Concentrates (% DM intake)	0	0	7	2	12	0	15	4	6	0	16	8
Pasture altitude (m a.s.l.)	2086	1520	2500	258	812	500	1200	251	317	250	375	49
Fresh herbage characteristics												
DM (%)	34.7	24.2	47.2	6.5	23.0	18.2	31.4	4.3	22.0	18.2	32.5	5.2
NDF (% DM)	53.2	43.5	65.6	6.0	52.2	44.0	62.2	5.4	44.6	40.7	49.0	3.1
CP (% DM)	11.0	8.1	13.9	1.5	13.6	12.0	17.3	1.6	17.3	15.6	19.3	1.4
NSC (% DM)	27.5	19.0	35.6	5.0	23.8	15.5	32.6	4.3	25.5	21.9	28.4	2.8
Grasses (% DM)	46.0	20.1	67.5	16.5	51.8	21.8	83.3	19.5	31.2	4.4	47.3	14.5
Legumes (% DM)	16.1	1.0	58.1	17.5	11.5	0.3	32.4	10.6	62.6	49.0	93.2	16.2
Forbs (% DM)	38.0	7.1	75.5	16.8	36.6	16.4	63.1	15.4	6.3	0.0	16.8	7.7
Phenology (BBCH scale)	31	19	49	9	30	20	43	8	51	36	77	17
Milk FA (g/100g FA)												
De novo FA	18.23	15.67	21.76	1.78	19.06	16.40	22.62	1.79	19.09	16.57	20.95	1.61
C16:0	21.86	19.46	24.97	1.21	23.93	21.20	28.08	1.90	21.87	20.68	23.74	1.15
C18:0	11.07	9.10	13.42	1.10	10.63	8.61	12.20	0.95	12.22	11.18	13.08	0.83
C18:1trans11	4.16	2.67	5.98	0.91	3.33	2.33	4.53	0.75	2.80	2.09	4.01	0.68
C18:1cis9	22.45	18.24	27.59	2.66	23.19	19.67	26.60	2.07	23.71	21.68	26.49	2.00
C18:2n-6	1.58	1.15	1.98	0.27	1.47	0.94	1.98	0.35	1.48	1.13	1.97	0.34
C18:3n-3	1.72	0.87	2.82	0.44	1.12	0.79	1.62	0.30	1.14	0.88	1.38	0.21
CLAcis9trans11	1.90	1.14	2.48	0.44	1.72	1.17	2.28	0.39	1.25	0.85	1.89	0.35
SFA-EC	51.58	47.35	56.81	2.48	53.92	49.87	59.63	3.06	53.56	51.30	56.20	1.98
OCFA	2.85	2.28	3.46	0.35	2.71	2.38	3.11	0.21	3.14	2.55	3.69	0.45
BCFA	2.75	1.82	3.47	0.44	2.52	2.18	3.09	0.29	2.55	2.05	2.89	0.34
MUFA	33.76	29.53	37.98	2.37	33.62	29.04	37.86	2.49	33.84	31.21	35.93	1.78
PUFA	6.82	5.20	8.62	0.82	5.67	4.54	7.11	0.91	5.51	4.90	6.47	0.62

Milk FA concentration showed large variation within each altitude group, however the range of variation were widely overlapped among highland, mountain and lowland groups for almost all FA. Higher maximum in highland group were observed only for C18:3n-3 and PUFA compared with the others groups, whereas the lowland group showed a lower maximum for CLAcis9trans11.

The small size of dairy herds, the low milk yield, and the pasture based diets (occasionally supplemented with hay and small amounts of concentrates) were farming practices common to all the studied farms, regardless the altitude. Thus, these farms can be considered representative of the extensive dairy farming system of north western Italy. Fresh herbage characteristics varied widely within each altitude group. The dry matter (DM) content of fresh herbage showed higher maximum and minimum values in the highland group, whereas NDF had a lower maximum in the lowland group. The fresh herbage non-structural carbohydrates (NSC) had an higher minimum in the lowland group. The maximum and minimum for crude protein (CP) content decreased from highland to lowland. Lowland herbage had less forbs and grasses, than the two other groups, whereas legumes became dominant. In lowland herbage was grazed at a later phenological stage than in highland.

According to the PCA, high concentration of milk SFA-EC were associated to mature herbage, and low herbage proportion in cow diet, in agreement with previous findings in controlled conditions (Coppa et al., 2011; Couvreur et al., 2006). The C18:1cis9 showed high concentrations in milk when herbage NSC content was high and NDF content was low, suggesting increase in this FA in mature herbage (Coppa et al., 2011; Tornambé et al., 2010). Milk branched chain FA (BCFA) were positively related to herbage NDF content. Vlaemink et al. (2006) demonstrated that BCFA derive from ruminal cellullolytic bacteria, and they increase in milk as fiber content increases in cow diet. High concentrations of CLAcis9trans11 in milk were associated with high herbage proportion in cow diet. High concentration in C18:3n-3 and PUFA were associated to high herbage proportion in cow diet, high forbs proportions, and early phenological stage. Increases in CLA cis9trans11 and C18:3n-3 with increasing herbage proportion in cow diet are in agreement with Couvreur et al. (2006), and high concentration of C18:3n-3 in milk have been observed when cow grazed herbage at an early phenological stage (Tornambé et al., 2010). An increase in C18:3n-3 with high forbs proportion in ingested herbage have been explained by a possible partial inhibition of ruminal biohydrogenation bacteria by plant secondary metabolites, which are abundant in forbs (Leiber et al., 2005).

On the PCA sample distribution plot (Figure 1) samples belonging to different altitude groups were confounded, suggesting that altitude itself had a small effect on FA of pasture-derived milk, if compared to fresh herbage nutritive value and phenology. Altitude could mask some difference in farming practices, such as different herbage proportion in cow diet, or pasture grazed at different phenological stages, due to different distribution in herbage allowance during the season, or finally different pasture botanical composition, and, when these factors are separated from the altitude in "*sensu stricto*", the altitude effect reduces in its importance.

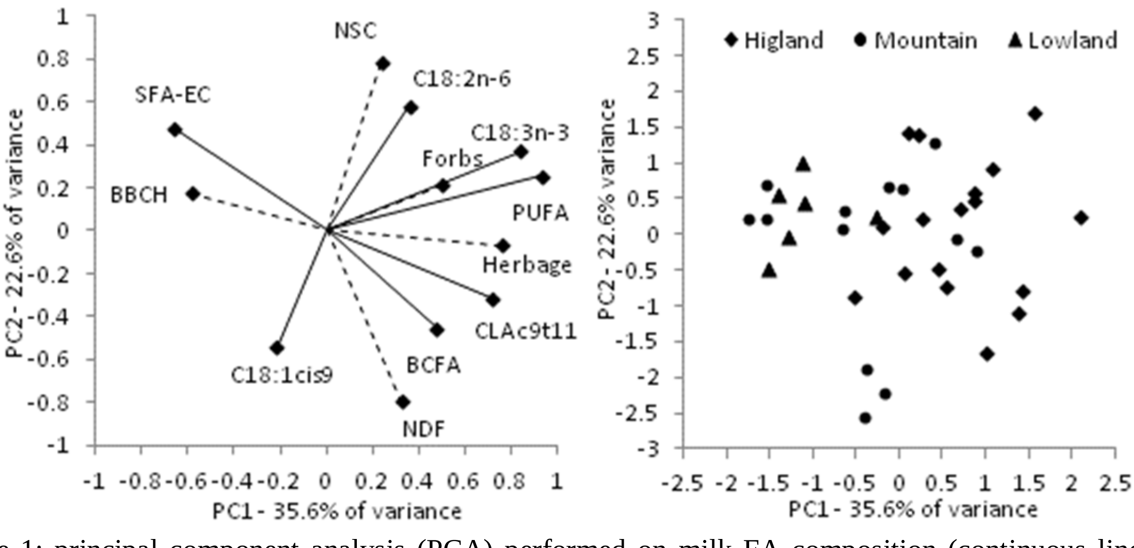

Figure 1: principal component analysis (PCA) performed on milk FA composition (continuous lines) and production condition and herbage characteristics (dotted lines). Plot of variable (left side) and sample (right side) distribution projected on the two principal components (PC1 and PC2). Herbage = % of fresh herbage in cow diet; NDF = neutral detergent fiber; NSC = non structural carbohydrates; BBCH = herbage phenology (BBCH scale); Forbs = % on DM of forbs on grazed herbage; SFA-EC = sum of even chain saturated FA; BCFA = sum branched chain FA; PUFA = sum of polyunsaturated FA.

Promising prediction models (Figure 2) were developed for C18:3n-3, basing on herbage DM content, phenological stage and proportion of forbs (C18:3n-3 = 2.63(±0.43) -0.029(±0.01)*herbage DM-0.021(±0.006)*BBCH+0.008(±0.003)*Forbs; R^2adj = 0.61, RMSE = 0.29); and for PUFA, basing on herbage proportion on cow diet, phenological stage and forbs proportion (PUFA = 5.29(±0.97)+ 0.018(±0.09)*fresh herbage %-0.030(±0.012)*BBCH+0.015(±0.008)* Forbs; R^2adj = 0.51; RMSE = 0.71), confirming the trend sowed by the PCA.

The work highlighted the greater importance of herbage phenological stage and nutritive value compared to altitude on FA profile of pasture-derived milk.

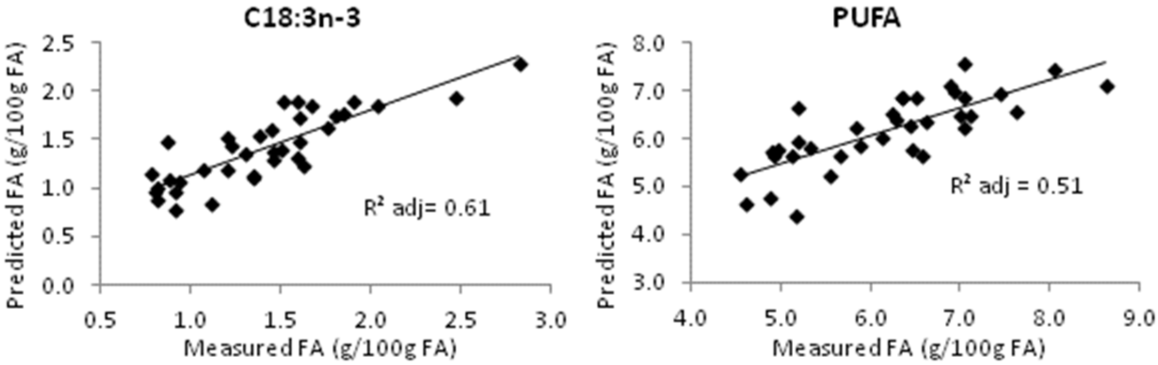

Figure 2: Linear regression plots of measured versus predicted values for C18:3n-3 and PUFA model based on farming practices and herbage characteristics.

Acknowledgments

This work was funded by the Regione Piemonte, Assessorato Qualità, Ambiente e Agricoltura, years 2010 to 2013 project “Miglioramento della qualità nutrizionale e della sicurezza alimentare e microbiologica della filiera lattiero-casearia in Piemonte”

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High altitude stress of the Tibetan Plateau confers alpine herbages and animal products with high nutritive value and quality

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Abstract

The Tibetan Plateau, often called the 'third pole of the world', is the highest and largest mountainous plateau on the globe with a mean altitude of above 4,000 m a.s.l. With an area of 129.3×10^6 ha of grassland, it accounts for 32.5% of China total grassland area. Year-round survival of the Tibetan livestock is largely dependent on the native alpine pastures, which are characterized by high altitude, suffering from very low annual average temperature (-5 to -1 °C) and strong ultraviolet radiation, short growing season (from June to September), quite low primary productivity, and without an absolute frost-free period. Under the harsh environment, physiological adaptation of native herbages to the high altitude stress normally results in increases of crude protein, antioxidants, total lipid, soluble carbohydrate, α-linolenic acid concentrations as well as *in vitro* dry matter digestibility by the herbivores, and decreases in neutral and acid detergent fibers, lignin, and some fatty acids (*i.e.*,palmitinic, palmitoleic, stearic, oleic, linoleic acids). These chemical components changes not only confer alpine herbages with high nutritive value to local herbivores, but also allow the herbivores produce high quality food. Compared with milk from low land ruminant species, yak milk products seem to be particularly rich in nutritional and biologically active ingredients, such as protein and some essential amino acids, lipid, antioxidants of vitamins A, E and C, *n*-3 fatty acids (FA) and conjugated linoleic acids (CLA); and the proportions of total polyunsaturated FA (PUFA), total unsaturated FA (UFA) and the *n*-3/*n*-6 FA ratio are higher in yak milk fat and its products than that from cattle, sheep and goats. The relative richness in functional and bioactive components is thought to play a role in maintaining the health status of Tibetan nomads under high altitude stress.
Keywords: high altitude stress, alpine herbage, animal products, Tibetan Plateau

Introduction

The Tibetan Plateau is the highest and largest mountainous plateau on the globe with a mean altitude of above 4,000 m a.s.l. and an area of 2.5million km^2 (Liu and Chen, 2000). Because of its high altitude and harsh environment, agricultural cultivation is excluded in most areas of the plateau. The major way of land use on the plateau is grazing animals. As described by Miller (1998), the Tibetan Plateau is an extremely harsh environment and one of the harshest pastoral areas on earth still used extensively by pastoralists. Over half of the plateau is covered by the native rangeland, and more than 14 million yaks (*Bosgruniens*) and over 50 million Tibetan sheep (*Oviesaries*) are inhibited on this plateau. About 10 million populations of pastoralists including nomadic, semi-settled and entire-settled herders are living on this plateau relying on grazing Tibetan ruminants, and obviously native rangeland is their vital resources of livelihoods (Long, et al., 2008). Interestingly, the physiological adaptation strategies of alpine plants to the harsh environment of the Tibetan Plateau normally result in alpine herbages with high nutritive values to herbivores (Guo et al., 2012). Consequently, herbages from the alpine pastures and the high altitude stress confer some beneficial characteristics to the animal product, such as yak milk, with higher concentrations of human healthful fatty acids than conventionally produced lowland milk, and those beneficial characteristics in animal products of yak were thought to play an important role in maintaining health status of Tibetan nomads living under high altitude stress (Guo et al., 2013).

Characteristics of the nutritive value of alpine herbage growing on the Tibetan Plateau

Numerous literatures have reported that herbages growing in alpine pastures of the Tibetan Plateau are characterized by high concentrations of crude protein, soluble carbohydrates, nitrogen free extract, energy, digestibility, and low fibre concentration compared to the herbages from low land pastures (Long et al., 1999; Guo et al., 2012; Shi et al., 2013). All these nutritive characteristics of alpine herbages were proved to be attributed to physiological adaptation of these plants to the harsh environment of cold, strong ultraviolet and possibly hypoxia. Basically, when plants are grown at high altitudes, increases in crude protein (CP), ether extract and some carbohydrates cause higher concentrations of them in cell protoplasm, which decreases its freezing point and enhances its adaptive resistance to cold (Zhang and Ma 1982). As reported by Urrutia et al. (1992), there are some ‘antifreeze’ proteins in ‘antifreeze’ plants, and proposed that expression of these proteins is a result of adaptation of the plants to the cold. Therefore, the increased CP in the herbage was probably due to accumulation of ‘antifreeze’ proteins under the increased cold stress of high altitude. Moreover, it has been proved that the low temperature at high altitudes can restrain plant respiration and cause slower metabolic activities, which increases the pool of metabolites in the cellular content such as nitrates, proteins, and soluble carbohydrates, and thereby are favorable to soluble carbohydrate accumulation. This could decrease some structural carbohydrates such as cellulose, hemicellulose and lignin because the low temperature prevented lignifications of plant cell walls (Zhao and Zhou, 1999; Xu et al., 2002).

Our previous research showed that crude protein and ether extract concentrations in the alpine herbage of *Kobresia. littledalei* were higher at the higher altitude, but fiber concentration was lower at the lower altitude, and CP content increased by as much as 50% when elevation increased almost one thousand meters from 3,980 to 5,100 m (Guo et al., 2012).The structural fiber concentration in the herbage was lower at the higher altitude and that, from 3,980 to 5,100 m, the neutral detergent fiber (NDF) concentration in the herbage decreased about 10%, and lignin concentration in the herbage growing at 5,100 m decreased by almost 70% compared to that at 3,980 m. In addition, proportions of fatty acids in the lipid fraction of the herbage from different elevations differed. Lower cis-9 C18:1, C16:0, cis-9 C16:1, C18:0, cis-9, cis-12 C18:2 and higher in cis-9, cis-12 and cis-15 C18:3 occurred in the herbage growing at the highest altitude. Therefore, high concentration of α-linolenic acid in alpine herbage may contribute to the high proportion of polyunsaturated fatty acids in milk fat from highland (Leiber et al., 2005). Therefore, it can be concluded that the metabolic changes and physiological processes which protect herbages growing on cool alpine pastures of the Tibetan Plateau result in herbages with a high feeding value to local herbivores, and consequently contribute the herbivores produce high quality food.

Characteristics of animal product quality of yak on the Tibetan Plateau

Based on the fatty acid composition of yak meat and cheese (Table 1), animal products of yak contain more health beneficial fatty acids than that from lowland cattle. The reason for the healthy fatty acid composition in highland animal products is still unclear despite several hypotheses such as: (i) body fat mobilization with a preference for 18:3n-3 takes place as a result of an energy deficiency associated with high altitude due to insufficient feed intake; (ii) ruminal biohydrogenation activity was reduced by a dietary energy deficiency and (iii) unknown plant secondary components which inhibit ruminal microbial growth, have been addressed (Leiber et al., 2005). However, high concentration of α-linolenic acid in alpine herbage could be one of the reasons that contribute to the high proportion of polyunsaturated fatty acids in milk fat from highland grazed cows.

Table 1. Proportions of fatty acids and groups of fatty acids in meat and cheese from yak and lowland cattle (g/kg of total fatty acids)

Fatty acid	Meat[1]		Cheese[2]	
	Highland yak (Bosgrunniens) meat	Lowland beef cattle meat (Bostaurus)	Highland Yak Cheese	Low land Cow cheese
Linoleic acid	9.4	4.31	21	28
α-linolenic acid	-	-	17	4.9
Arachidonic acid	3.4	1.52	1.2	1.5

CLA	-	-	23	5.7
EPA	2.3	0.92	0.68	0.41
DHA	0.18	0.05	0.23	0.06
SFA	50.9	59.5	595	651
MUFA	34.0	33.2	324	301
PUFA	15.4	7.1	45	37

Data sources: [1]Yang et al., 2008;[2]Or-Rashid et al., 2008.
CLA, conjugated linoleic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; SFA, short chain fatty acid; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

It was proposed that in the highland pasture ecosystem of the Tibetan Plateau, the flow of some critical nutrients (*i.e.* antioxidants and omega-3 fatty acids)from native plants to animals and humans may play an important role on the health of Tibetan nomads living under high altitude stress (Guo et al., 2013). The relative richness of nutritional and biologically active ingredients in yak meat and milk derived food, under the inhospitable high-altitude environment, could be an excellent example of how an indigenous diet may have enabled these nomads to adapt and live healthily for thousands of years in the extreme environment of the Qinghai-Tibetan Plateau. Although some research has been conducted to investigate the multi-functionality of animal food from yak, systematic studies are still needed to demonstrate the potential role of the functional ingredients in the foods derived from yak on human health in a more mechanistic way. This systematic work would be much meaningful in helping us to better understand the relationship among plant, animal and human being in the whole alpine ecosystem of the Tibetan rangeland.

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Alpine vegetation type affects composition of nutritionally important C18 fatty acids in tissues of lambs from different breeds

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Abstract

A total of 110 lambs of the breeds Engadine Sheep and Valaisian Black Nose Sheep were fattened on one lowland and three different alpine pasture types. The experiment was conducted in two consecutive years and lasted for 9 weeks of grazing in each year. Immediately afterwards, the lambs were slaughtered. Perirenal adipose tissue and the *Longissimus dorsi* muscle were analysed for fatty acid composition. The lambs on the lowland pasture had the lowest proportions of linoleic and α-linolenic acid in the lipid fraction of these tissues. Additionally, there was a clear differentiation in these proportions when lambs grazed different alpine vegetation types. This was related to the content of phenolic compounds rather than the fatty acid contents of the swards, and an increasing phenolic level probably resulted in a higher ruminal protection of the native plant fatty acids. Intermediates of biohydrogenation (vaccenic acid and conjugated linoleic acid) were highest in the lowland lambs. Animal breed effects were weak.

Introduction

The generally positive effect of grazing alpine pastures on the fat quality of ruminant-source foods is well established, especially for dairy foods (Leiber, 2011). There is evidence for an influence of plant secondary compounds from the alpine swards on ruminant lipid metabolism (Leiber, 2011), but there is only few data about actual phenolic concentrations in different vegetation types and the related fatty acid (FA) profiles in the foods produced (Falchero et al., 2010; Povolo et al., 2012). Further, there is only little knowledge about the lipid quality in lamb meat derived from mountain pastures (Ådnøy et al., 2005). Therefore, a study was designed to evaluate the FA composition in the lipids of adipose and functional tissues of lambs fattened on different lowland and alpine vegetation types. By fattening two different breeds on each pasture, it was also targeted to investigate the interaction of animal breed and vegetation type.

Animals, Pastures & Methods

In two summer seasons, 2010 and 2011, lambs of two indigenous Swiss mountain sheep breeds, Engadine Sheep (ES) and Valaisian Black Nose Sheep (VS), were fattened for respectively 9 weeks either on lowland vegetation or on one of three different alpine vegetation types (2000 m a.s.l.). In each year, 6-7 lambs per breed and pasture type were included in the experiment. At the start of the experimental periods the live weights of ES and VS were 32.7±3.5 kg and 30.8±2.9 kg (2010) and 35.1±4.3 kg and 37.5±5.0 kg (2011), respectively. The ages of ES and VS were 26±2, 18±7 (2010), and 26±2 and 27±3 weeks (2011), respectively.

The vegetation types were selected to clearly differ in forage quality and plant species composition. The lowland pasture ("lowland") contained 9 species (as found according to the method of Braun-Blanquet, 1964), while the alpine high quality pasture (nutrient-rich *Crepido-aurea Festucetum*; "alpine HQ") contained 30 species, the alpine moderate quality pasture (nutrient-poor *Crepido-aurea Festucetum*; "alpine MQ") contained 71 species and the alpine low quality pasture (*Geo montani-Nardetum*; "alpine LQ") contained 37 species (more details given in Willems et al., 2013). Neutral detergent fibre (NDF) was analysed according to Van Soest et al. (1991); phenolic compounds were determined as described by Jayanegara et al. (2010), and fatty acid proportions were measured gas chromatographically following the settings as presented by Leiber et al. (2011).

After 9 weeks, the lambs were slaughtered. Samples from the *Longissimus dorsi* muscle and the perirenal adipose tissue were taken from each animal. Lipids from these samples were extracted, transesterified and analysed for fatty acid profiles by gas chromatography as described by Leiber et al., (2011). Data was subjected to analysis of variance considering pasture breed and year as fixed effects and animal as random effect using SAS (version 9.2, SAS Institute, Cary, NC, USA).

Results and Discussion

On the two high-quality pastures (lowland and alpine) the NDF contents were lower in 2011 than in 2010; on the other pastures the values did not differ between years. On average of both years, the neutral detergent fibre contents (NDF) were 51, 42, 44, and 67 g/100 g dry matter (DM) for lowland, alpine HQ, alpine MQ, and alpine LQ, respectively. The corresponding contents of total phenolic compounds (averages over both years) were 1.6, 2.9, 4.6, and 2.3 g/100 g DM, respectively. This means that the alpine MQ pasture had almost three times higher concentrations of phenolic compounds than the lowland pasture ($P<0.001$). This effect was also true for both individual years. Proportions (g/100 g total FA) of linoleic acid (LA; 18:2n-6;) and α-linolenic acid (ALA; 18:3n-3) in herbage were 16.9 and 49.7 for the lowland pasture, 16.2 and 48.6 for the alpine HQ, 16.1 and 38.3 for alpine MQ, and 14.0 and 32.2 for alpine LQ, respectively. Overall, proportions of these fatty acids were lower in the alpine pasture swards ($P<0.001$). For ALA, there was a year effect (2010 higher than 2011), but no interaction with pasture type; the pasture effect was the same in both years.
The proportions of LA and ALA in the perirenal adipose tissue of the lambs were the lowest when grazing in the lowlands (2.28 and 1.19 g/100 g FA), followed by alpine LQ (2.73 and 1.43), alpine HQ (2.97 and 1.84) and alpine MQ (3.53 and 2.23) (vegetation effect, $P<0.001$). There was no year effect for any of both FA. The proportion of conjugated linoleic acid (CLA; 18:2*c*9*t*11) was highest when lambs grazed in the lowlands (0.88 g/100 g total FA) compared to the alpine pastures (0.72, 0.69 and 0.66 in alpine HQ, MQ, and LQ, respectively; vegetation effect, $P<0.001$). in 2011, the CLA concentrations in adipose tissue were higher than in 2010 ($P<0.05$). Vaccenic acid (VA; 18:1*t*11) proportion in adipose tissue was highest in the lowland group ($P<0.001$); here, no year effect occurred.
In the intramuscular lipids, the proportions of LA and ALA were more than twice as high compared to the adipose tissue. Again, the lambs that grazed the alpine MQ pasture showed the highest proportions of these FA. In detail, the respective proportions (g/100 g FA) of LA and ALA were 8.69 and 3.44 in alpine MQ lambs and 5.71 and 2.18 in lowland lambs ($P<0.001$). The ALA and LA concentrations were intermediate for the lambs from the other two alpine pastures. In 2011, the concentrations of LA and ALA in the muscle were lower than in 2010 ($P<0.001$). Only the proportion of CLA (but not of VA) was increased in the muscle lipids under lowland grazing conditions compared to the alpine grazing treatments.
Only few effects of the sheep breed occurred, like a higher proportion of polyunsaturated FA concentration in the adipose tissue of VS compared to the ES ($P<0.05$).
The results show that increasing total phenol concentrations in the forage were associated with an increase in ALA and LA proportions in the body tissue lipids, regardless of the proportions of these FA in the forage lipids. The same was indicated by the year effect on ALA and LA proportions in the intramuscular fat, which corresponded to the year effect on phenolic compounds in the swards. The phenolic compounds may have reduced the first steps of ruminal biohydrogenation, resulting in enhanced carry-over of ALA and LA, depending on the botanical and chemical composition of the swards. Also in agreement with data from other *in vivo* and *in vitro* studies (e.g. Cabiddu et al., 2005, 2010; Leiber et al., 2005; Jayanegara et al., 2011), it becomes clear that phenolic compounds from herbs may act as efficient inhibitors of the first biohydrogenation step and that this influences the lipid composition of meat and milk, also in mountain pasture grazing systems.
By contrast, the biohydrogenation intermediates VA and CLA are more accumulated under lowland grazing conditions, indicating a different effect of the same phytochemicals on these FA. A general promoting effect of fresh pasture on these two FA has been repeatedly shown for cattle (Leiber et al., 2005; Khiaosa-ard et al., 2011), but the differentiated effects of varying pasture types are not the same as for LA and ALA.

Conclusion

In conclusion, the positive effect of alpine grazing on the lipid composition of ruminant-source foods has also been shown for lambs, and furthermore, a clear phenolic-compound linked differentiation between contrasting alpine pasture types with respect to their influence on the FA profile in animal tissues was demonstrated.

Acknowledgement

This work was funded by the ETH Research Grant no. ETH-24 09-3 of ETH Zurich.

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SESSION 2 – Management of pastoral areas

Dynamilk: a farming system model to explore the balance between forage and milk production in mountain grassland based systems

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Abstract

Leaning towards a better feed and forage self-sufficiency enables to improve dairy farm competitiveness and their ability to cope with climatic events and production constraint changes. A better match between dynamic of dairy cattle needs and herbage supply could allow the farming system to enhance forage self-sufficiency at farm-scale. Building a model at farm-scale enables to explore different dairy systems with contrasting production strategies to understand what are the possible trade-offs between animal production, feed and forage self-sufficiency and sustainable grasslands use. Such a dynamic model, called Dynamilk, has been developed.

Two systems have been simulated, the first one based on autumn calving distribution from August to February (AC), and the second one based on spring calving from March to June (SC). Several simulations have been accomplished to evaluate concentrate decrease on milk production, herbage utilization and forage self-sufficiency. Results have shown that: i) milk performances are significantly better for SC than AC and SC system is less sensitive to forage quality variations than AC; ii) effects of concentrate feed reductions on milk yields are mitigated by a better use of grass.

Keywords: dairy farming system, modeling, grasslands, forage system, forage self-sufficiency

Introduction

Dairy farming systems located in mountain areas undergo geographical, soil and weather conditions constraints which minimize their competitiveness on domestic market. Maintaining cost production at a low level, developing and promoting quality products to diversify dairy production from average standard milk are both ways to compensate their lack of competitiveness (Poetsch, 2007, Bernuès *et al.*, 2011). Subscribing to Protected Geographical Status (PGS) specifications enables to promote a quality production and the special link between farming practices, milk production and “terroir” (Barjolle and Sylvander, 2003). In order to reinforce this link, cheese PGS specifications require forage systems to be based on grassland utilization through production constraints such as a better forage self-sufficiency, limits on feed concentrates supply. Maintaining cost production at a low level and abiding by the PGS specification demands can be achieved by optimizing the use of grasslands, forage and dairy cattle management. Nevertheless, these possible ways to improve forage and feed self-sufficiency should not be carried out at the expense of environment (i.e. grassland floristic diversity), milk quality and production, or impair the ability of dairy farms to cope with climatic events or production constraints changes. Indeed, dairy farming systems located in mountain areas are based on grasslands with a predominance of permanent pastures managed with low chemical inputs. Thus, these systems are very sensitive to environmental variations, climatic events and production constraints changes (Blanc *et al.*, 2010). A better match between dynamic of dairy cattle needs and herbage supply could allow the farming system to enhance forage self-sufficiency at farm-scale and its ability to cope with production changes or climatic events.

In this context, a model at farm-scale (Dynamilk) has been built in order to explore different dairy systems under geographical and production constraints with contrasting production strategies in order to understand what are the possible trade-offs between animal production, feed and forage self-sufficiency and sustainaible grasslands use.

Material and methods

Dynamilk is a dynamic model which mimics the farming system functioning of a grassland dairy farm. It is a deterministic model with a daily time step. Dynamilk is based on a bio-technical approach focused on dynamic relationships among farmer management and production system components such as dairy cattle, grasslands and feed resources. Dynamilk is designed to consider: i) dynamic animal needs and production determined by dairy cattle characteristics and farmer management; ii) dynamic herbage production depending on grassland type, forage management and weather conditions. Dynamilk is made-up of three sub-systems i.e. the farmer and its decisions, the dairy herd and the ressources with grasslands, forage stores and feed (Figure 1).

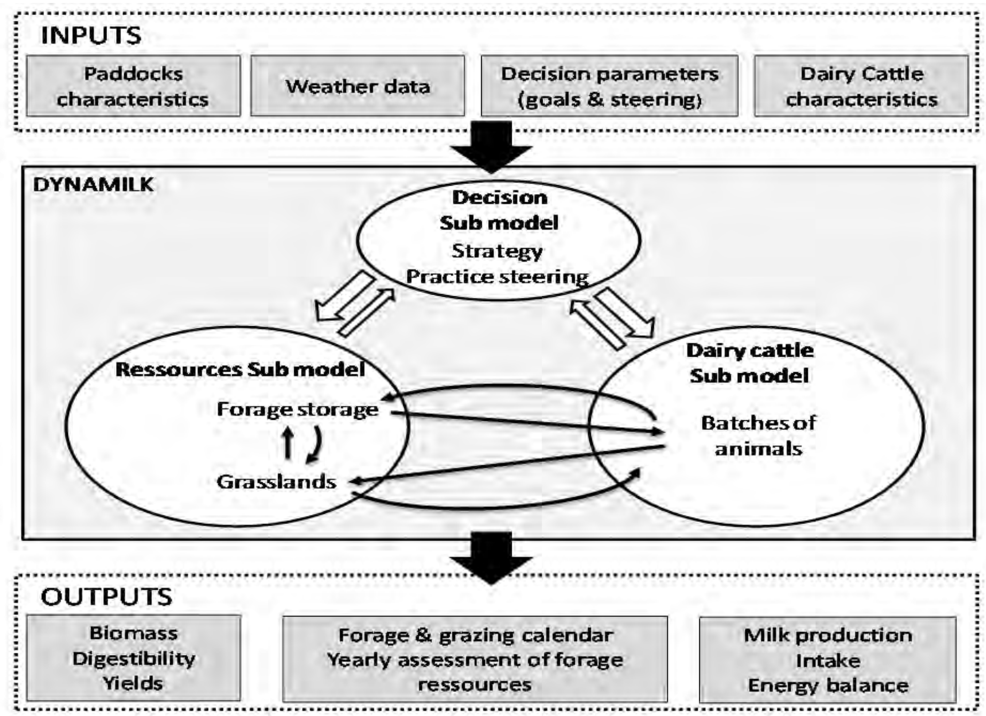

Figure 1 : Dynamilk architecture with three interrelated sub-models and the main inputs and outputs (➡ Biomass and matter flows, ⇨ information flows)

The production system components are monitored by the **decision sub-model** which represents farmer decisions and which is made up of farm management strategy with production goals and a set of rules to steer the bio-technical components towards the definied production goals. The main practices are mowing, forage stores, winter feeding, concentrate distribution and simplified rotational grazing management. The **resources sub model** is made up of field pattern with paddocks and forage storages. Each paddock is made up of sward model which predicts dynamics of biomass, structure and digestibility of herbage according to its grassland community, defined by its composition in functional types of grasses (Cruz *et al.*, 2002). This model was developped and evaluated by Jouven et al.(2006), and was designed to respond to various defloliation regimes (cut or grazing), perform multiple-year simulations. **Dairy cattle sub model** consists in 2 units: demographic structure unit and intake, milk production and body reserve use unit. This model considers calving period and distribution, dairy cattle characteristics (ability of animals to produce milk and use its body reserve) in order to test the match between animal needs and feed supply. Milk production is modeled as a result of the energy requirements defined by potential milk production, the variation of energy supply by diet and, the ability of dairy cows to mobilize or store body reserves. Energy supply by winter diet or pasture does not always match with animal requirements, defined by their physiological status (lactation, growth, pregnancy and potential milk production)

The **inputs** of Dynamilk are weather data, paddock and herd characteristics and management rules. Farm management strategy and parameters of management practices are defined in a simulation script called "scenario". These inputs enable to simulate either real dairy farms or artificial ones. Dynamilk **outputs** are milk yield in relation with herbage, forage and concentrate offers, annual herbage yields and energy values of different kind of forages, annual biomass utilization rates of grasslands, daily biomass intake, bodyscore and daily weight variations of dairy cows. In addition, Dynamilk calculates the year to year evolution of forage self-sufficiency and annual milk production. A validation of Dynamilk has been conducted by submodel and on the whole model's behavior (Jacquot *et al.*, 2012).

In order to study a better match between animal needs and herbage offer, two contrasted systems have been simulated with Dynamilk: the first one based on autumn calving distribution from august to february (AC), and the second one on spring calving from march to june (SC). A majority of milk is produced during winter time for AC and during the grazing season for SC. Farm area (about 80 ha), paddocks characteristics (grasslands dominated by productive grasses, Baumont *et al.* (2011), dairy cattle characteristics (7000kg.cow^{-1}.y^{-1} for potential milk), stocking rate (0.94 LU.ha^{-1}) and concentrate amount (1200 kg.cow^{-1}.year^{-1}) are identical for both systems, these data are based on farm survey data (Jacquot *et al.*, 2010). Only the percentage of farm area dedicated to first cut or grazing changes between AC and SC. Then, several simulations have been accomplished to evaluate effects of concentrate decrease (from 1200 to 0 kg.cow^{-1}.y^{-1}) on animal production, herbage utilisation and forage self-suficiency rate. Both system performances have been analysed on predicted results generated from weather data over 1995-2011 period. A focus on weather data over 2007-2011 period has been carried out, especially for concentrates simulations.

Results and discussion

AC and SC have been simulated over the time series 1995-2011 with a supply of 1200 kg.cow^{-1}.y^{-1} of concentrates and a stocking rate of 0.94 LU.ha^{-1}. Both milk yields of the two systems (Figure 2) point out that inter-annual variation of milk yields over 1995-2011 period is lower for SC with 211 kg.cow^{-1}.y^{-1} than AC with 284 between the two most extreme years (the average milk yield is respectively 6697 and 6791 kg.cow^{-1}.y^{-1} for AC and SC). SC milk performances seem to remain stable at the opposite of AC which shows a slow decrease from 2004 that is reinforced from 2007. Indeed, the average energy value of these forages is 0.79 UFL (French milk feed unit) between 1995 and 2003 and only 0.75 UFL between 2003 and 2011. Considering that a majority of milk is produced during winter time for AC, this drop is linked to the slow but consistent decrease of first cut forage digestibility. The correlation coefficient between digestibility and milk yield is 0.47 for AC and 0.00 for SC.

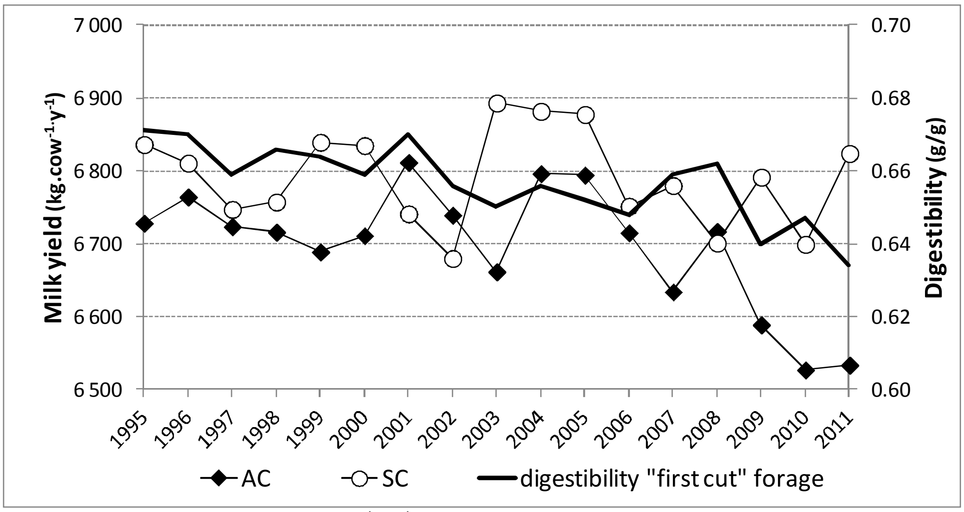

Figure 2 : Evolution of milk yields (kg.cow^{-1}.y^{-1}) of AC and SC systems and first cut forage digestibility on 1995 – 2011 time series

Simulations results on 2007-2011 time series indicate that, at a moderate stocking rate of 0.94 LU.ha^{-1} (Table 1), both AC and SC systems acheived forage self-sufficiency with no purchased forage for AC and only 1t DM for all dairy herd (12 kg DM.LU^{-1}.y^{-1}) for SC. SC has a better annual milk yield than AC. However, SC uses less grass than AC, due to a larger area allocated to grazing compared to AC, a difference which is not offset by higher requirements of dairy cows. However, both biomass utilization rates are lower than the optimum one between utilization and maintenance of a certain biodiversity, defined for this types of grasslands (Jouven and Baumont, 2008). The average simulated values for first cut fodder yields of these grasslands are 3.7 t DM.ha^{-1} for grass silage (0.80 UFL), 3.5 t DM.ha^{-1} for field-dried hay (0.69 UFL). Thereby, it indicates that at stocking rate of 0.94 LU.ha^{-1}, and with relatively productive grasslands, both systems underuse grass offer.

Table 1: Comparison of annual performances between AC and GP systems on weather data time series 2007-2011 (mean ± SD, * indicates a significant difference between AC and SC, P<0.05)

	Milk yield (kg.cow^{-1}.y$^{-1)}$	Forage self-sufficiency (t DM.LU^{-1})	Purchased forage (t DM)
AC	6600 ± 78	0.52 ± 0.51	0 ± 0
SC	6759 ± 56 *	0.34 ± 0.37	1.1 ± 2.5

Simulation of a concentrate decrease (Figure 3) implies a reduction of milk yields according a non-linear relationship between concentrate supply and milk production with a decrease of 0.90 to 1.17 kg of milk per kg of spare concentrates for AC and 0.83 to 1.05 for SC. This shows that grass offer allows to soften the effect of concentrate reductions. Figure 2 reveals that, despite the subsitution between concentrate and forage, forage self-sufficiency remains positive. Biomass utilization rate is slightly improved by respectively 3 and 2% for AC and SC due to an increase of grass intake.

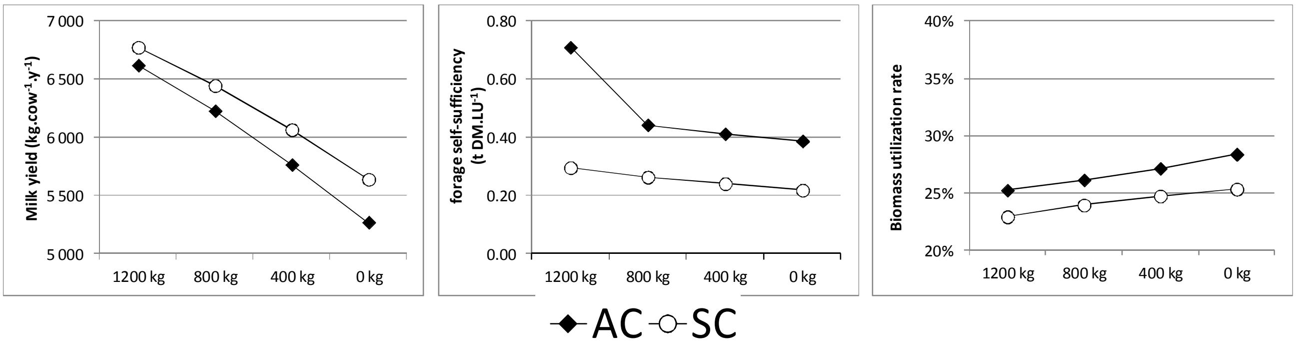

Figure 3: Effects of concentrate decrease on milk yield, forage self-sufficiency and biomass utilization rate of paddock grazed by dairy cows for AC and SC systems, average values on 2007-2011 periods.

The results of the simulations indicate, that a better match between animal needs and grass offer through spring calving could allow a better balance between milk production and grass utilization at farm-scale and a better resistance to climatic and production constraint changes. Dynamilk enables to test a wide-range of production strategies on dairy cattle, grasslands and forage system management, for production systems only based on grasslands as in mountainous areas.

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A practicable approach to get the sustainable development of alpine pasture-livestock system on the Tibetan plateau

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Abstract

The conflict between feed requirement of livestock and forage supplement is the big block for sustainable development on Tibetan plateau, caused by huge livestock number and deterioration of natural rangeland. The sowing pasture should be increased about 6.4 times of present total area. Directly fencing enclosure in degraded grassland is practicable and low cost approach of restoring as to good grazing pasture, and that need just 3-4 years. Reducing the grazing pressure (about 50%) from marsh pasture is the first task to get sustainable management of alpine ecosystem. Although, those suggestions are very simple, it is very hard to implement. Therefore, it should be combined with the national project of livelihood and ecological engineering to conduct in the field gradually.
Keywords: Grassland ecosystem, Tibetan plateau, Ecological restoration, alpine pasture

Introduction

The sustainable development of grassland-livestock system is important issue for the construction of the ecological environment of Tibetan plateau, the improvement of Tibetan people's livelihood and the ecological health of the world's third role. Currently, about 95% of whole grassland vegetation on Tibetan plateau is degrading, meanwhile, great high livestock stocking rate in the alpine pasture region result in the tremendous grazing pressure on grassland, which is the big problem of its sustainability (Shang et al., 2012). Especially, the biggest question is the forage shortage in cold season, which caused the gap between livestock industry and forage supplement. At the present, the urgent affairs of grassland-livestock system associated to achieve the healthy development is increasing the forage supplement and reducing the stocking rate on the pasture area of Tibetan plateau (Shang et al., 2012). In here, based on our investigation and experiment in north Tibet, we discussed the result of three approaches to increase the forage supplement and reduce the stocking rate on pasture. The objective is strengthening the confidence of local government to implement those approaches.

Material and Methods

According to the Tibet statistical year book and Qinghai statistical year book (TARBS, 2010; QPBS, 2010), we calculated the dynamic of stocking rate in Tibet and Qinghai from 1974 to 2009. Also, we did some field experiment and survey in north Tibet to test, 1) forage productivity of sowing pasture and marsh pasture; 2) variation of forage source in typical pastoral village. Those field works were done from 2008 to 2010. Meanwhile, under the supporting of a national project, we measured the biomass of vegetation and forage product area of fencing enclosure in the grazing period on degraded grassland in north Tibet from 2008 to 2010. All field work method was based on the guideline book of grassland investigation edited by Chen &Wang (2004) and Ren (1998).

Result and Discussion

Following the human population growing up after 1949, the livestock number increased fast from 1949 to 2009, especially in about 20 years from 1959 to 1979 (Fig. 1). The livestock number had achieved huge the economic interest in the pasture area, and to date, the herders of pasture area do not want to reduce the high stocking rate because of the current income. Therefore, to some extent, the present degradation of native grassland on Tibet plateau was caused by the long-term heavy grazing. However, some study argued that grazing is not the reason of grassland degradation on Tibetan plateau (Klein et al., 2007; Harris, 2010; Wang et al., 2012; Li et al., 2013).

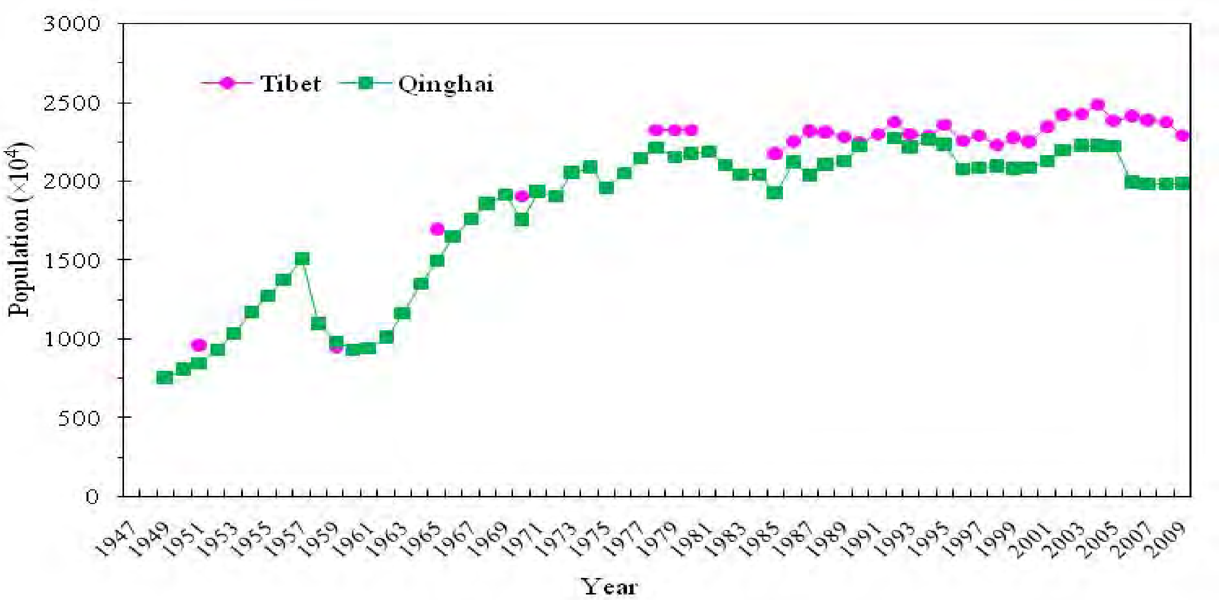

Figure: 1 Year-end total populations of domestic livestock (cattle, horse, donkey, mule, camel, sheep and goat) in Qinghai and Tibet from 1947 to 2009

According to the current status of livestock structure and amount in Tibet, we calculated requirement of forage supplement (Table 1, 2, 3). Native rangeland (except marsh) can feed 675×10^4 yaks (other animals transferred to yak), but there were about 1500×10^4 yak units in Tibet. Marsh pasture is the major area for available for grazing during winter and spring on Tibetan plateau. At present, the total forage productivity of marsh pasture can support about 75.34×10^4 yak units in Tibet and actually about more than80% of livestock graze on marsh pasture in spring and winter. The current sown pasture can support a number of livestock equal to about 102×10^4 yak units. Therefore, the total native rangeland, marsh pasture, sown pasture can support about 675+75.34+102=852.34 ($\times10^4$ yak unit) of livestock. So that, the shortage of forage for actual livestock number in Tibet (1500×10^4 yak unit) is about 1500-852.34=647.66 ($\times10^4$ yak unit), (≈650×104 yak unit). How would be possible to feed properly these animals (650×10^4 yak unit)? At present, more forage should come from commercial feed or increasing sown pasture area. However, the commercial feed is too expensive, and then we have to increase the sown pasture area. Thus, we should increase 6.4 times the current area of sown pasture, i.e. about 73.6×10^4 ha.

Table 1 Forage status and supporting number of livestock from natural rangeland

Area of natural rangeland (ha)	Forage productivity (kg hay per ha)	Total livestock number transferred to Yak	Consumption of hay per day of total livestock(kg hay)	Natural rangeland support number of livestock (50% utilized rate)
8207×10^4	180	1500×10^4	4000×10^4	675×10^4

Table 2 Forage status and supporting number of livestock from natural marsh pasture

Area of marsh pasture (ha)	Forage productivity (kg hay per ha)	Consumption of hay (kg hay per yak per year)	Marsh pasture can support number of livestock (50% utilized rate)
110×10^4	1500	1095	75.34×10^4

Table 3 Forage status and supporting number of livestock from sown pasture

Area of sown pasture (ha)	Forage productivity (kg hay per ha)	Consumption of hay (kg hay per yak per year)	Sown pasture can support number of livestock (50% utilized rate)
11.5×10^4	9750	1095	102×10^4

Based on our investigation in a typical pastoral village in north Tibet, we found out that the most forage supplement to livestock was coming from natural rangeland and marsh pasture, and a little commercial supplement from outside (Fig. 2). The forage shortage was significantly heavy, i.e. about 25-50% of the total forage requirement. Especially, in the heavy snow reason, lot of yak, sheep died for starvation. Thus, the artificial forage product is very important to balance the shortage of forage in cold season. The key question is the development of sown pasture for more forage production. Meanwhile, we must concern the protection of native rangeland, biodiversity, because some land will be turned into arable land by developing sown pasture.

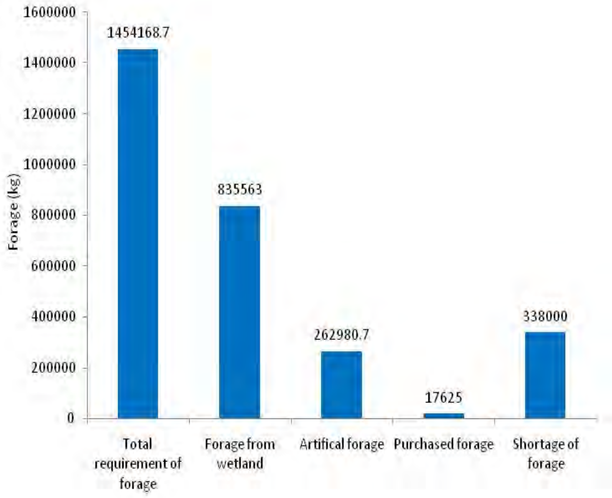

Figure 2: Forage structure (supplement, shortage, and requirement) of a typical village in north Tibet

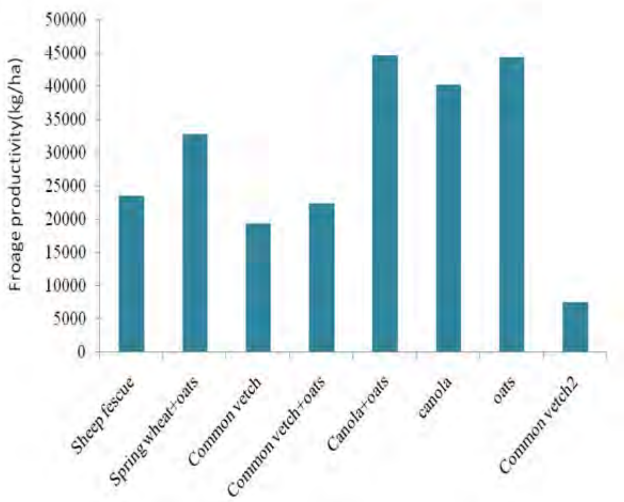

Figure 3: Artificial forage productivity at household level of north Tibet

Because of the long-time nomad lifestyle, the local herders prefer grazing than cropping and harvesting on the Tibetan plateau. Most artificial forage crops depend on weather conditions and are rarely successful. Then, the productivity is very low and very little feed is available for the livestock in cold season (Fig. 3). Forage planting was in the animal shed by most herders in summer season, which was very small area and little forage product. At the county level, there were some larger land areas for producing artificial forage, but the total productivity was limited and not sufficient to cover the forage shortage. Till now, according to some policy and technology guidelines, in some villages people are beginning to plant forage crops in large areas which offer the possibility to supplement feed during the cold season at village level or for corporate herders.

We did the experiment of restoration experiment on degraded grassland limited by a fencing at the altitude of 4700 m in Naqu County (north Tibet). The result was that after 3-4 years the degraded grassland could be recovered totally in vegetation coverage and yield (Fig. 4). However, restoration of degraded grassland, by rotation grazing, needs a long time period and proper management.

Improving the supplement of artificial forage implies also a decrease of the stocking rate from the marsh pasture. The current status of marsh pasture is worse than 30 years ago, e.g. the height of vegetation is just about 50% of 70s of the 20^{th} century. That is a very danger signal for alpine wetland ecosystem on Tibetan plateau, because the whole natural-social ecosystem on Tibetan plateau is built on the alpine wetland ecosystem and was formed in a long term. If the deteriorating trend of alpine wetland ecosystem keeps going on, it will cause the catastrophe of the Tibetan plateau. We surveyed the vegetation under different grazing regimes in marsh pasture in north Tibet. The results showed that the method of winter-grazing can preserve the good biodiversity and vegetation of marsh pasture (Table 4).

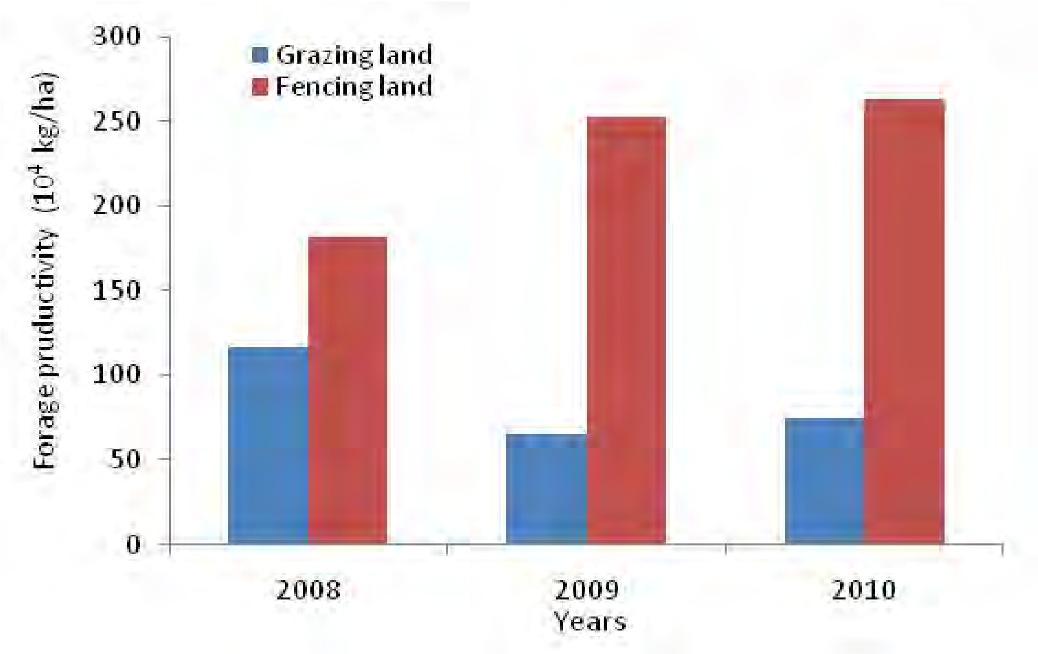

Figure 4: Forage productivity of alpine pasture under grazing and fencing from 2008 to 2010

Table 4 vegetation status of marsh pasture under different grazing ways

Grazing method	Vegetation height (cm)	Vegetation cover (%)	Biomass (g/m^2)
Winter grazing	2-26	95	767.20
Winter-Spring grazing	2-18	87	431.04
Entire year grazing	1-13	80	204.32

In conclusion, a practicable approach to resolve conflicts between forage shortage and livestock feeding and to sustain the whole grassland-livestock system in the Tibetan plateau consists in several management practices i. a. enlarging the area of artificial pastures, restoration of degraded grassland, decreasing the grazing pasture of marsh pasture. However, this approach is very hard to transfer to highlands and cold regions, where there is a long term grazing tradition, and also because of the local hard environmental conditions and the agricultural cultural level. Therefore, detailed investigations and accurate plans must be developed to avoid negative results and cause detriment to biodiversity and the environment.

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Use grassland diversity to improve efficiency of milk production in dairy ewe systems: case study in the Roquefort French region.

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Abstract:
In southern France, the area producing the "Roquefort" cheese is mainly a limestone karst plateau whose the semi-natural calcareous grasslands are holding conservation stakes. For many years, most farmers have not used these semi-natural calcareous grasslands to feed their ewes because of intensification of the milk production per ewe. However faced with the livestock farming crisis, few farmers consider changing their pastoral scheme in order to use more semi-natural calcareous grasslands and long-term seeded grasslands too. To maintain a high milk production level at the beginning of the grazing period, farmers have to define the best combination between the seeded grassland use on one hand and the semi-natural grassland use on the other hand. The aim of this study is to characterize the diversity of grasslands' management by shepherds. Twenty farmers' interviews were carried out to give an insight into grasslands' management and flock feeding practices. The milk production of each farm was analysed for the two first months of the grazing period by considering milk production level and persistency. We identified a wide range of grassland use mainly during the turn-out to pasture period. Following the farmers' practices analysis, we described five feeding patterns based on a combination between the grazing of seeded grassland and semi-natural grasslands, possibly associated with feed supplementation. Two main benefits of semi-natural grasslands use were recognized: firstly the well-adapted grassland use for low levels of milk production; secondly, the leading role of grasslands as a "buffer feed" during rainy periods to maintain grazing. The main conclusion focuses on the benefits of a combination between a large range of seeded grasslands and semi-natural grasslands to provide more flexibility in farm management. We consider this is a first stage to improve new agroecological farming systems.
Keywords: Livestock farming system, forage practices, technical change, cheese production, sheep

Introduction

In the last century, the intensification of livestock production and the development of larger and more specialized farm units have resulted in a decrease in grassland use (Kristensen et al. 2005). In mountain and less favoured areas, rural exodus and agricultural modernization in the 1960s induced the abandonment of the less productive land (Quetier et al. 2005). Livestock is faced with new agricultural context and grassland use comes back as an alternative to intensification. To develop agroecological farming systems, livestock animals can play a role in increasing agroecosystem diversity (Gliessman 1998). According to Altieri (2002) the diversity of resources is one of those agroecological principles. At the farm level diversity of resources can improve sustainable farming systems. The diversity of grassland resources and livestock management enable farms to cope with changes and variability in the context of production (Darnhofer et al., 2008). Firstly, managing the diversity of resources ought to ensure the "*room for manoeuvre*" at the farm scale thus improving its adaptive capacity. Farmers build management schemes with different combinations of land use and livestock practices (Thénard et al., 2006). Regardless of the diversity of resources and management, practices' combinations are not random but combined to preserve the farm consistency (Meynard et al., 2001). Secondly, maintaining the diversity of resources ought to increase the role of the farm to favour the preservation of the biodiversity. Nevertheless increasing grassland use requires having a well-adapted quality of grass to ensure it meets the livestock's needs. The milk production is highly impacted by grazing conditions. In the sheep dairy systems the main important period is the turn-out to pasture (TOP). This is a critic period because a decrease in the milk production cannot be made up the lack of milk later. Milk production persistency can be used as a criterion of grassland management efficiency. In southern France, in the area known to produce "Roquefort" cheese, farmers have developed many different grassland management practices during the TOP period. A study was undertaken to design and assess the grazing and feeding management practices through this key-period. This study was conducted with farmers within the framework of a participatory research project. In this paper, after a few explanations of the methodology, we focus on the results defining a range of patterns of different TOP managements. In a second part, we propose new elements to link farmer's practices and the persistency of milk production. These preliminary results could be used in future projects to improve farm adaptability.

Materials & Methods

Case study: A training framework in The Roquefort cheese context.

This study takes place in the "Grands Causses" region, a limestone plateau in south central France (3270 km² around Millau - 44°05'N-3°04'E). The altitude ranges from 700 m to 1200 m above sea level. The climate is under three influences; oceanic, Mediterranean and continental. The annual average rainfall is from 700-1000 mm in accordance with region and altitude, but with a significant contrast between years, and with a dry summer. Average temperature is 12°C (-20 to +40°C). The climate and natural soil conditions favour very specific vegetation: the semi-natural calcareous grassland. Plants on calcareous grassland are typically short and hardy including grasses and legumes. In this region, farming activities are mainly sheep farming systems based on the Lacaune breed. It is the traditional area of Roquefort cheese production. This PDO cheese is produced with raw ewe's milk and aged for three months in natural calcareous caves. Ewes are milked during 6 months, with 2 or 3 months while the grazing period. To maintain the level of milk production farmers must use high quality forages. From the 1960s to the 1980s, milk production had been intensified and grazing use had regressed. During the last 50 years, farmers have developed production of many forage types (alfalfa, Italian rye-grass, forage cereals.) to improve milk production. Also many intensive farms were based on intensive forage production and farmers decided to abandon semi-natural calcareous grassland because of their low production. But during the 1990s farmers had to reduce production costs and they have searched less intensive practices. They have developed long term grassland based on alfalfa and orchard grass or based on a many-species seed mixture. The types of grasslands used and mentioned in this paper are described in table 1. Since 2000, the new PDO specifications have new requirement: 75% of the forage is produced in the PDO area, grazing must be used in spring.

Table 1: Types of grassland grazed at turn-out to pasture period

SNG	Semi-Natural Grassland: typical calcareous grassland	Rangeland grazing
PG	Permanent Grassland: no typical calcareous grassland	Grassland grazing
STG	Short-term seeded Grassland: 1-2 grasses; 1-2 years	Sown Grassland grazing
LTG	Long-term seeded Grassland: 1-2 grasses + 1-2 legumes; 5 years	Sown Grassland grazing
MSG	Long-term seeded Grassland based on multi-species seed mixture	Sown Grassland grazing
FC	Forage Cereal grazed at immature stage	Cereal grazing

In this context, an association of farmers and veterinarians (AVEM) was founded at the end of the 1980s. This association is based on the exchange of knowledge and know-how between farmers, veterinarians and some researchers. Advices and exchanges are based on a holistic approach of flock functioning. Many farmers of this association would like to improve grassland use for dairy ewe diet and to developed grassland management practices around TOP period which have favourable impacts on milk production. We have lead with them a study about these questions. We decided to analyse the first two months of grazing for a farms' sample. To explain the links between grassland diversity and grazing management practices at the TOP, we have defined a 20-farm sample. Firstly, it was interesting to study these links at the beginning of the lactation period, while milk production level was important for annual production; we have chosen farms which begun the milking for a short time before TOP date. Secondly, it was necessary to limit the impact of the lactation stage; thus we have decided to choose farms with a similar lambing date.

Methods to analyse practices and to define management patterns

From March to June 2009, semi-directive interviews were carried out among 20 farmers to identify flock management during the grazing period and more particularly during the TOP period. In this farm's sample, the date of TOP ranged from March 9th to April 20th. We used the milk production data previously published

(Thénard et al., 2010). At the TOP date the milk production was 2.00±0.45 litre per day per ewe. Farms were characterised by 4 levels of milk production persistency defined by the milk level at the TOP date and the milk production decrease during the 2 first-months of the grazing period (table2):

Table 2: Milk Production Persistency after the first two months of grazing (Thénard, 2010)

Low milk production persistency	High milk production persistency
P1: High Milk production and large decrease (more 35 %)	P3: Low milk production and low increase (0-10%)
P2: Low Milk production and average decrease (20-25%)	P4: High Milk production and average decrease (20-25%)

Farmer's interviews were analysed by identification of farmers' practices (Girard, 2006), we have built criterion and their modalities based on the diversity of practices explained by farmers. These criterion and modalities can be statistically analysed. To perform management patterns, we used a descriptive analysis of practices based on Multivariate Component Analysis and Clustering method. These analyses were computed with the *factominer-Package* of R software (R Core team, 2012).To identify the main practices linked with the milk production efficiency, Classification and Regression Tree method was used and computed with the *rpart-package* of R software (R Core team, 2012).

Results

Diversity of the farmer's practices

Collected data allowed identifying 10 different criteria to describe practices of grassland management and animal feeding. Each criterion is defined with 2 or 3 modalities (table 3).

Table 3: Criterion and modalities of the farmers 'practices (Thénard, 2013)

	Diversity of grassland grazed		
A	Sown pasture (3 farms)	Sown pasture, PG and SNG (6farms)	Sown pasture and FC (11 farms)
	Daily combination of resources grazed		
B	One type of grassland (11 farms)	Two types of grassland (4 farms)	Grassland(s) and FC (5 farms)
	Rangeland grazing		
C	No rangeland (13 farms)	Rangeland use (7 farms)	
	Type of seed-mixture		
D	1-2 grasses (5 farms)	1-2 grasses + 1-2 legumes (4 farms)	many-species seed mixture (11 farms)
	Forage supplementation		
E	Quick decreasing (5 farms)	Slow decreasing (10 farms)	No decreasing (5 farms)
	Concentrate supplementation		
F	Energy supply (9 farms)	Energy and protein supply (11 farms)	
	Daily Grazing time after 4 weeks of grazing		
G	Short-time 3-4 hours (7 farms)	Medium time 6 hours (2 farms)	Long-time > 8 hours (11 farms)
	Grazing system		
H	Leader-Follower grazing (7 farms)	Leader grazing (5 farms)	Free-Grazing (8 farms)
	Area per ewe at the start of one parcel use		
I	>650 ewes/ha (6 farms)	250-650 ewes/ha (7 farms)	<250 ewes/ha (7 farms)
	Grazing habit during raining		
J	Grazing under raining (4 farms)	Limited Grazing under raining (7 farms)	No Grazing under raining day (9 farms)

Diversity of the TOP managements

The three first axes of the MCA have explained 48.6% of the observed variability. The first axis (19.1%) represented the diversity of resources and grazing systems. It compared farmers who fed their ewes with grassland and forage cereal during the TOP period *vs.* those who fed them only with different types of grasslands. The second axis (17.8%) represented the grazing system and the rangeland grazing. It compared farmers who done Leader Grazing and used rangeland *vs.* those who used free grazing and had a high level of forage supply. The third axis (11.8%) represented the daily grazing time and the daily combination of resources grazed. It compared farmers who used Long time grazing and use at least two daily resources including cereals *vs.* those who limited the daily grazing time. The clustering method revealed a range of four patterns of turn-out to pasture management. The first group was composed of 6 farms which have a **diversified grazing management system**. These farmers used daily MSG and FC, but no SNG. Ewe grazed for a long time every day, except during rainy days. The second group was composed of 5 farms which have a **limited grazing management system**. These farmers used STG, LTG, MSG or FC, but only one type of grassland for a short time every day. The third group was composed of 5 farms which have a **supplemented grazing management system**. These farmers use only STG, LTG and PG (without SNG) and they provided a large forage supplementation and protein supply to the animals. The fourth group is composed of 4 farms which have an **alternative grazing management system**. This group used rangelands (SNG) during this period in association with another grazed resource (STG, LTG, MSG, FC).

Key-Practices and milk production efficiency

Based on the 4 levels of milk efficiency, the CART method shows that the main practices involved in the success of the TOP managements. In the table 4, we present the TOP managements could be discerned as a failure or a success in the practices choice (table 4).

Table 4: Examples of successful or unsuccessful combinations of factors to maintain milk production during the turn-out period

	Success in turn-out to pasture	Milk Efficiency	Failure in turn-out to pasture	Milk Efficiency
Diversified Grazing	Daily FC grazing Protein supply	P4	MSG grazing No Protein supply ---------------- STG grazing only	P2 P1
Limited Grazing	Energy and protein supply MSG grazing Grazing under raining	P4	No Protein supply ---------------- STG grazing only	P2 P1
Supplemented Grazing			Energy and protein supply MSG grazing ---------------- STG grazing only	P2 P1
Alternative Grazing	Maintaining energy and protein supply MSG grazing SNG grazing	P3	Energy supply only STG grazing only	P2 P1

Discussion and conclusion

The aim of this study was to improve grassland use to maintain milk production. The main results are related with the links interactions between feeding practices and milk production. Many practices are favourable for maintaining a high level of milk production: a wide diversity of grassland grazed, forage cereals grazing, and protein supply. Two main benefits of semi-natural grasslands use were recognized: firstly the well-adapted grassland use for low levels of milk production; secondly, the leading role of grasslands as a “buffer feed” during rainy periods to maintain grazing. Milk persistency can be maintained through grassland management practices, by using a wide diversity of resources in accordance with this agroecological principle. The two main recommendations are firstly that the traditional feeding system can be used for low levels of milk production. Secondly, the livestock intensification needs a supplementary protein supply combined with the use of a large diversity of cultivated grasslands. According to our experience, these two practices can be easily adopted by farmers. The study showed the benefits of a large diversity of seeded grassland to provide more flexibility in farm management.

This project was supported financially by the Research Project - ANR 09 - STRA – 09 - O2LA

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Mixed grazing efficiently helps to limit gastrointestinal parasites infection of grazing sheep

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Abstract

Many experiments have shown that mixed grazing may be beneficial in regard to the health or performance of animals. However, this practice remains uncommon in western and central Europe, especially in Switzerland.

During a three years study, conducted on a mountain farm at 1’200 m a.s.l., two groups of lactating grazing animals were compared: a first group (O), comprising only ewes and lambs, and a mixed group (MI) composed of ewes, lambs, suckler cows and calves. The pasture was organised in a rotational system, the ewes and the paddocks being assigned to one of the two treatments (groups) for the whole duration of the study. The stocking rate was about 1.7 LU/ha. The height of the grass was measured once a week by means of a rising plate meter. Botanical observations were made for describing the botanical evolution of the pastures. Coprological examinations took place at the beginning of each rotation on 10 ewes and 10 pairs of lambs (twins). Body weight and growth performance were also assessed to this time.

The abiotic factors influenced much more the botanical evolution than the agricultural practices. The lambs of the MI-group showed less eggs of gastrointestinal parasites than those of the O-group. In accordance to these results, the daily weight gains of the MI-lambs were higher than those of the O-lambs. In conclusion, our results show that mixed grazing can largely contribute to improve the health and performance of sheep.

Keywords: mixed grazing, sheep, cattle, mountain pasture, gastrointestinal parasites.

Introduction

Mixed grazing is defined as the use of a pasture by different species of animals, simultaneously or separately in time. The main interest of this practise relates to the benefits in terms of parasitism. Indeed, the gastrointestinal nematodes represent an important health problem by the small ruminants.

Most of the nematodes are quite specific to their host (Hoste *et al.*, 2003); the sheep are for example not sensitive to the same parasites than cattle. The combination of different species of animals has therefore the same effect than a reduction of the stocking rate. Some studies report favourable effects on animal health (Jordan *et al*. 1988), while other are more mitigated in their conclusions (Moss *et al*. 1998; Niezen *et al*. 1996). In this study, we evaluated mixed grazing as alternative production system, in comparison to the group composed only of sheep.

Material and methods

The trial was conducted between 2009 and 2011 in an experimental farm located in the Jura mountain chain, at 1'200 m a.s.l. During three grazing seasons (begin of Mai to November), two groups were compared: a sheep group (O), constituted of about 20 lactating ewes with their lamb(s) and a mixed group (MI), comprising 9 suckler cows with their calves and about 45-50 ewes with their lamb(s). Sheep, as well as the paddocks, were allocated to one of the two groups at the beginning of the trial. The ratio between cattle and sheep in the MI-group was about 4.5 ewes (+ lambs) for one cow-calf pair. The stocking rate in the two groups was similar, 1.7 LU/ha. The pasture was organised in a rotational system with 8 double paddocks. The two groups were moved simultaneously from one paddock to the next. No feed-supplement was given to the animals, except salt. Only one anthelmintic treatment was administrated to sheep, in July 2010.

The grass on offer was estimated with a rising plate meter (Jenquip, NZ), once a week till mid of July and then each fifteen days. The botanical surveys were made in Mai 2009 and Mai 2012, according to the method of Daget and Poissonet (1971), along 24 transects of 10 m located in four zones of the experimental farm. At the beginning of each rotation, the animals were weighted in order to assess their daily weight gain. Simultaneously, faecal samples were taken on 2 × 10 pairs of lambs (twins) and analysed by McMaster technique (Bauer, 2006). The daily weight gains were calculated for the period from the turn-on to the first slaughtering date.

Results and discussion

The growth of grass was quite different from one year to another (fig. 1). While 2009 was characterised by a large amount of grass, 2010 and 2011 were markedly different: the levels of available grass remained below 600 kg DM/ha. The grass on offer was similar for the two groups, except 2009 where the MI-group benefited of a higher amount of forage than the O-group.

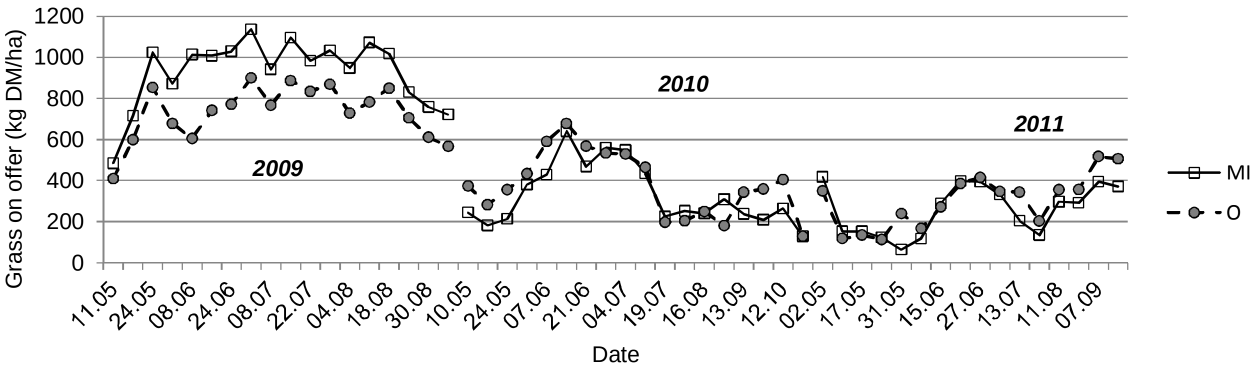

Figure 1: Grass on offer during the three grazing periods. MI = mixed group; O = sheep only.

The vegetation showed few changes during the three years of the study. Due probably to the short time of the survey, the factor 'group' hadn't any influence on the botanical composition. The effect of the year and the zone was however more important (fig. 2). The specific contributions of four species varied significantly (pairwise comparisons between 2009 and 2012): *Festuca rubra* increased in average from 11 to 27%, whereas *Trifolium repens* decreased from 12 to 2%. The proportion of *Taraxacum officinale* and *Ranunculus friesianus* also diminished but in a lesser extent. These changes were observed in both groups (data not shown).
During the three grazing seasons, the lambs of the MI-group were significantly less infected with helminths than those of the O-group. The pressure of the parasites regularly increased over the season. In 2011, the peak was attained earlier, at the beginning of the third rotation, about two months after the turn-on (fig. 3). For some lambs (data not shown), the pressure diminished afterwards, thanks to the development of a partial immunity.

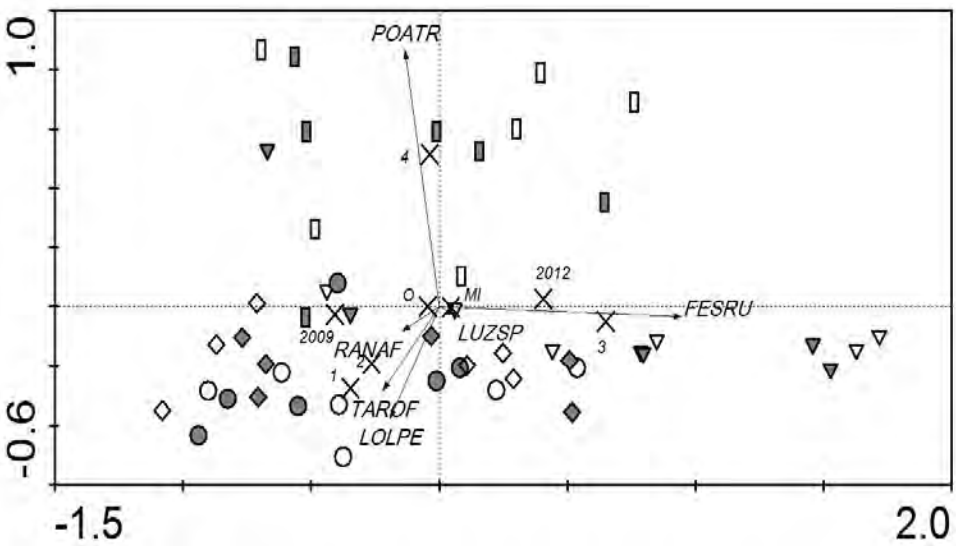

Figure 2: PCA of the botanical analyses made in 2009 and 2012. Variance explained by the two first axes: 64%. The four symbols represent the four geographical zones. The transects grazed by the mixed group are in white, those grazed only by sheep in grey. The environmental factors are indicated by a crux (passive projection of the centroids): **zone** (1 to 4), **year** (2009 and 2012) and **group** (MI and O).
FESRU = *Festuca rubra*; LUZSP = *Luzula sp.*; LOLPE = *Lolium perenne*; POATR = *Poa trivialis*; RANAF = *Ranunculus friesianis*; TAROF = *Taraxacum officinale.*

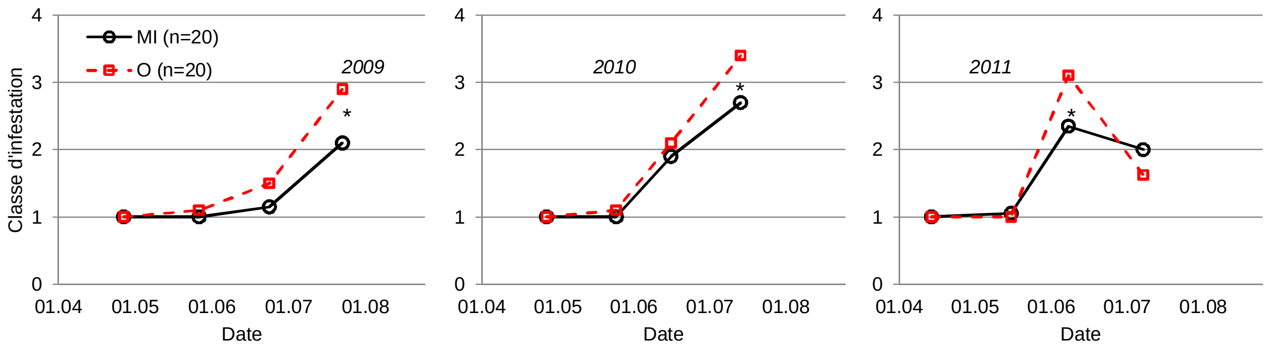

Figure 3: Evolution of the eggs per gram (EPG) values by the lambs. Infestation level: 1 = 0-100 EPG; 2 = 150-500 EPG; 3 = 550-1000 EPG; 4 > 1000 EPG. * Significant difference with p < 0,05, Fisher' exact test.

The daily weight gains of the MI-lambs were higher than those of the O-lambs. The *p* values were marginally significant in 2009 and highly significant in 2010 and 2011. In 2011, 40% of the O-lambs didn't even reached the weight of 40 kg. Thus, the values of the Table 1, covering only the period up to the first slaughtering date in July, only partially reflect the differences between the two groups. Despite the low level of the grass on offer in 2010 and 2011, the daily weight gains of the animals of the MI-group remained stable and satisfactory, about 250 g per day (Table 1). This was however not the case for the lambs of the O-group, which performances became worse over the three seasons. These results suggest that the lower infestation level of the lambs in the MI-group explain, at least partially, the better performances realized by these animals. Other factors might also have played a role, such as a better valorisation of the pastoral resource.

Table 1: daily weight gains of the lambs (n = 20) for the three grazing seasons.

		2009		2010		2011	
		Group MI	Group O	Group MI	Group O	Group MI	Group O
DWG	Turn-on -> July	266	248	264	214	252	201
p	*(t-Test)*	*0,065*		*< 0,0001*		*< 0,0001*	

Conclusions

The results of this study show that the mixed grazing in the conditions of the Jura mountains is practicable. However, this study focused only on zootechnical and phytosociological aspects. It is further important to keep in mind that lamb meat represents a niche market in Switzerland. Moreover, the production of lamb in traditional dairy farming areas is still affected by a strong negative image, which lessens the extent of mixed grazing systems.

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Ecological and vegetation characterization and livestock production of a mountain marginal area of N-W Sardinia

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Abstract

Aim of this work was the ecological and vegetation characterization of a mountain marginal area of N-W Sardinia, ever-grazed by beef cattle, to evaluate its strategic role in the sustainability of agro-forestal activities. The study was conducted between April 2011 and June 2012 in an experimental area of 24 ha, 670 m a.s.l., dominated by woody vegetation, mainly *Quercus pubescens* L. with an herbaceous cover limited to the glades.
Keywords**:** Sardinia, grazing value, sustainability, cattle-breeding, vegetation, High Nature Value Farmland, HNVF, habitat Nature 2000

Introduction

The protection of biodiversity is actually considered as a priority requirement for Nature conservation. With the adoption of 92/43/EEC Directive habitats, the European Community recognized the importance of biodiversity and contributes to its safeguard through the conservation of natural and semi-natural habitats and wild flora and fauna (Celada, 2003). In 1999 European Community has further recognized the importance of semi-natural pastures adopting EU 1257/99. The specific objective of the directive is the location and conservation of the European High Natural Value Farmlands, and to supply the normative tools for their correct management to preserve the biodiversity.

It has been well established that the maintenance of grassland communities in Western Europe depends on their management and that in grassland a moderate grazing by livestock contributes to the maintenance of plant diversity, by reducing the abundance of competitive dominant species (Klimek et al., 2007). The conservation of biodiversity, of landscape variety and of vegetation ecosystems is strictly linked to the prosecution of traditional agro-pastoral activities in Mediterranean area (Forconi V. et al., 2010; Klimek et al., 2007). Aim of this work was the ecological and vegetation characterization of a Sardinian marginal area and the evaluation of its strategic role in the sustainability of meat livestock production system.

Material and methods

Research area - The research was carried out between April 2011 and July 2012 in the experimental farm of Agris Sardegna, located in North-West Sardinia (lat 39°N, long 9 °E), at 670 m a.s.l.. The study area's surface is of 24 ha, grazed by cattle for 40 years, and it is characterized by a vegetation cover dominated by Mediterranean trees, 55% mainly Downy Oak (*Quercus pubescens* L.), and *Pteridium aquilinum* (L.) Kuhn, 24%, while the remaining patches are composed by rock (4%) and herbaceous cover.

The climate is Mediterranean with hot, dry, sunny summers and mild and rainy winters with some days of snow (Tmax = 28.1; Tmin = 3.3; total annual rainfall = 905 mm). For the phytoclimatic setting the area can be recognized (Farris et al., 2007) as belonging to the Mediterranean pluviseasonal oceanic bioclimate, inserted in the phytoclimatic belt *Upper Mesomediterranean* thermotype with an *Upper Subhumid* ombrotype and an *Euceanic* continentality. The soil of the area is of volcanic origin, clay-sandy with 5.5 pH.

Vegetation - A census of plant species was taken within the study site, over a 18 months sampling period, and it was used to assess chorological and biological spectra. Plants were classified following Pignatti (1997) and Arrigoni (2006 and 2010) and categorized to biological and chorological types (Pignatti, 1997). Endemisms and Species of Conservation Interest were then identified (Arrigoni et al., 1976-1991; Camarda and Valsecchi, 1983 and 1992; Gaminans and Marzocchi, 1996; Pignatti,1997).

The research area was subdivided in five parts according to phytocoenosis and the homogeneity of landscape: oak wood (OW), glades with dominance of fern (FN), glades with no water seasonal stagnation (MD) characterized by meadows with dominance of *Trifolium* spp. and *Asphodelus microcarpus* Salzm. et Viv., glades with vegetation of wet meadows (WL), where water stands only during rainy seasons, rocky glades (RK), where rock covers more than 30% of the surface, with low soil and water stagnation plants.
Vegetation communities, grazing value and grassland's productivity were assessed within each one.
The grazing value was evaluated in each phytocoenosis during spring 2012, adopting the phytopastoral method of Daget and Poissonet (1971). The overall grazing value of the research area was obtained through the ponderal mean of the different grazing values. Ten transects of 20 m were used and 100 vertical point quadrates were taken in each transect, sampling every 20 cm. Specific indices were given as suggested by Cavallero et. al. (1992), Roggero et al. (2002), Gusmeroli et al. (2007).
Biodiversity (Species Richness and Shannon index) was evaluated in each phytocoenosis adopting the phytopastoral relevés. Total species richness was calculated as the total number of species collected. Vegetation communities were observed at the end of spring 2012 and identified through 56 phytosociological surveys (Braun-Blanquet, 1951). The phytosociological data relating to cover, underwent multivariate analysis using Primer software. The sintaxonomy follows the criteria of Rivas Martinez et al. (2002), Bacchetta et al. (2004 and 2009), Farris et al. (2007) and Blasi et al. (2010). Phytosociological and census data were used to identify the presence of habitats of European importance included in 92/43/EEC Directive habitats (Biondi et al., 2010).
The biomass productivity was evaluated monitoring monthly herbage on offer (HO, t DM ha-1) by cutting 84 stripes (0,10 m x 5 m), spread on all the experimental area. Sward height (SWH, cm) was also measured with weighted plate (150 records per ha). Data were analyzed with the GLM procedure of SAS using the phytocoenosis as fixed effect.
Livestock system - The research area was continuously grazed from April 2011 until July 2012 by twenty-four calves weaned at 6 month of age, 168.5 kg ± 16.2 Live Weight (LW, average ± st.dev.). The calves, divided in 4 groups [Sarda (S), castrated Sarda (Sc), Sardo-Modicana (SM) and F1 Charolaise bull X Sarda], received hay and concentrate as supplement since September 2011 (3,5 and 4,5 kg head^{-1}day^{-1}, respectively). Calf final live weight (LW, kg) was recorded and the Average Daily Gain (ADG, kg head^{-1}day^{-1}) was calculated. A sample of *Longissimus Dorsi* muscles was removed at 24 h post mortem after a refrigeration at 4±1 °C to evaluate pH and α tocopherol content (Panfili et al., 1994). LW were analyzed with the GLM procedure of SAS using the breed as fixed effect and the pre-experimental LW as covariate; ADG was analyzed with Mixed procedures of SAS using breed as fixed effect and animal as random effect. At the beginning of August 2012 half of S, Sc and F1 animals were slaughtered and their meat quality were assessed, while the other half was slaughtered after 6 months of fattening (data not shown).

Results

Vegetation characterization - A total of 252 species were recorded, referable to 46 families. Prevailing families are *Graminaceae* (19%), *Compositae* (13%), *Leguminose* (8%) and *Liliaceae* (6%). Chorological spectrum highlights the dominance of Euromediterranean (31%) and Stenomediterranean (31%) species, with a relevant percentage of Eurasians (17%). Endemisms and species of conservation interest represent 10% of total census. The prevalent Endemics are those with Sardinian-Corsican distribution and those with Sardinian-Corsican and Tuscan Archipelago distribution. The comparison of biological spectrum revealed the prevalence, including bulbous, of perennial species: the hemycriptophytes are 32% and geophytes 15%, while therophytes are 44%.
The biodiversity identified for each phytocoenosis is reported in table 1. The analysis of the phytosociological relevés has allowed the recognition of 7 sintaxa. Two of these sintaxa, *Ornithogalo pyrenaici-Quercetum ichnusae* Bacchetta, Biondi, Farris, Filigheddu & Mossa 2004 (*Querco roboris-Fagetea sylvatica* class) and *Isoetion* Br.-Bl. 1935 (*Isoëto-Nanojuncetea* class), take up 58% of total research area surface and have permitted to recognize two habitats of European importance. They are the habitat *3130* - EUNIS Code C3.4 - " Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*" and habitat *91AA**- EUNIS Code G1.72- "Eastern white oak woods" subtype 41.72, characterized by Mediterranean and sub-Mediterranean Adriatic and Tyrrhenian woods with dominance of *Quercus virgiliana*, *Q. dalechampii*, *Q. pubescens* e *Fraxinus ornus*. The average grazing value of total research area is 25. The HO pick was recorded in Spring (1.16 and 0.98 t DM ha^{-1}, in

2011 and 2012, respectively), whereas in both Autumn and Winter the herbage on offer resulted very low (0.40 t DM ha^{-1}, Tab.1). The HO measured in autumn in OW (1.61±0.38 t DM ha^{-1}), because of the shedding of the Downy Oak leaves, and in FN, because of the great abundance of fern growing from late spring until autumn, resulted higher than the others (P<0.05).

Table 1: Biodiversity, grazing value (VP), total average herbage on offer (HO, t DM ha^{-1}) and sward height (cm) recorded in Oak Wood (OW), Fern (FN), Meadow (MD) and Wetland (WL) phytocoenosis during the trial (standard errors in bracket).

		OW	FN	MD	WL	RK
Species Richness		31	50	76	37	46
Shannon Index		4.2	4.4	5.4	4.3	4.5
VP		17	30	40	42	44
HO	t DM ha^{-1}	0.82 (0.07) b	1.73 (0.11) a	0.62 (0.03) c	0.49 (0.06) c	*nr
Sward height	cm	3.4 (0.14) b	18.5 (1.76) a	5.0 (0.17) b	4.0 (0.64) b	*nr

*nr= not recorded; different letters within rows indicate statistical differences (P<0.05)

Livestock system - In table 2 animal performance are reported. The F1 group showed both higher live weight at slaughtering and growth rate than SC being the S group an intermediate. Any differences were detected in cold dressing percentage and meat quality. Ultimate pH is within the normal range, showing any of pre-slaughter stress. The meat showed α-tocopherol levels within the range needed to extend the shelf-life of retail beef (0.30-0.35 mg 100 g-1 of fresh meat; Geay et al., 2001) and higher than that recorded in animal fed with hay and concentrate as reported by Acciaro (2013) in Sarda young bull and by Realini et al. (2004).

Table 2 : Live weight (kg), average daily gain (kg head-1 day-1), cold dressing percentage (%), meat pH and α tocopherol *L. Dorsi* muscle content of experimental animals (F1=Charolaise bull X Sarda, S=Sarda, SC=castrated Sarda)

	F1	SC	S
Live weights at slaughtering (kg)	382 a	325b	360 ab
Average Daily Gain (kg head^{-1} day^{-1})	0.508a	0.386b	0.480ab
Cold dressing precentage %	46.9	47.4	47.8
pH	5.78	5.77	5.89
α tocopherol	5.21	5.63	5.44

*different letters within rows indicate statistical differences (P<0.05).

Discussion and conclusions

The average daily gain of Sarda young bulls resulted lower than that recorded by Acciaro et al. (2011) in young Sarda beef cattle raised at pasture (0.780 ±0.06). Meat quality results good despite low production. The grass antioxidants cause in grazed animals higher muscles levels of α-tocopherol with benefit of lower lipid oxidation (Acciaro, 2013). The herbage availability, following the Mediterranean pattern, resulted different among the phytocoenosis and low if compared to the value reported from other authors in the same environment (Sitzia and Fois, 2008). This fact, together with the low dressing percentage recorded, confirms that forage production of the studied areas is unable to cover the growth requirements of animals. On the other hand vegetation analysis highlights an elevate natural value of the area proved by an high level of biodiversity and endemisms and species of conservation interest (10%). It is furthermore relevant that 58% of the study area surface is resulted occupied by two habitat of European interest. This fact underlines not only the natural value of marginal areas but also the importance of vegetation communities to identify the habitats of European importance and how 92/43/EEC Directive habitats could be an useful instrument to identify the High Natural Value Farmlands which European Community's States are undertaken to locate adopting EU 1257/99. These results show that the value of beef cattle farming system in marginal areas is not related only to the economic sustainability of the system but also to the provision of other services strictly linked to the quality of human life and nature conservation.

Acknowledgments

The “PO Italia-Francia Marittimo 2007-2013” for the financial support (Projects MARTE+ SC Prot. n.AOO-GRT 109013/F.45.60 of 21/04/2010). Mr. G. Meloni, Mr. S. Mastinu, Mr. A. Pintore, Mr. G. Becugna, Ms. R. Coinu, Mr. Giuseppe Testoni, Mr. M. Carboni, Mr. M. Pintore, Mr. G. Scanu, Mr. M. Delrio for their technical help.

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Pastoralism on oak forest ecosystems: competition or compatibility?

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Abstract

A 5-year study was carried out to determine the foraging behaviour of cattle and goats grazing on coppice oak forests, which carry high amounts of herbage. An experimental area was chosen with three forest stands of different coppice age, one year (FSCA-1), four years (FSCA-4), and seven years (FSCA-7) after clear cutting, in which cattle and goats were grazing all round year at the stocking rate of 0.4 AU/ha. In each forest stand, five 10 m x 10 m paired plots were located, which represented grazed and protected patches. The herbage biomass within all plots (protected and free of grazing) was measured during the growing period (May – November). In both protected and open plots the height of all oak sprouts on 5 preselected stumps was measured for the five years of the study. Five cows and five goats were selected and visually observed for three days in several representative grazing periods, which corresponded to the four seasons of the year. All forest stands carried similar amount of available herbage (averaged over forest stands and growing season, 2580 kg/ha). Grazing animals removed throughout the growing period the amount of 1040 kg/ha. However, cattle took the vast majority of their bites on herbage (97%) while goats' bites consisted of a mixture of oak browse (45%), herbaceous species (33%), and other woody species browse (22%). The height of sprouts was significantly ($P<0.001$) affected by grazing. The fact that the three forest stands had similar sprout heights in the protected plots in 2001, advocates that long grazing applied on FSCA-7 (7 years after clear cutting) and FSCA-4 (4 years after clear cutting) affected the height of oak sprouts. It seems that goats selected almost the half of their diets from oak sprouts are responsible for that negative growth of sprouts; however, cattle grazing seem to be compatible with the oak forest growth.
Keywords: Grazed forests, diet selection, cattle, goats

Introduction

Mediterranean forests provide a wide array of benefits --wood and non-wood products-- and often have a high potential to contribute to local economies. A great part of forests (needle-leaved and broad-leaved) is managed for both wood production and livestock grazing throughout the Mediterranean areas. Depending on the conditions, grazing can affect positively or negatively a forest ecosystem (Liacos, 1980). A proper forest grazing provides diverse sources of income and enhances the health of forest ecosystem. However, uncontrolled forest grazing is considered to be catastrophic regarding the contributing to deforestation and degradation of productive forests.
The effect of a particular animal species has on a forest ecosystem is depended on its foraging ecology and the degree and type of physical disturbance that it causes. For example, cattle (*Bos* spp.) are less discriminate feeders of large quantities of abundant but less digestible material such as grasses (Hofmann and Stewart 1972). On the other hand, goats (*Capra hircus*) are classed as true intermediate feeders, behaving as both, browsers and grazers (Hofmann and Stewart 1972).
Deciduous oak forests suffered more than any other forest type by grazing in the Mediterranean basin, although there is evidence that in some cases coexisting of livestock and forest production can be a realistic management approach (Liacos, 1980). Oak forests cover a significant area (1,471,839 ha) in Greece and the majority are intensively managed, with a clear cutting cycle ranging from 20 to 30 years. The absence of over storey cover after the clear cutting favours herbaceous vegetation and such stands carry high amounts of herbage (Papachristou et al. 2005). These ecosystems are attractive for grazing and herders lead their flocks within them but without any grazing plan. Little information exists on how grazing animals select their diets in such ecosystems and whether this knowledge could be incorporated into forest management practices. The objective of the study reported here was to determine the foraging behaviour of grazing cattle and goats on coppice oak forests after clear cutting and whether this behaviour affects oak sprout growth.

Materials and methods

A 5-year study was conducted at Skepasto, Thessaloniki, in Northern Greece. The canopy vegetation was dominated by deciduous oaks such as *Quercus frainetto* Ten., *Quercus petraea* Liebl. and *Quercus pubescens* Willd. There were also were other woody species such as *Carpinus sp*., *Fraxinus sp*., *Quercus coccifera* L., and an undergrowth vegetation of forbs and grasses.

An experimental area of 45-ha was chosen, which consisted of three coppice oak stands (15-ha) that had been clear-cut one year (FSCA-1), four years (FSCA-4) and seven years (FSCA-7) before the initiation of the study. All stands were grazed by cattle and goats since they had been clear cut almost all year round. Both cattle and goats on the whole grazing land had a stocking density of 0.4 AUs/ha. In each forest stand, five 10 m x 10 m paired plots were chosen, which represented grazed and protected patches. The herbage biomass within all plots was measured during the growing period, from May to November in the 2nd and 3rd year of the duration of the study. Behavioural observations on grazing animal species were conducted during the four seasons of the year and the proportion of each vegetation category (i.e. oak sprouts, other woody species and herbage) in animal total bites was calculated using the following formula: percent of bites on forage category (%) = bites per forage category / total bites x 100. In both protected and open plots the height of all oak sprouts on 5 preselected stumps was measured during the start of the experiment and at the end of each of the following five growing periods (end of November) the study lasted.

Data on herbage production, bites on forage category and shoot growth were subjected to analysis of variance and significant differences among means were detected at the 0.05 probability level, using the LSD test. The experiment consisted of three forest stands, replicated over two years and either seven for herbage or four periods for bite rate data, and five years for shoot growth data.

Results and discussion

All forest stands carried similar amount of available herbage, which averaged over forest stands and growing season, 2580 kg/ha (Fig. 1). There was a significant difference in biomass between protected and grazed plots, indicating the impact of grazing on the reduction of herbage production.

Grazing animals removed throughout a growing period an herbage amount of 1040 kg/ha. However, cattle took the vast majority of their bites on herbage (97%) while goat bites consisted of a mixture of oak browse (45%), herbaceous species (33%), and other woody species browse (22%) (Fig.2). The highest selection on the other woody species by goats was recorded in winter; these woody species were *Carpinus* sp., *Fraxinus* sp. and *Quercus coccifera*.

The average height of oak shoots across forest stands was significantly higher on the protected plots comparing to the grazing plots in all 5 years ($P< 0.001$). It was 0.68 m for both protected and grazed plots in April 1997 (i.e. at the beginning of the experiment), rose up 1.05 and 0.87 m in November 1997, and finally reached out 1.83 and 1.24 m in November 2001, respectively. At the end of the experiment in November 2001, after five years of protection of the three stands with different grazing history (i.e. CL1996: few months grazing before the protection; CL1993: four years grazing before protection; CL1990: seven years grazing before protection), the grazing treatments had a significant effect ($P <0.001$) on shoot height but there was no forest stand or grazing treatment x forest stand interaction (Table 1). As a result the oak shoots in the protected plots of the three stands had a similar height although they differed in coppicing age. This suggests that long grazing applied on FSCA-7 and FSCA-4 affected the height of oak sprouts. A critical finding was that the absence of grazing for three years after the clear cutting (Table 1, protected plots of FSCA-1) ensured a height beyond the reach of goat ability to browse (1.5 m). This result may help managers to create new grazing strategies that integrate goats in coppice oak forests. For example, grazing of goats in coppice oak forests could be applied three years after the clear cutting or during winter, when they select much browse of evergreen woody species (see Fig. 2; winter, other woody species).

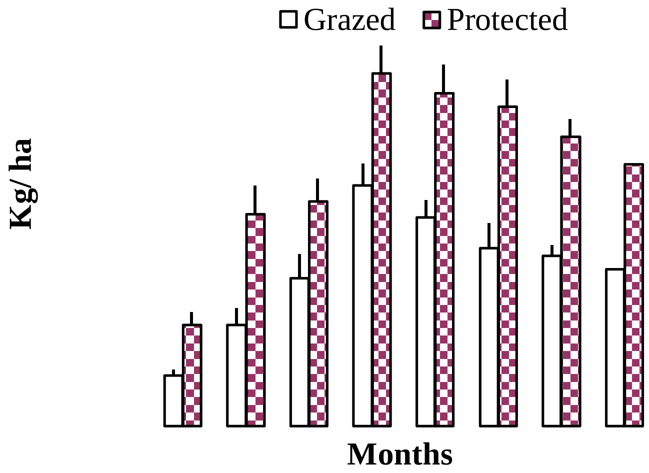

Figure 1: Available amounts of herbaceous vegetation (kg/ha; +upper 95% confidence limit) of the studied coppice oak forest during 7 months of the year (May – November; mean values from 3 coppice oak stands and 2 yrs). $LSD_{0.05}$ = 263.9 kg/ha to compare grazing×month means.

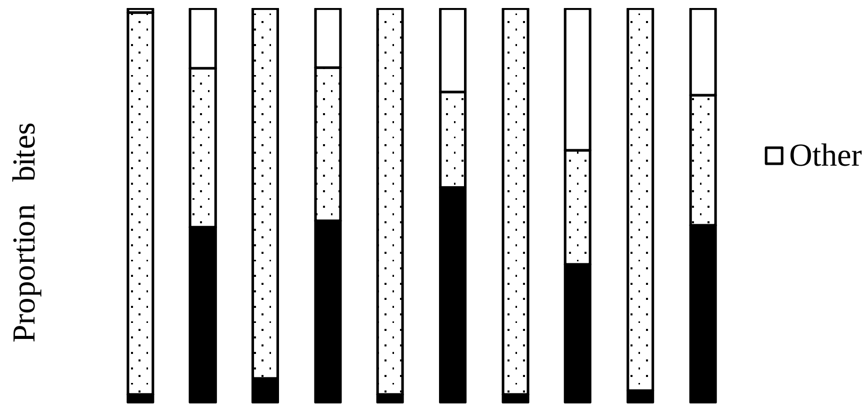

Figure 2: Proportion of bites from vegetation categories (oak, herbs and woody species) by cattle and goats grazing on the studied coppice oak forest during the four seasons of the year in northern Greece.

Table 1. Mean height (m) trends of sprouts in grazed (G) and protected (P) plots of the three oak stands of different coppice ages for 5-years. Both grazed and protected plots up to the initiation of the experiment were grazed.

	FSCA-1		FSCA-4		FSCA-7	
Years	G	P	G	P	G	P
Start	0.4	0.4	0.8	0.8	0.9	0.9
1st yr	0.8	1.0	0.9	1.2	0.9	1.0
2nd yr	0.9	1.3	1.0	1.5	1.1	1.3
3rd yr	0.9	1.5	1.1	1.6	1.2	1.4
4th yr	1.0	1.7	1.2	1.8	1.2	1.5
5th yr	1.0	1.9	1.4	1.9	1.3	1.7

$LSD_{0.05}$ = 0.3 m to compare forest stands x grazing x years.

Conclusion

The applied grazing scheme reduced significantly the herbage but it had an impact on oak sprouts. It seems that goats selected almost the half of their diets from oak sprouts, are responsible for the negative growth of sprouts; however, cattle grazing seem to be compatible with the oak forest growth.

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Management of cattle and draught horse to maintain openness of landscapes in French Central Mountains.

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Abstract

To analyze the impact of mixed herds on grazing management in mountain grasslands, we surveyed 25 farms, managing dairy and/or beef cattle with a small horse herd representing about 10% of the total livestock. Farmers favoured the two animal species grazing together on the same pastures. However, horses also used alone pastures ungrazed by cattle: about 10% of the total grassland area in beef systems and 15% in dairy systems, reflecting their use by farmers as landscape managers.

Keywords: horse, cattle, mixed grazing, mountains

Introduction

The analysis of the more recent French agricultural census highlights that the French Central Massif, and particularly the Auvergne area, is mainly devoted to beef and dairy cattle productions (Agreste, 2012). This area also takes the first national position for draught horse farming (REFErences, 2011). Surveys on horse farming in Auvergne show that for half of the farms, horse breeding is associated with other farming activities such as beef or dairy productions (Morhain, 2011). So, the two animal species can graze the same pastures, particularly in highlands where the draught broodmares density increases (Bigot *et al*, 2010). To precise mixed grazing managements, and consequently impacts on keeping open landscapes of agricultural lands, we surveyed farms managing together cattle and horses.

Material and methods

A face to face survey covered 25 farms located between 800 m and 1000 m in altitude, managing beef or dairy cattle or the both herds associated with a horse livestock (5 broodmares and more). Farmers have been enquired about the aim, structure, reasons of the different animal productions and especially about grazing management. Data on grazing management were collected per group of homogenous fields with same technical management practices particularly on harvesting, type of grazing animals and any other maintenance practices. In each group, data took into account area, distance to the main stable, and hay harvesting dates, grazing periods as well as type and number of grazing animals.

Results

Main features of investigated farms and their grassland managements

These surveyed farms worked an agricultural area of 128 (+/-50) ha. Permanent grasslands covered 86% of these area whatever the cattle husbandry: 11 beef farms, 8 dairy farms and 6 mixed (beef and dairy) farms. The total livestock was 128 (+/- 25) Livestock Units (LU) and draught horses reached on average, 9% of this total (a little bit more in dairy farms). The equine herd included on average 15 horses (broodmares, stallion and replacement fillies) mainly coming from 4 French breeds: Trait Comtois, Breton, Percheron and Ardennais. The stocking rate of farms was about 1.0 LU ha^{-1} of total agricultural area, with no differences between the cattle productions.

In these mountain farms, grass areas exclusively grazed by livestock, reached more than 50% of the grasslands. Moreover hay harvesting was the most common practice on others grasslands. Less than 25% of farmers ensilaged grass accounting for less than 10% of the total grassland area. After one or seldom two cuts, plots were generally grazed. A part of grasslands was often topped to stagger the harvest periods. So, farms showed between 4 or 5 different technical ways of grassland use, according to the types of harvesting and grazing animals. The fodder balance was reached or positive in most of the farms.

Practices of the equine-bovine mixed grazing

During the grazing period, cattle and horses staid outside round the clock, regardless of farming systems. In beef farms and mixed cattle systems, farmers used preferentially the two species (equine and bovine) grazing simultaneously on 50% of the pasture area (Figure 1). In dairy farms, horses grazed paddocks after the cattle grazing on almost half the pasture area, so that the cattle and horse simultaneously grazing concerned only 35% of the total grassland. Horses also used pastures ungrazed by cattle: about 10% of grasslands area in beef systems and 15% in dairy systems. On contrary, pastures only grazed by cattle were rare and absent in dairy systems.

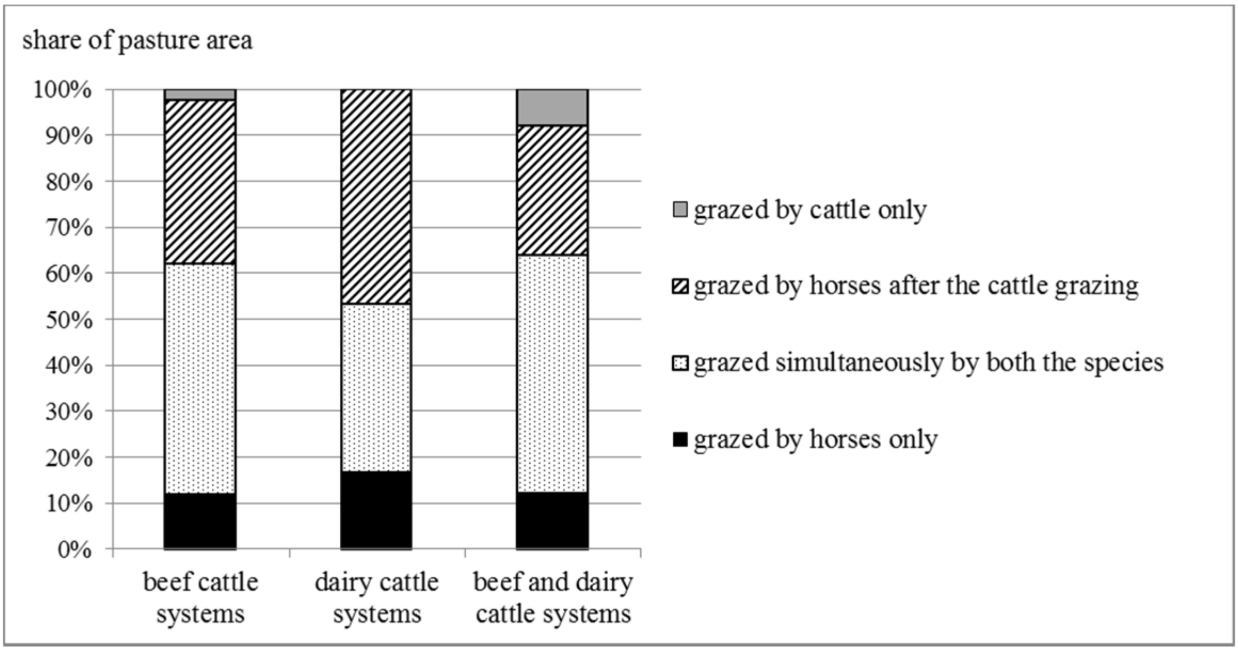

Figure1: Mixed grazing practices according to the bovine system with horses, expressed as a percentage of the total pasture area

In each farm, cattle and horse grazing associations varied according to the paddocks features (size, location, distance from the facilities, productivity) and to the type and size of herds, particularly cattle herds: dairy or beef cows, heifers. Some major practices used in more than 5 farms could be depicted according to the paddocks types, the bovine herds and the main managements (table 1). Horses and cattle grazed simultaneously especially on large plots (more than 40 ha) in beef systems. In these cases, all the equine herds (young horses, broodmares and the stallion) grazed with beef cows associated or not with heifers. This mixed grazing was particularly used in uplands between May and October. Young horses could sometimes be associated with heifers on smaller plots. In this case, the stocking rate was higher because there was no harvest. Whatever the harvesting, horses grazed after dairy cows during spring and summer and after beef cows and heifers in autumn. During the grazing season, horses could also graze alone small parcels (less than 10 ha) which were not or seldom cut. Draught horses were maintained outdoors around the year. During winter (120 days), horses could access freely all the lower altitude grasslands while bovine herds were in barn. Horses were fed outside with sole hay only during snowy and bad times.

Reasons expressed by farmers for mixing horse and cattle in grass use

The surveyed farms have been existed for over 10 years. Horses have been introduced on average 3.5 years after the start of the farms. All farmers managed horses because they liked them and 80% mentioned also the equine ability to use small and unproductive fields and to exploit the grasses refused by cattle. Without horses, 44% of farmers would have to cut grass refusals after cattle grazing, 15% would have leaved small and far parcels and only 24% would have increased the cattle livestock. But farmers did not want to increase their equine livestock because of its low economical results.

Table 1: Main practices of the equine and bovine grazing according to herds

Grazing practices		Horse and cattle simultaneous grazing			Horse grazing after cattle grazing			Horses only
Types of grazing cattle herds		Beef cows	Beef or dairy heifers	Beef cows and heifers	Dairy cows	Beef cows	Beef or dairy heifers	
Number of farms		9	5	5	8	5	5	11
Average grazed area (ha)		**45**	**23**	**42**	**27**	**28**	**15**	**7**
Management practices	Grazing only	49%	100%	53%	57%	50%	48%	84%
	Hay (1 or 2 cuts) + Grazing	51%	0%	47%	43%	50%	52%	16%
Stocking rate on grass (LU/ha)		0.6	1.1	0.7	1.4	0.9	1.1	1.6
Average number of equine LU		**8.8**	**2.2**	**9.0**	**8.8**	**6.0**	**7.3**	**7.7**

Discussion

The surveyed farms had larger areas than the regional average area and the rate of permanent grassland was in accordance of mountain farms data (Agreste 2012). In dairy systems, cows generally grazed paddocks with the high forage value and located near facilities to limit herd movements for daily milking (Brunschwig *et al*, 2006, Bigot *et al*, 2011), so draught horses which need few cares, did not graze with dairy cows. In this survey, heifers grazed the smallest, less productive and farther paddocks. The dairy and beef mixed systems were often a solution to use effectively the diversity of grasslands productions and some plots away from the facilities (Brunschwig *et al*, 2006). This investigation shows a small number of draught horses could use small or remote paddocks. Horses could also graze some very poor lands unusable by cattle, even by heifers, because of their morphologic and digestive characteristics (Fleurance *et al*, 2011). That is the reason why some surveyed farmers explained some paddocks would be neglected without horses.

Furthermore, farmers favour grazing of the two species simultaneously on pastures where the stocking-rate is around 1.0 Livestock Unit per hectare during the grazing season. This management could be explained by different experimental results. On the one hand, a mixed (horse and cattle) herd could limit some ligneous vegetation under low stocking rate (Orth, 2011). On the other hand, when vegetal resource is limited, horses could modify their foraging behavior to use grass resources they don’t usually eat (Osoro *et al*, 2012). On contrary, cattle feed always on the same vegetal species (Orth, 1998). So, a mixed herd of horses and cattle can adapt more easily to changes in annual grasses resources than cattle herd alone (Orth, 1998). In this survey, a proportion of about 10% horses out of the total livestock seemed to have no influence on the forage balance, comparatively to specific bovine farms (Bigot *et al*, 2010). Horses could be fed with grass refusals after cattle grazing during summer and autumn as observed in Franche-Comté region (Mugnier *et al*, 2012). As formerly presented (Micol and Martin-Rosset, 1995), horses are fed essentially by grazed grass and secondly by hay during the year without any concentrates. At term, the mixed herds could improve the forage value of mountain grasslands as demonstrated before (Loiseau et Martin-Rosset, 1988).

This equine and bovine mixed farming preserved also the farm animal biodiversity. In France, grassland areas were essentially used by cattle which represented in 2009, 88% of the national herbivore livestock (expressed in Livestock Units), and the equine livestock represented only 4% (Morhain, 2011). As main local breeds (Miraglia, 2012), the four French horse breeds raised in these farms are endangered, in accordance with European laws.

Conclusion

Horse grazing alone or associated with cattle grazing was often studied in experimental conditions, especially in high environmental value grasslands. This investigation presents data on more usual practices in mountain farming systems. Cattle and horse mixed herds seem to be appropriate to use uplands. Mixed herds are better suited to annual and structural changes in the productivity of grasslands. Horses can valorize vegetal resources unusable by cattle. The complementary behaviour of the two species seems to maintain feed value of the grass resources with low inputs. This first investigation can be improved by studies on biodiversity maintenance according to usual management practices.

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SESSION 3 – Agro-pastoral activities for environmental conservation

Multilevel modelling unveils environmental drivers of the effect of forest succession on plant species loss in Alpine pastures

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Abstract

Several studies report a decrease in the number of species on mountain pastures subjected to forest succession. However, most studies analysed forest succession at only one site or at a number of sites covering a very limited range of environmental gradients. Our study was conducted on eight sites with pasture-to-forest gradients in the Southern Italian Alps. We analysed how plant species richness is affected by natural forest succession and how this effect depends on environmental site conditions.

Each of the eight sites had different environmental conditions and soil substrate and was dominated by a particular woody species. At each study site, we assessed species richness along the gradient from open grassland (0% woody species) to closed forest (100% cover by woody species). Generalized linear mixed models (GLMM) were built to analyse the effect of environmental factors on the observed relationship between species richness and wood cover.

The relationship between wood cover and species richness was linear to hump-shaped and, in general, negative, displaying marked differences within sites. We found that effects of forest succession on plant species richness depend strongly on environmental conditions: analysis with GLMM unveiled that mean annual temperature captures differences between sites well and can be used as a surrogate of site to predict species richness in dependence of wood cover. The highest numbers of species were found at low to intermediate levels of wood cover. This trend is more evident in the sites with higher mean annual temperature.

Our investigations showed that pasture management should pay particular attention to biodiversity aspects on sites with higher mean annual temperature.
Keywords**:** land-use change; reforestation; species richness; subalpine pastures

Introduction

In the past half a century, the Southern Alps have undergone a tremendous and arguably unprecedented change in land use; these changes include the reduction and abandonment of grazing and favored the establishment of woody or shrubby species. The process of reforestation depends on presented dominant woody species, because each woody species has a specific response to environmental factors (for example De Gasperis and Motzkin, 2007; Tasser and Tappeiner, 2002). Natural reforestation changes vegetation composition and species richness in pastures. Several studies report a decrease in the number of species with increasing forest cover (Anthelme *et al.*, 2001; Kesting, 2009). However, most studies analysed forest succession at only one site or at a number of sites covering a very limited range of environmental gradients.

In order to study environmental drivers of the effect of forest succession on plant species richness, we investigated pasture-to-forest gradients on eight contrasting sites in the Italian Alps (constituted by summer pastures). Our hypothesis is that environmental conditions have direct effects on the vegetation and also affects the dynamics that occur thereafter. Furthermore, we hypothesize that a low percentage of wood cover outcompetes a comparatively larger number of shade-sensitive grassland species and hence species richness decreases with wood cover.

Materials and Methods

This study was carried out on eight sites located in the Eastern Alps of Italy, between 2006 and 2010 (further information available in Pornaro *et al.*, 2013). Each site was dominated by a particular woody species (Table 1).

Table 1: Main characteristic of the eight study sites.

ID site	A	B	C	D	E	F	G	H
Dominant woody species	Fagus sylvatica	Picea abies	Larix decidua	Pinus mugo	Alnus viridis	Picea abies	Larix decidua	Rodhodendron ferrugineum
Substrate	carbonate	carbonate	carbonate	carbonate	silicate	silicate	silicate	silicate
X coordinates*	5078100	5092270	5096180	5091965	5127085	5126725	5128975	5105810
Y coordinates*	699850	701070	697195	693095	690120	700305	715490	685140
Altitude [m a.s.l.]	1150	1350	1700	1650	1050	1550	1750	1700
Annual mean temperature [°C]	0,297222222	05.38	0,17083333	03.48	0,30208333	04.00	03.51	04.36
Annual precipitation [mm]	1463	1546	1546	1546	800	1050	1050	917
N content [g kg-1]	02.06	06.09	14.03	05.04	04.09	05.03	07.03	07.08
Organic matter [g kg-1]	128.06.00	212.02.00	309.05.00	295.00.00	156.07.00	148.07.00	245.05.00	226.00.00
Total number of species (approx. γ diversity)	190	147	128	81	141	128	116	106
Red list species**	5	4	1	2	4	0	2	0

* Projection system is IGM95 / UTM zone 32N.
** according to Moser et al. (2002).

In each site, soil was sampled at 0% wood cover and used to estimate general soil characteristics of each site. Soil pH, N content, and soil organic matter were measured using the Italian standard soil analysis techniques (G.U., 1999). Mean annual temperature at each site was derived from the high-resolution alpine temperature interpolation by Hiebl *et al.* (2009). Mean annual precipitation was derived from the weather station (ARPAV and Meteotrentino data) nearest to each site.
At each study site, thirty plots of 10 m x 10 m were established with particular levels of wood cover. Care was taken that plots had homogenous levels of wood cover that were well distributed between 0 to 100%. In each plot, the percentage of wood cover was visually estimated as the wood projection over the ground and all species present were recorded. In addition, red-list species (according with Moser *et al.*, 2002) were counted in each plot and correlated against wood cover. Generalized linear mixed models (GLMMs) were built to explain observed variation in species diversity richness depending on wood cover and environmental conditions.

Results and Discussion

Including environmental variables into the GLMM demonstrated that they have significant influence on species richness alone or on the effects of wood cover on species richness. The most important environmental factors were mean annual temperature ($P\chi2<0.01$), organic matter ($P\chi2<0.001$) and N content of the soil ($P\chi2<0.01$), having significant effects on species richness alone, as well as on the effect of wood cover on species richness. Other site variables such as altitude, slope and pH had no significant effects on species richness or on the effect of wood cover on species richness.
Subsequent model simplification showed that the most parsimonious GLMM (i.e. having the lowest Akaike's Information Criterion [AIC]) was a model with cover, its square, and mean annual temperature as fixed effects (Table 2). This means that mean annual temperature captured differences between sites well and can be used as a surrogate of site properties to predict species richness in dependence of wood cover. Other environmental descriptors do not explain substantially more of the variability in the data because they are collinear to mean annual temperature.

Table 2: Estimated coefficients of explanatory variables in generalized linear mixed-effects models to plant species richness 100 m^2 with wood cover and mean annual temperature as fixed effects. Significances are based on likelihood-ratio tests. Estimated coefficients are at log scale because of the use of a Poisson GLMM.

Sampling area	100 m^2		
	Df	Estimate	Pχ2
Intercept	2	3.94	
cover	1	-0.48	<0.001
$cover^2$	3	-1.27	<0.001
mean annual temperature	1	0.1	<0.05
cover x mean annual temperature	1	0.01	n.s.
$cover^2$ x mean annual temperature	1	-0.26	<0.05

This means that mean annual temperature can stand in as a proxy for other environmental variables.
Because the model contains only three variables, the prediction can be visualized as a 3D surface. A significant interaction between the squared wood cover and mean annual temperature was found. The estimated response of species richness to wood cover was therefore hump-shaped at high mean annual temperature, while at low mean annual temperature, the decrease was linear (Fig. 1).

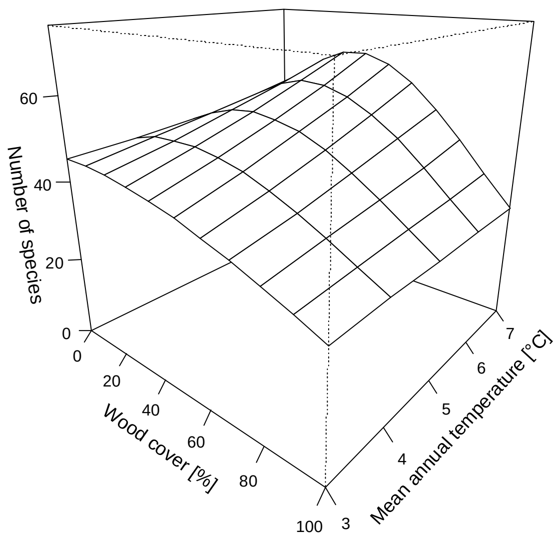

Figure 1: Effects of wood cover and mean annual temperature on the number of species. Surface is predicted from a generalized linear mixed-effects model fitted to the data.

Our investigations show that species richness generally decreases with increasing wood cover with a more or less strong hump at low to intermediate levels. This is consistent with most studies that investigated consequences of land use changes in the Alpine region (see for example Dullinger *et al.*, 2003; McDonald *et al.*, 2000; Öckinger *et al.*, 2006).
Evaluating the consistency of our model with two published transect studies, we found that the monotonic decrease of plant species richness with increasing wood cover at low mean annual temperature found by Anthelme *et al.* (2001) and the hump-shaped relationship at high mean annual temperature reported by Kesting (2009) agree very well with Fig. 1. Thus, sites with higher mean annual temperature are the most vulnerable to loss of species by forest succession.
In addition, at the warmer sites 4 or 5 red-listed species were found in comparison to a maximum of 2 species in the other sites. High numbers of red-list species were found at low to intermediate percentages of wood cover, with the relative frequency of red-listed species negatively correlated to wood cover (Spearman's R =-0.7, p=0.02). In conclusion, management strategies should be promoted which maintain of

a low percentage of shrubs or trees on pastures but do not necessarily keep them free of shrubs or trees. Because of the higher heterogeneity created by grazing than by mechanical operations (Wrage *et al.*, 2011), a combination of animal grazing with mechanical interventions to regulate shrub cover may maintain the highest species numbers.

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A trait-based approach to assess the resistance of a mountain grassland during an extreme drought event and the impact of management

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Abstract

In the Swiss Jura mountains, grasslands are at the core of herbivorous farming. Knowledge of their evolution in the context of climate change, especially their response to the predicted increased frequency of extended drought periods, is therefore a major challenge. Identifying the potentially interactive effect of management and extreme climatic events is also highly needed. For this purpose, we set up in 2012 an experiment combining rainfall manipulation, to simulate a severe drought, and two management regimes (rotational grazing vs. mowing) on a grassland in the Swiss Jura mountains. We studied the resistance (i.e. the magnitude of changes after drought) of the grassland community by means of a plant functional trait approach (i.e. by monitoring changes in both species abundances and plant trait values of species). We observed that the response to drought mostly occurred through changes in plant trait values of species, whereas species composition was rather stable. Changes in mean trait values and functional diversity at the community scale reflected a sharp slowdown in plant growth as well as a shift (toward higher conservation of resources) and a diversification in the strategies of plant species. These changes were more pronounced with grazing than with mowing. This can be due to the higher number of utilisations with grazing which maintained the plants in a younger development stage and made the grassland community less resistant to the water stress. Changes in mean plant traits can be good predictors of modifications of grassland services such as biomass production and its nutritive value which were negatively affected by drought and grazing. Overall, this study suggests the role of intraspecific trait variability (i.e. physiological plasticity within each species) as a process allowing the botanical composition of a plant community to remain relatively stable after short-term drought events. Such stability of community composition foreshadow the potentially high resilience of these grassland communities.
Keywords: plant functional traits, plant species composition, drought resistance, mountain grassland, management regime

Introduction

In the Swiss Jura mountains, grasslands are at the core of herbivorous farming and the new Swiss agricultural policy supports forage autonomy and encourages farmers to feed their livestock without having to rely on foreign forage. However, with the pressure of climate change, grasslands will be challenged to meet this growing demand for providing forages. Climate change is expected to increase the magnitude and the frequency of extreme climatic events such as droughts (IPPC 2007). In the west part of Switzerland, the occurrence of dry summers should increase and precipitations might reach, in extreme years, only 30% of total summer precipitations (CH2011). Knowledge of resistance and resilience of grassland functions in mountainous areas during such drought events is a major challenge, and, understanding how grassland management will influence this response in such context is therefore highly needed. The plant functional approach, in which species composition of grasslands is expressed on the basis of plant traits (i.e. morphological and ecophysiological characters of plants), is a promising tool to study grassland responses to environmental changes (Schellberg and Pontes 2012). Indeed changes in plant trait values inform on variations of species ecological strategies within plant communities and thereby on ecosystem processes and functioning. For instance, variations in leaf trait values, such as increased leaf dry matter content and/or decreased specific leaf area, can reflect the regulation of water loss through leaves (Wright *et al.* 2001) and negatively influence the decomposition rates of the litter (Garnier *et al.* 2004) as well as the quality of the forage (Ansquer *et al.* 2009). In this study, we addressed the following questions: What are species and trait composition changes after a short-term drought event under contrasted management regimes? Do these changes highlight mechanisms of community resistance to drought? Can these changes inform on grassland forage production and quality?

Material and methods

The experiment was set up on a permanent grassland dominated by grasses at the experimental research station of La Frêtaz in the Swiss Jura mountains at 1200 m a.s.l. We established 16 large experimental units (6 x 12 m) that enabled grazing by sheep (6 rotations during the 2012 growing season) and the use of a mower for the mowing treatment (3 times). Half of the 8 plots of each management type were covered with transparent rain shelters during mid-June to end of August to simulate the effects of an extreme summer drought as predicted for 2050 in the western part of Switzerland (CH2011) (i.e. 70% of precipitation was removed during the June to August period), while others plots received natural precipitations. Monitoring of microclimatic variables was continuous during the whole experimentation and showed very low artefact effects of rain shelters since temperature at 0.5 m aboveground did not change and the photosynthetically active radiation was reduced by 20% at its maximum. As expected, the use of rain shelters led to a strong reduction of soil humidity (in average -40% during the covered period). Botanical relevés were realised in the core area of each plot to estimate species relative abundance. In each treatment, plant functional traits were measured for the 7 dominant species and 8 minor species (cumulated abundance of these 15 species reach at least 90% of each plot total abundance). Plant vegetative height, specific leaf area and leaf dry matter content were measured according to standardised protocols of Cornelissen *et al.* (2003). Biomass samples were collected prior to each grazing and mowing to assess the dry matter yield and the nutritive value of the forage at each utilisation.

Results and discussion

Species composition was slightly affected by the drought treatment (Figure 1A), and two months later, some species were still negatively affected (e.g. *Trifolium repens*) whereas others were favoured (e.g. *Poa sp.*), depending on the management regime (Figure 1B). However, the variations of abundance of most of species were not significant because of high variability among plots of the same treatment. Species richness, diversity and evenness were not affected by the drought treatment and management regime (data not shown, $p>0.05$ following two way ANOVAs).

In contrast to these small changes in species abundances, the trait values of each species were strongly affected immediately after the drought. As a consequence, the **mean trait value at the community scale** (Figure 2A) showed marked changes. The decrease in mean plant height was consistent with the simultaneous decrease in mean specific leaf area (SLA) and increase in mean leaf dry matter content (LDMC). This reflected a sharp slowdown in plant growth rates and a shift in plant strategies toward the conservation of resources allowing the regulation of water loss through leaves (Wright *et al.* 2001, Cornelissen *et al.* 2003). The **functional diversity**, measured by the Rao's index and reflecting the range of trait values in the community (see de Bello *et al.* 2006 for index computation), was also strongly affected, especially in the grazing treatment (Figure 2B). The increase in functional diversity during the drought indicated a diversification of species ecological strategies although the number of species did not increase and, therefore, a better partitioning of resources between species (de Bello *et al.* 2006). Changes in mean and diversity of trait values were further enhanced in the grazing treatment compared to the mowing one ($p<0.05$ for the interaction between drought and management after two way ANOVAs). This can be due to the maintenance of plants in a younger development stage in the grazing compared to the mowing treatment, reflected by lower mean plant height and lower mean LDMC in the control situation. Younger plants were probably more vulnerable to water stress which led to a less resistant community (i.e. higher magnitude of changes in the grazing than in the mowing treatment) (Vogel *et al.* 2012). The effect of drought was still detectable two months later for the mean plant height (lower in drought plots, Figure 2A) which also showed higher functional diversity (Figure 2B). However, for SLA and LDMC, mean values were almost no longer affected by drought 2 months later, whereas their functional diversity were in the mowing treatment.

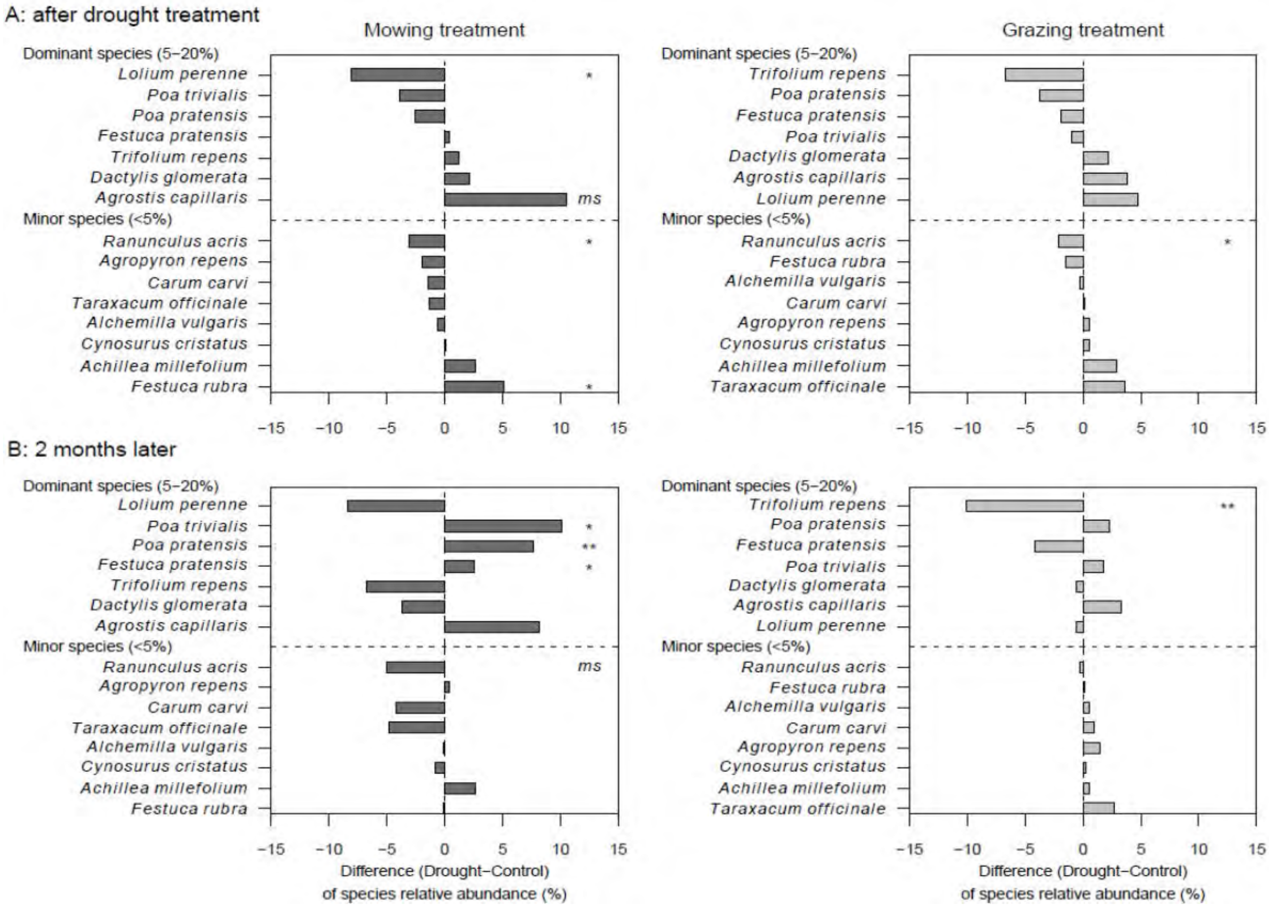

Figure 1: **Difference in the relative abundance of each species in control vs. drought plots** in the grazing and mowing treatments assessed at two periods (A and B). Significant differences (derived from post-hoc tests following two way ANOVAs) are indicated on the right side of each panels (*ms*: marginally significant 0.05<p<0.1; *: p<0.05; **:p<0.01).

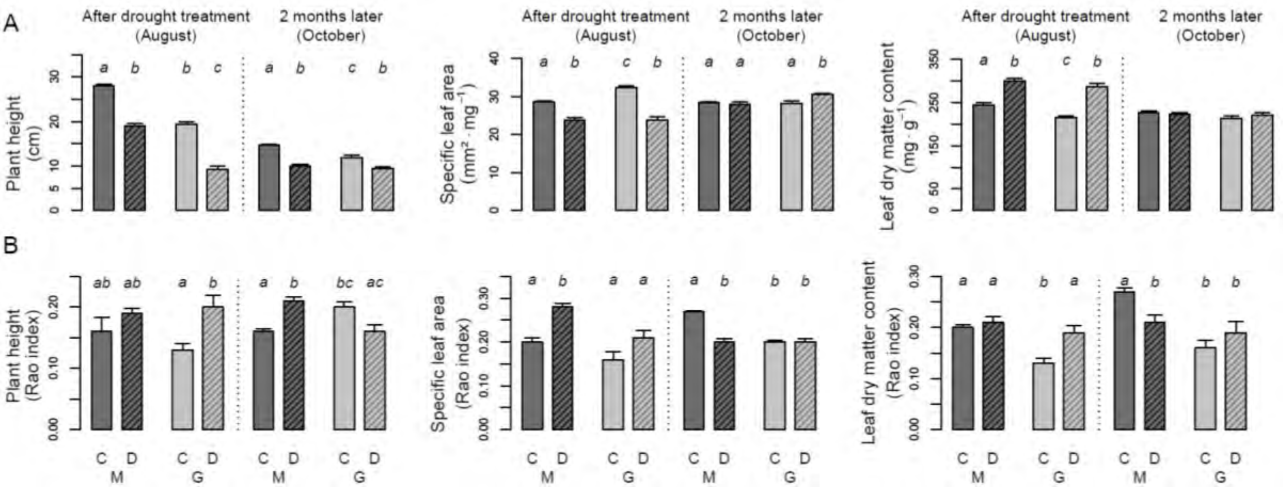

Figure: **A) Community weighted mean trait values** (i.e. mean of species trait values weighted by species abundance) and **B) Rao's index of functional diversity** (i.e. dissimilarities of trait values between all pairs of species weighted by species abundances) at two different periods in the mowing (M) and grazing (G) treatments and in control (C) and drought (D) conditions. Bars indicates mean values (n = 4) ± SE. Different letters above bars indicates significant differences (p<0.05) derived from post-hoc tests following two ways ANOVAs.

Lastly, we observed that community mean plant traits could be good predictors of the biomass production and its nutritive quality (Figure 3) as already documented for different grassland ecosystems (e.g. Garnier *et al*. 2004, Ansquer *et al*. 2009). In particular, decrease in mean plant height can estimate the loss of dry matter yield between control and drought plots during a drought event. A decrease in mean SLA can indicate a decrease in crude proteins content, and, an increase in mean LDMC may for instance indicate a decrease in net energy for lactation. Both changes could thus predict a decrease in the nutritive value of the forage.

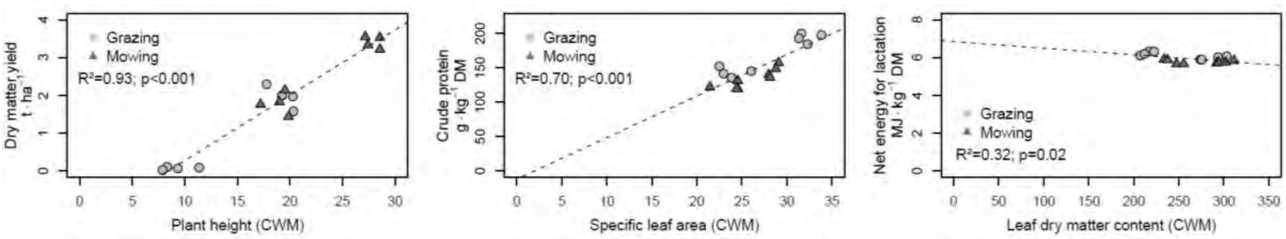

Figure 3: **Relationships between community weighted mean (CWM) of plant traits and several components of biomass production and nutritive value** for both drought and control plots immediately after the drought treatment. Dash lines represent linear regressions.

Conclusion

In response to a severe but short-term drought, the plant community mainly reacted through marked changes in plant traits whereas the species composition was rather stable. This suggests that intraspecific trait variability (i.e. physiological plasticity of species) was a predominant response process compared to changes in species composition. Changes in species composition would rather be expected in response to long-term perturbations (Evans *et al.* 2011). Species plasticity is known to be a stabilizing process that enhance stress tolerance in ecosystems frequently submitted to perturbations (Lloret *et al.* 2011). In this study, we showed that this stabilizing process may also occur in relatively high productive mountain grasslands. The observed trait variability did not ensure short-term stability in biomass production and forage quality but foreshadow the potentially high resilience (i.e. return to the initial state) of such grassland community since species composition was relatively well preserved (Lloret *et al.* 2011).

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Effect of the grass-shrub mosaic in species richness of plants, butterflies and grasshoppers on a Swiss subalpine pasture

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Abstract

Centuries of agricultural activities have shaped Swiss alpine landscapes contributing to their rich biological diversity. However, current land-use changes are threatening this biodiversity, with some areas being managed more intensively, and others being abandoned leading to shrub encroachment and reforestation. The aim of this study was to investigate the relationship between grazing intensity and cover by dwarf shrubs, and their role in shaping the diversity of vascular plants, butterflies and grasshoppers on an encroached Swiss subalpine pasture. Heavily grazed areas showed very low dwarf shrub covers. In contrast, areas with low grazing intensity tended to be heavily encroached. This interaction affected plant species richness, which was highest in a grassland-shrub mosaic with intermediate dwarf shrub cover. In turn, plants played an important role for both butterflies and grasshoppers, but no direct effect of shrub cover or grazing intensity was found. Whilst plant species richness, altitude and aspect showed a significant effect on the species richness of butterflies, plant beta diversity and slope significantly affected grasshopper species richness. Our study shows that grass-shrub mosaics are valuable for the conservation of plant and insect diversity on subalpine pastures.
Keywords: alpine, dwarf shrub, insect, management, shrub encroachment

Introduction

Summer pastures in the Alps and Jura Mountains make up a third of the agricultural area in Switzerland (Baur *et al*., 2007). Their high biological diversity developed over centuries of agricultural activities (Bätzing, 2005). However, current land-use changes driven by altered social and economic conditions are causing many areas to be underused or abandoned, and subsequently invaded by woody plants (Tasser and Tappeiner, 2002). This transformation has an impact especially on remote grassland patches or marginal locations, so-called “agricultural marginalization” (Baldock *et al.*, 1996). Indeed, more than two-thirds of the area affected by shrub encroachment and reforestation belong to the summer pasture ecosystem (Baur *et al.*, 2006) threatening the long-term sustainability as well as biodiversity of these grasslands.
The increasing number of summer pasture areas affected by shrub encroachment poses a conservation issue and urges for the development of counteracting measures. The study aims at examining the dynamics between grazing intensity and shrub encroachment, and their effect on the species richness of plants, butterflies and grasshoppers. This was investigated on a Swiss subalpine pasture presenting a gradient from open pasture to entirely encroached areas.

Material and methods

The survey was carried out in 2010 and 2011 on a subalpine pasture, Alp Sura, nearby the village of Guarda in southeastern Switzerland. The pasture is used by cattle, about 100 ha large and situated at an elevation between 2097-2410 m a.s.l.. Open grassland areas intermix with highly encroached areas dominated by the dwarf shrub *Juniperus communis.*
Three cows were equipped with GPS loggers during the whole summer 2011, during which the animal positions were recorded every 20 seconds. The density of points transformed into livestock units (LU) per ha was used as a measure for grazing intensity. The effect of grazing intensity on shrub stem breakage frequency was studied in 49 areas of $100m^2$ highly encroached by *J. communis*. Here, the number of broken stems was counted and the relationship with grazing intensity was analysed with linear regression. To study

the growth of *J. communis* plants under different grazing intensities, eight shrubs in heavily grazed areas and eight shrubs in areas rarely visited by the grazing animals were chosen. For each shrub, five shoots growing at the interior and five growing at the exterior were randomly selected. The length of the shoot fraction grown during the previous three years was measured. An ANOVA test was used to test the effect of the position on the shrub (interior vs. exterior) and grazing pressure (intensive vs. extensive grazing).

Thirty-three plots of 30 x 30m were distributed in a grid on the pasture. The vegetation was recorded in nine quadrats of $1m^2$ as well as during further 30 minutes search over the whole plot. Adult butterflies and grasshoppers were recorded in a serpentine-like transect traversing the plot during five and two occasions, respectively. For each plot we recorded in addition altitude, slope, aspect and cover by dwarf shrubs. Grazing intensity per plot was also calculated. The effect of dwarf shrub cover (and its square term), grazing intensity, altitude, slope and aspect on the species richness of plants, butterflies and grasshoppers was investigated with path analysis models. For the insect groups, plant species richness and plant beta diversity were also included in the starting model.

Results and discussion

Local grazing intensity formed a very heterogeneous pattern across the pasture. Flat areas were grazed rather intensively and presented low cover by dwarf shrubs. Instead, sloping areas were rarely visited by the animals and tended to be highly encroached (Fig. 1). This indicates a link between grazing and dwarf shrub cover patterns in association with slope, which is an important factor affecting movements of grazing animals (Ganskopp and Vavra, 1987).

The significant positive relationship ($p < 0.01$) between number of broken *J. communis* stems and grazing intensity on encroached areas further suggests that the trampling of the animals is an important constraint for these shrubs. In fact, *J. communis* as well as other dwarf shrubs are fairly grazing sensitive and the negative effect of grazing on these woody plants was shown in previous studies (Fitter and Jennings, 1975; Palmer *et al.*, 2003). The increased frequency of damage with increasing intensity indicates that grazing plays an important role in the control of dwarf shrub spreading. However, the growth of *J. communis* shrubs appears to vary under different intensities: The grazing intensity ($p < 0.001$) but not the position of the shoot within a shrub ($p = 0.919$) significantly affected the mean length of *J. communis* shoots in the three recent years (Fig. 2). The mean shoot length in areas intensively grazed were significantly longer than in areas subjected to low grazing intensity. This relationship might be linked to the higher nutrient availability for shrubs growing under intensive grazing conditions. Otherwise, the age of the plants might also be an explanation: shrubs growing under intensive conditions might be younger and have a more vigorous growth than shrubs growing in areas rarely visited by cattle (Edwards and Ekins, 1997).

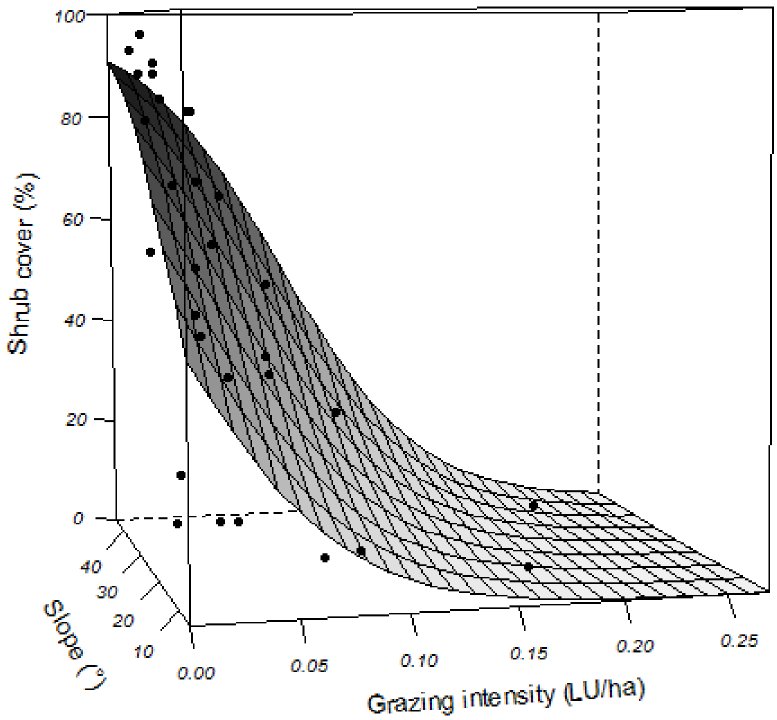

Figure 1: Shrub cover (%) plotted against grazing intensity (LU/ha) and slope (°) for 33 plots of 900m^2 on the Alp Sura. A binomial GLM curve with logit transformation was used to model the data.

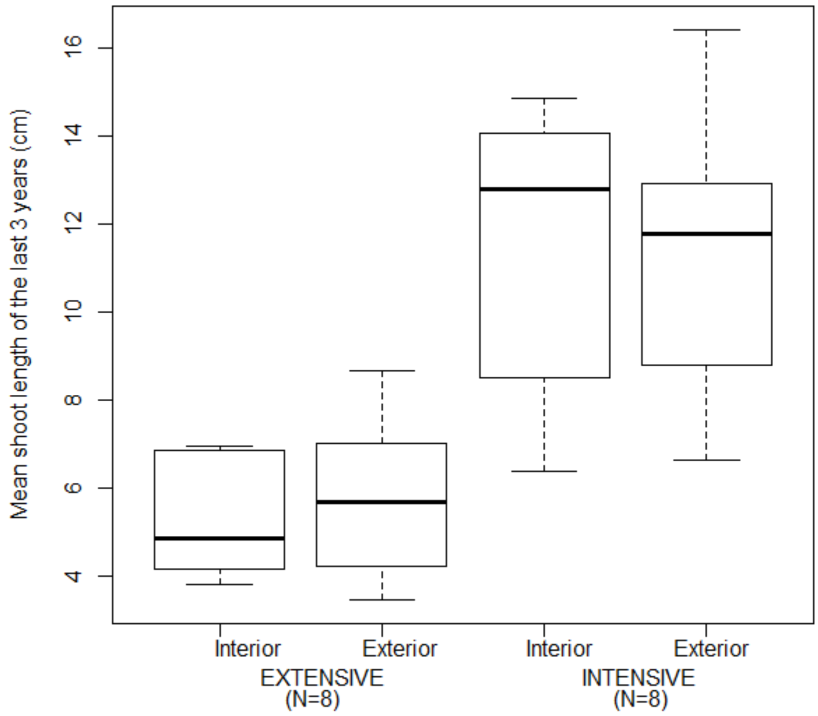

Figure 2: Mean length of shoots growth of three years for five *Juniperus communis* shoots measured at the interior and exterior for every of 8 shrubs surrounded by extensive and intensive grazing conditions.

The path analysis models explained 72%, 66% and 35% of the variation in species richness of plants, butterflies and grasshoppers, respectively. Plant species richness was significantly affected by shrub cover (composed by shrub cover and its square term; $p < 0.001$) and grazing intensity ($p < 0.05$). Whilst the relationship with grazing intensity was positive, plant species richness and shrub cover showed a hump-back shaped relationship. Highest species numbers were recorded in the grassland-shrub mosaic with a shrub cover of about 50%. In contrast, open grassland and fully encroached areas harboured less plant species. These findings agree with previous studies also reporting highest species richness of plants at intermediate dwarf shrub cover (Anthelme *et al.*, 2001; Isermann *et al.*, 2007). Although shrubs clearly alter the microclimatic conditions below their canopy, they can also provide advantages such as increasing habitat heterogeneity or giving protection to grazing sensitive grassland species (Callaway *et al.*, 2000). In contrast to plants, no significant effect of grazing intensity or shrub cover upon the insect groups was found. Butterfly species richness was positively affected by plant species richness ($p < 0.001$) and negatively by altitude ($P < 0.001$) and aspect ($p < 0.05$), meaning that more butterfly species were recorded in south-west-facing rather than west-facing plots. Instead, grasshopper species richness was positively affected by plant beta diversity ($p < 0.01$) and slope ($p < 0.05$). The important role of plant measures for both butterflies and grasshoppers is likely to be related to their association with the plant group as food, oviposition and cover resource. The more generalist feeding strategy of grasshoppers and their link to rather structural aspects of the vegetation might further explain the importance of plant turnover instead of plant species richness for this taxon (Szövényi, 2002).

In conclusion, grazing animals play an important role in the control of shrub encroachment and thus the long-term sustainability of summer pastures. Whilst plant species richness is affected by both grazing intensity and shrub cover, the impact upon butterflies and grasshoppers appears to be only indirect through the plants. The grassland-shrub mosaic is a valuable habitat for plant, butterfly and grasshopper species richness on encroached summer pastures.

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Are vascular plants adequate surrogates for butterfly and grasshopper diversity on Swiss summer pastures?

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Abstract

Because of current land use changes the high biodiversity of summer alpine pastures is decreasing. Political instruments in Switzerland did not support efforts in conservation of biodiversity in these areas for a long time but now the extension of the ecological measures implemented in the lowland is under discussion. Biodiversity indicators for high quality pastures are therefore needed. The assessment of surrogate taxa as indicators for biodiversity is widely used in conservation biology. Available studies evaluating the surrogate value of vascular plants for other taxa yielded inconsistent results, and investigations in alpine habitats are rare. The extent to which vascular plants are adequate surrogates for butterfly and grasshopper diversity was therefore investigated by examining the congruence of species richness and community similarity patterns in two subalpine pastures in the Swiss Alps. Species richness of plants and the invertebrate taxa was in most cases positively correlated, but there were some inconsistencies as well. At the community level, congruence between vascular plant and invertebrate taxa were very consistent. Based on the results it is concluded that vegetation-based indicators also are expected to contribute to the conservation of butterflies and grasshoppers in subalpine grassland habitats.
Keywords: arthropods, community similarity, plants, species richness, summer pastures, surrogate taxa

Introduction

The subalpine grasslands used as summer pastures are harbouring up to three times as many species as the forest they replaced (Zoller and Bischof 1980). However, land use on summer pastures is changing, with a trend towards land use polarisation: Productive and accessible areas are managed with increased intensity and remote, steep and less productive areas are underused or even abandoned. Both trends lead to a decrease of biodiversity (Tasser and Tappeiner 2002). In Switzerland, alpine summer pastures are not yet supported by the agri-environmental scheme but its implementation is now under discussion. The intention is to pay farmers for high quality summer pastures with respect to biodiversity.

Vascular plants are commonly used in practice as indicators for biodiversity because they are easy to sample and identify, and support a large number of animal species (e.g. Marini et al. 2007). In addition, the use of selected vascular plants for assessing ‘high quality’ for financial support has been shown to be both efficient and well accepted by farmers (Klimek et al. 2008). However, studies investigating the surrogate value of plants in general, and subsets of plant species in particular, for other taxa have produced results in support (eg. Duelli and Obrist 1998) and in contradiction (e.g. Billeter et al. 2008). Furthermore, very few of these studies have considered the relationships between plant and invertebrate diversity in subalpine areas (Favreau et al. 2006).

The aim of this study was therefore to investigate the adequacy of various measures of plant species richness and composition as surrogates for the diversity of diurnal butterflies and grasshoppers in the summer pasture habitat. We examined those patterns in two heterogeneous subalpine pastures in the Swiss Alps.

Material and Methods

The investigation was carried out on two subalpine pastures in south eastern of Switzerland, in Mesocco and Guarda. Both pastures have a south-west aspect, are approximately 1.5km^2 in area, grazed by cattle, and situated in marginal locations just above the present tree line. The vegetation is dominated by *Nardus stricta*,

dwarf ericaceous shrubs and junipers (*Juniperus* spp.). Fifty plots of 30m x 30m (900m^2) were located in a grid on each pasture. Data collection was carried out between June and September 2010. Plants were surveyed in nine quadrats of 1m^2 placed systematically within the 900m^2 plots and any additional species in the plots were added to a total species list for each plot. We recorded all adult butterflies and grasshoppers by walking over the 900m^2 plots in a serpentine-like transect, on five occasions for butterflies, and on two occasions for the grasshoppers. For both insect taxa, data of different sampling times were pooled at the plot level for data analysis.
Two measures were used to test congruence at the species richness level: 1) total number of species, hereafter ‘species richness” and 2) the number of target species considered to indicate ‘high ecological quality” of Swiss agricultural surfaces (BAFU & BLW 2008), hereafter ‘quality species’. Comparisons between the two plant measures and the two measures for butterflies and grasshoppers were performed by means of pairwise partial Spearman’s rank correlations corrected for spatial autocorrelation. Partial procrustean randomization tests with Bray-Curtis similarity matrices were used for community similarity comparisons between the plant and insect taxa at each site. Both, the presence of all plants and the presence of quality plants were used for comparisons with the insect abundance data that is number of individuals of species and quality species. The species data were square-root transformed previous to data analysis.

Results and discussion

In Mesocco 318 plant, 44 butterfly and 8 grasshopper species were identified. In Guarda 332 plant, 52 butterfly and 14 grasshopper species were recorded.
The two measures of plant diversity - species richness and number of ‘quality species’ - generally showed moderate to strong positive correlations with both the butterfly total species and quality species richness at both study sites (Table 1). At Mesocco, the correlations between the number of quality plants and quality species richness of butterflies did not quite reach the level for significance (p=0.057) although the trend was the same. At Guarda, the correlations between the plant measures and species richness or number of quality species of grasshoppers were not significant but all correlations showed a positive trend.
The relationships between plant and insect community data showed highly significant positive correlations at both sites (Table 1, Figure 1). In Figure 1, the first two dimensions of the procrustean similarity diagram indicate in addition that the variance between plant communities was higher than between the communities of butterflies and grasshoppers.

Table 1: Pairwise comparisons between plant measures and measures for butterflies and grasshoppers in the study sites Mesocco (n=49) and Guarda (n=50). Correlation and significance values (p, in brackets; significant values in bold) are reported.

Study site and Comparisons	Species richness		Community similarity[b]	
	All plant species	Quality plant species	All plant species	Quality plant species
Mesocco				
All butterfly species	**0.362 (0.009)**	**0.337 (0.016)**	**0.480 (0.001)**	**0.447 (0.001)**
Butterfly quality species	**0.302 (0.034)**	0.273 (0.057)		
All grasshopper species	**0.387 (0.005)**	**0.408 (0.003)**	**0.329 (0.007)**	**0.355 (0.004)**
Grasshopper quality species[a]	-	-		
Guarda				
All butterfly species	**0.579 (<0.001)**	**0.668 (<0.001)**	**0.577 (0.001)**	**0.537 (0.001)**
Butterfly quality species	**0.426 (0.001)**	**0.472 (<0.001)**		
All grasshopper species	0.245 (0.087)	0.164 (0.259)	**0.607 (0.001)**	**0.584 (0.001)**
Grasshopper quality species[a]	0.227 (0.114)	0.148 (0.309)		

[a]no comparison because of the presence of only one quality grasshopper species
[b]no comparison for insect quality measures because of too many zero values in the community matrices

Our study

shows generally positive congruence between vascular plant and the two investigated insect groups, butterflies and grasshoppers in species richness and in species composition. In Guarda, the correlation of plant species richness with grasshoppers showed only trends, but not statistical significance. This result may be explained by the fact that grasshoppers are using plants as generalists and are more responding to the structure of the canopy than to specific plant species (Detzel 1998; Szövényi 2002). Correspondence for community diversity measures that account for species identity as well as species abundance, however, showed consistently significant correlations for butterflies and grasshoppers. The use of community measures for studies investigating surrogacies is thus recommended. We are aware that our correlation values are below the threshold of 0.75 advised by Lovell et al. (2007) for the acceptance of vascular plants as adequate surrogate for other taxa. However, given the overall strong correspondence, we are confident that vascular plants make a good surrogate for butterflies and grasshoppers on subalpine pastures with *Nardus stricta* communities. Conservation measures developed to protect plant diversity are thus also likely to benefit butterflies and grasshoppers, especially at the local scale. Other invertebrate taxa closely linked to plants such as bumblebees and syrphid flies are also expected to profit. In contrast, poor congruence is to expect for animal taxa showing less association with the plant group.

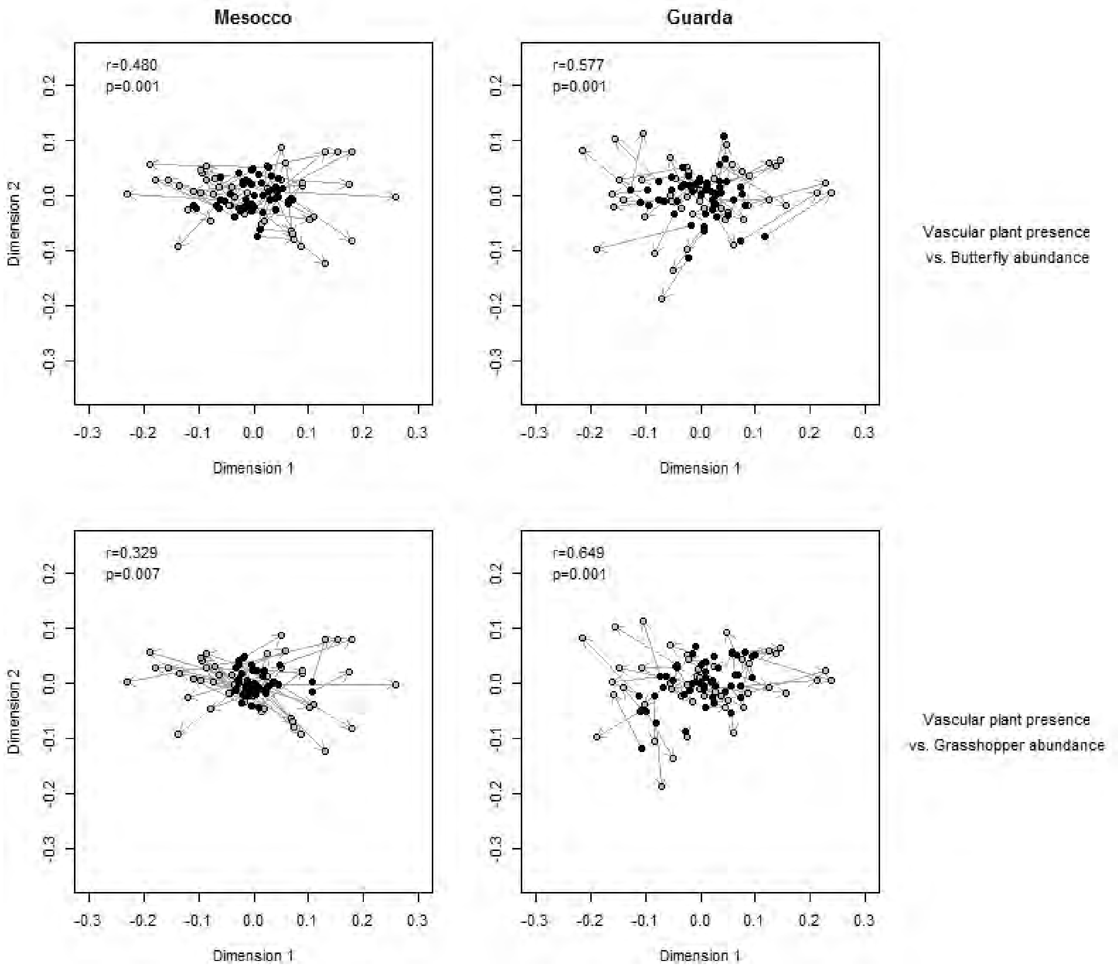

Figure 1: Correlation plots between species composition of vascular plants (presence) and butterfly (above) or grasshopper (below) species composition (abundance) in Mesocco (49 study sites) and Guarda (50 study sites). Correlations (r) and significances (p) are reported in the graphs. The procrustean errors (residuals) are denoted by arrows. Butterfly or grasshopper species composition at a site is indicated by black circles, vascular plant composition by grey circles.

For an agri-environmentral scheme like previewed in Switzerland for summer pastures, recording a subset of vascular plants (the 'quality species') can substantially increase the efficiency of assessments without reducing their predictive value as surrogates for other taxa. The good correspondence between quality plant species and the insect taxa in this study suggests that the Swiss 'quality species' are suitable to represent insect species richness and community similarity. This indicates their adequacy to assess result-oriented policy.

Acknowledgements

We thank Serge Buholzer, Nina Richner, Anna Stäubli, Thomas Walter and Rafael Wüest for field support and assistance and also to the landowners that permitted access to the field sites. The study is affiliated to the AlpFUTUR project (www.alpfutur.ch) and was partly funded by the Swiss Federal Office for the Environment (FOEN), Armasuisse, Kanton Graubünden, Ricola, and Sophie und Karl Binding Stiftung.

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SESSION 4 – Grazing behavior and GPS tracking

Manipulation of the spatial grazing behaviour of cattle in extensive and mountainous rangelands

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Abstract

Spatial behaviour of livestock is a critical factor in rangeland management. Ongoing research suggests that new approaches can be used to manipulate where beef cattle graze in extensive or rugged rangeland pastures. The combination of strategic supplement placement and low-stress herding can be used to target cattle grazing and potentially may be useful for managing fine fuels. A phenotype to genotype association study of cattle grazing distribution suggests that use of rugged terrain and areas far from water is inherited. Although more research is needed, selection for animals specifically adapted for mountainous terrain or extensive pastures may be an option for improving grazing management in the near future.

Keywords: Distribution, selection, supplement, genomics, water, GPS tracking

Introduction

Stocking rate, timing of grazing, animal type and distribution are the four principles of grazing management (Vallentine, 2001). In arid and semi-arid grasslands, water availability often limits grazing distribution in extensive pastures, and forage utilization decreases with increasing distance from water (Valentine, 1947). Mountainous terrain also constrains where livestock graze. Cattle readily use gentle slopes (< 10%) but avoid steep (> 30%) slopes (Mueggler, 1965; Holechek, 1988). Roath and Krueger (1982) found that vertical distance to water is critical for determining where cattle graze in rugged terrain. Holechek (1988) recommended excluding steep slopes and areas farther than 3.2 km from water during stocking rate calculations, because typically livestock spend little time grazing in these areas. Correspondingly, management that increases use of rough topography and areas distant from water can reduce overgrazing of preferred areas and/or sustainably increase stocking levels. Manipulation of spatial grazing patterns also may help alleviate effects of drought if livestock can be encouraged to use areas that they typically avoid.

Almost all of the tools we currently use to manipulate spatial grazing behaviour of livestock have been known for almost 60 years (Williams, 1954). However, recent advances in global positioning system (GPS), geographic information system (GIS) and genomic research technologies have allowed us to study the underlying behavioral mechanisms associated with distribution practices. The objective of this presentation is to discuss our recent and ongoing research, which uses novel approaches to understand and manipulate the spatial behaviour of beef cattle.

Targeting Cattle Grazing

Strategic placement of supplement in areas that receive little grazing can be a useful tool for manipulating grazing distribution. Cattle are attracted to supplement even if it is placed in rugged terrain or areas far from water. After walking to the supplement placement site, effort required to travel to nearby areas is minimal. Low-moisture block protein (LMB) supplements are more effective for managing cattle grazing patterns than salt or salt mineral mixes (Bailey and Welling 2007; Bailey *et al.*, 2008a). However, a salt-mineral mix was effective in luring cattle to steep terrain in the Italian Alps (Probo *et al.*, 2013).

Pastoralists have used herding to direct livestock spatial behavior for centuries. However, development of low-stress livestock handling techniques has improved our ability to direct where cattle graze, and does not require herders to continuously remain with the animals (Hibbard, 2012). Herding cattle away from streams using low-stress livestock handling techniques is an effective method for protecting riparian areas (Bailey *et al.*, 2008b). Low-stress livestock herding combined with strategic LMB placement can be used to target cattle grazing. Cattle tend to remain near LMB supplement if intake is near recommended levels (Figure 1). Consumption of LMB helps ensure cattle remain in target areas after herding. If forage is actively growing or if cattle do not readily consume supplement, animals may not stay within the target area. Joint research conducted in a mountainous area in Arizona showed that cattle could reduce herbaceous standing crop (fine fuels) from 1500 kg/ha to 820 kg/ha in target areas located in steep terrain and 1 to 3 km from water (Bruegger, 2012). Research conducted in New Mexico showed that herbaceous fine fuels could be reduced from 1780 kg/ha to 990 kg/ha in target areas located over 2 km from water. Such reductions in fine fuels, can reduce flame heights and reduce rate of fire spread sufficiently to potentially reduce costs of firefighting based on fire behavior models (Varelas, 2012).

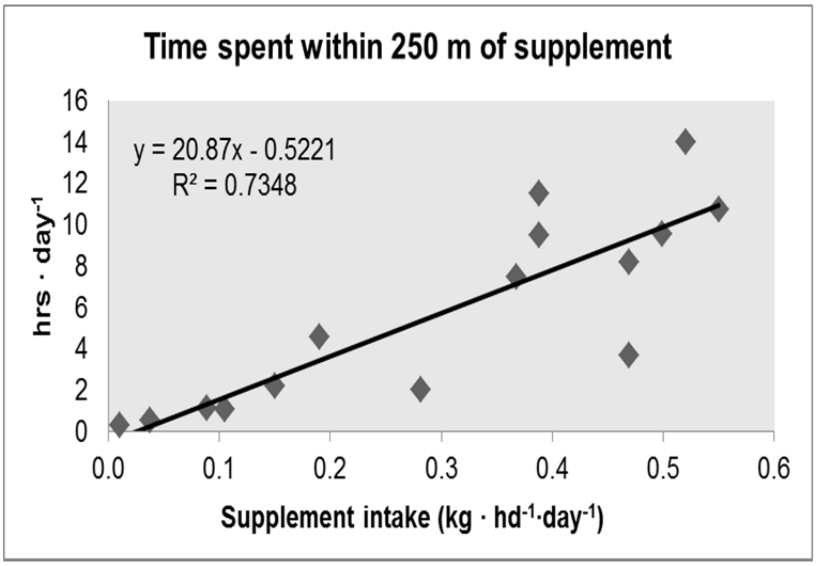

Figure1: Relationship between time spent within 250 m of supplement (target area) and intake of low-moisture block supplement. This summarizes 5 studies conducted in Arizona and New Mexico.

Development of Adapted Animals

Cattle can have very different grazing patterns with "hill-climber" cows naturally using higher elevations, steeper slopes and areas far from water, while "bottom-dweller" cows use gentle terrain near water (Bailey *et al.*, 2004). One approach to manipulate spatial behavior of livestock is to genetically select for hill climber cattle and cull bottom dwellers (Roath and Krueger, 1982; Bailey, 2005). One potential criticism of this approach is that hill climbers may no longer use rugged terrain after bottom dwellers are culled. However, Bailey *et al.* (2006) found that differences in grazing patterns between hill climber and bottom dweller cows continued even after these two groups were separated.

For genetic selection of cattle for spatial behaviour to be practical and cost effective, this trait must be heritable (i.e., estimatable portion of phenotypic variance is due to genetics). Training can dramatically change animal behavior, but it is labor intensive and often costly. In addition, genetic progress of culling cows results in much less progress than sire selection. Our research team conducted the first genotype to phenotype association study of difficult to measure quantitative production traits that are important for rangeland sustainability. A total of 87 cows were tracked for 1 to 3 months in mountainous and/or extensive rangeland pastures at 5 ranches located in New Mexico, Arizona, and Montana. DNA was collected from these cows and analyzed using the Illumina Bovine SNPHD array, which evaluates approximately 770,000 genetic markers (i.e., single nucleotide polymorphisms; SNP) across the 30 bovine chromosomes. The GPS data were used to characterize use of rough terrain and areas far from water using indices based on the normalized averages of slope use, elevation use, and distance to water. A chromosome region associated with these traits is known as a quantitative trait locus (QTL) and the significance is determined by the statistical association of genotypes with phenotype effects (-log10 p-value > 5). Significant QTL regions were detected on chromosomes 17 and 29 for slope and elevation. When these variables were combined with distance to water, QTL were detected on 11 chromosomes and a structural copy number variant was detected on chromosome 8. A QTL region can span many base-pairs on a chromosome and encompass numerous genes. However, QTL analyses are a useful entry-point for identifying functional loci and potential genetic markers to help understand the genetic and physiological basis of cattle grazing distribution. One genetic marker on chromosome 29 overlaid a gene that appears to be a factor in feeding behavior, appetite and locomotion based on our physiological knowledge of its function. This location accounted for 25% of the phenotypic variation in use of steep slopes and high elevations. A variant of this gene may be useful for identifying hill climbers. The QTL on chromosome 17 accounted for 21% of the phenotypic variation in slope and elevation use. Additional QTL found on other chromosomes accounted for 5 and 10% of the variation in slope and elevation use as well as distance travelled from water. These findings are very exciting, because most individual genetic markers account for only 1 or 2% of the phenotypic variation in a trait (Garrett *et al.*, 2008; DeAtley *et al.*, 2011; Luna-Nevarez *et al.*, 2011).

Using the results from the Illumina Bovine SNPHD array, a smaller panel based on 50 SNP was developed and evaluated on the 87 cows tracked previously and an additional 73 cows from 4 ranches in Arizona and New Mexico (n=160 cows at 7 ranches). Multiple genetic markers near or within the gene identified on chromosome 29 were associated with indices of terrain use and accounted for 10 to 18% of the phenotypic variation. In addition, a marker on chromosome 4 accounted for 26% of the variation in an index based on use of steep slopes, high elevations and areas far from water. Other QTL on chromosomes 8, 12 and 17 accounted for 10 to 15% of the phenotypic variation in indices of terrain use. Results from this evaluation of 50 selected SNP near candidate genes and QTL support the analyses from the Illumina Bovine SNPHD array. The association between indices of terrain use and multiple genetic markers near candidate genes clearly shows that grazing distribution and spatial behavior of cattle is a heritable trait.

A SNP panel designed to identify the genotypes associated with QTL for grazing distribution (similar to the one described above) could be used to identify cattle with superior genotypes for grazing distribution. With this type of information, a genomic estimated progeny difference (EPD) program can potentially be developed to give cattlemen a selection tool for grazing distribution. This ongoing research suggests that development of cattle that are specifically adapted to extensive and/or rugged pastures may be feasible within the foreseeable future.

Conclusions

Except during periods of active forage growth, the combination of strategic supplement placement and low-stress herding can be used to target cattle grazing in areas far from water and in rough terrain. Such targeted grazing may be useful in managing prescribed fire as well as wildfires. Spatial behavior of cattle appears to be heritable, and superior genotypes may potentially be identified by DNA tests. Selection of cattle for spatial grazing behaviour may be viable management option in the near future.

Acknowledgement

Funding for this research was provided by the USDA Western SARE and USDA AFRI programs.

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Restoration of shrub-encroached grasslands through the modification of cattle grazing patterns

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Abstract

Throughout the last decades, agricultural abandonment in European mountain areas has caused changes in traditional livestock management with consequences for semi-natural grassland use and vegetation. In the Western Italian Alps, continuous extensive grazing has become the simplest and the most common system for managing large cattle herds. As a result, limited grazing in many rugged locations has led to an extensive shrub-encroachment of semi-natural grasslands in the sub-alpine and alpine belts. A study was conducted to assess if the provision of mineral mix supplements (MMS): 1) increases the use of steep and shrub-encroached locations by beef cows, and 2) helps restore meso-eutrophic grassland vegetation around supplement-deployment sites. During the summer grazing season, MMS were placed within 10 steep and shrub-encroached areas in two adjacent pastures (364 ha and 366 ha), and 12 cows were tracked with GPS collars. For each supplement site, a paired control site was identified, and vegetation surveys were performed in the surrounding areas of both sites. Placement of MMS increased the use of areas within 12 m of supplement locations compared to corresponding control areas. Cattle use of areas within 100 m of the MMS sites was also greater than expected by chance. The use by cattle, associated with trampling, grazing and faecal deposition, reduced the cover of shrub and oligotrophic herbaceous species and increased the average nutrient *N* value and forage pastoral value of the new vegetation types established around MMS sites two years after their use by cattle. Strategic placement of MMS appears to be a sustainable practice to restore sub-alpine and alpine shrub-encroached grasslands. Nevertheless these results must be considered preliminary as a longer period is needed to evaluate the long-term effectiveness of this practice for the restoration of semi-natural grasslands.

Keywords: beef cows, continuous grazing, dwarf shrubs, feed blocks, GPS-tracking, sustainable restoration practice.

Introduction

Over the past decades, agricultural abandonment in European mountain areas has caused changes in the use of semi-natural grasslands, their management, and the composition of their vegetation, with extensive shrub and tree encroachment over large areas (MacDonald *et al.* 2000). In the Western Italian Alps, both a marked decrease in the number of livestock farms, cattle herds, workers per farm, and an increase in the average number of animal per herd have occurred. Consequently, traditional livestock management has been deeply modified. Since the decline in herding, continuous extensive grazing has become the simplest and the most common system for managing large herds (Probo *et al.* 2013). Higher stocking densities with these larger herds than in the past and the natural predilection of free-ranging cattle for flatter terrain have generally increased grazing in these areas and limited the use of steeper areas. As a consequence, limited grazing of many rugged locations in the sub-alpine and alpine belts has resulted in natural successional phenomena with changes in vegetative cover and composition. Herbaceous oligotrophic species and dwarf shrubs have encroached large areas of semi-natural grasslands, leading to a decrease in forage yield, pastoral value, and extent of meso-eutrophic habitats characterized by high plant and animal diversity (Cavallero *et al.* 2007) and to an increase in landscape homogeneity.

For these reasons, in many European countries the conservation and restoration of semi-natural grasslands have become an important agri-environmental issue. Such conservation and restoration have been mainly carried out by manual or mechanical shrub-clearing, mowing, prescribed burning and grazing management (Ascoli *et al.* 2009). Livestock can play an important role in the restoration process because trampling, grazing, seed transport and nutrient redistribution through faecal deposition can alter the cover and structure of vegetation as well as botanical composition (Olff and Ritchie 1998).

Strategic placement of mineral mix supplements (MMS) has been used to entice cattle into traditionally undergrazed areas in American rangeland systems (Bailey and Welling 2007). To our knowledge, the strategic placement of MMS has not been evaluated as a tool to restore semi-natural shrub-encroached grasslands. Modification of the grazing patterns of cattle through strategic placement of MMS could be a more sustainable restoration practice than manual or mechanical shrub-clearing or fencing, as it is less costly, has lower labour inputs, and could be more easily carried out on rugged alpine locations.

The objective was to assess if MMS could: 1) increase the use of steep and shrub-encroached locations by cattle and 2) help restore meso-eutrophic vegetation around supplement-deployment sites. It was hypothesized that: 1) providing MMS on steep and shrub-encroached locations would result in greater cattle use of areas around placement sites compared to similar control sites, so that 2) cattle trampling, grazing and faecal deposition would reduce the cover of shrub and oligotrophic herbaceous species and increase the cover of meso-eutrophic herbaceous species.

Materials and methods

The study was conducted in Val Troncea Natural Park (latitude 44° 57’ N, longitude 6° 57’ E), which is a protected area representative of the changes that have occurred on grasslands in the Western Italian Alps. Grasslands were mainly dominated by *Festuca curvula* Gaudin, *Carex sempervirens* Vill., and *Trifolium alpinum* L. and the shrub vegetation layer was predominantly composed by *Rhododendron ferrugineum* L. (alpenrose), *Juniperus nana* Willd. (dwarf juniper), *Vaccinium myrtillus* L. (bilberry), and *Vaccinium gaultherioides* Bigelow (northern bilberry), that have rapidly encroached wide areas of grasslands after the decline in agro-pastoral activities. The study area was selected within the two cattle farms still operating in the Park, and consisted of two pastures: Troncea (366 ha) and Meys (364 ha). Elevations ranged from 1 950 to 3 000 m and slope averaged 29 %. The Troncea pasture was grazed from 12 July to 29 September 2010 by 119 beef cows, predominantly of the Piedmontese breed, with some of the Valdostana Red Pied and Barà-Pustertaler breeds. The Meys pasture was grazed from 8 July to 20 August and from 7 September to 2 October 2010 by 150 beef cows of the Piedmontese breed. Both groups included heifers and non-lactating cows, varying in age from 1 to 15 years.

During the summer grazing season (early July to early October) of 2010, cows were offered MMS *ad libitum*. The MMS was placed at 10 sites, six in the Troncea pasture and at four in the Meys pasture. Supplement-deployment sites were positioned within the 10 largest patches of shrub-encroached grassland types and they were on steep areas with an average slope of 48.6 ± 3.4 % (mean ± SE). Within each site, MMS was supplied in 5-kg blocks, which were placed 5 m apart in pairs. Each pair of MMS blocks was considered as a treatment site and was paired with a control site having the same soil cover, vegetation features and distances from water sources with respect to MMS sites.

Seven randomly-selected cows per farm were tracked with global position system (GPS) tracking collars (GPS Model Corzo, Microsensory SLL, Fernán Núñez, Andalusia, Spain). Positions were recorded every 15 min, with an average accuracy of 6 m.

Botanical composition was determined using the vertical point-quadrat method (Daget and Poissonet 1971) along cross-shaped transects. One transect was placed at each control and supplement site, with the centre of the cross positioned in the exact middle of the pair of MMS blocks. Twenty vegetative transects were measured in early July 2010, in order to test the homogeneity of vegetation between supplement and control sites before the use of MMS by cattle. Transects were 12.5 m long across each of the four sides of the cross. In each transect, at every 50-cm interval, plant species touching a steel needle were identified and recorded. In early July 2012, the extent of areas, which had been modified by cattle around MMS locations, were visually estimated, following the sharp fine-scale fragmentation of the original dense shrub cover. A new cross-shaped transect was placed within each of these changed vegetation areas, with the purpose to evaluate vegetation differences between supplement and control sites. In 2010 and 2012, percentage of shrub, herbaceous, and bare ground cover was visually estimated within a 1-m buffer around the transect line.

Use by cattle of areas within 12 m of MMS placement sites was assessed. It is likely that cattle consumed supplement when they were inside the 12-m buffer because placement sites were located on steep slopes that cattle typically avoid. A visit to an MMS site was then defined as the location of a GPS collar within 12 m of the placement site, in accordance with Bailey *et al.* (2001). The number of visits to each supplement and control site was calculated for each tracked animal. Frequency of visits to supplement sites was calculated as the total number of the visits over the number of days cows were tracked (visits day^{-1}). The number of GPS locations for each collared cow within 100 m of the MMS sites was also computed to quantify the use by cattle of areas near placement sites (Bailey and Welling 2007). The area of the minimum convex polygon was calculated for each cow (Ganskopp 2001). Distribution of the number of visits per cow to MMS and control sites was tested for normality using the Kolmogorov-Smirnov test. Because neither raw data nor log-transformed data were normally distributed, use within 12 m of supplements was compared to corresponding control areas using the non-parametric Wilcoxon signed-rank test (Sokal and Rohlf 1995). Pearson χ^2 test was used to test if the number of locations for each cow within 100 m of the MMS sites differed from expected frequencies based on the average cattle use in the minimum convex polygon area.
For each plant species recorded in the vegetative transects the frequency of occurrence (f_i = number of occurrences/100 points) was calculated. Species relative abundance was calculated according to Daget and Poissonet (1971) and was used to detect the proportion of different species. The demand of each plant species for nutrients was estimated according to the Landolt nutrient value (index *N*, Landolt 1977) and each plant species was classified as oligotrophic (N = 1, 2), mesotrophic (N = 3), and eutrophic (N = 4, 5). An indirect vegetation *N* index ($N_{average}$) was calculated to evaluate the overall effect of fertilization produced by the cattle (Probo *et al.* 2013). Each species was also classified according to the Index of Specific Quality (ISQ) (Cavallero *et al.* 2007). In each transect, forage pastoral value (PV), a synthetic value summarizing forage yield and nutritive value ranging from 0 to 100, was calculated (Daget and Poissonet 1971). Kolmogorov-Smirnov test for normality and Levene test for homogeneity of variance were used to evaluate the distribution of vegetation variables. Variables not normally distributed were subjected to a log(x + 1)-transformation that normalized the data. A Pearson correlation was used to estimate the association between overall number of visits to supplement sites (all tracked cows pooled together) and the following variables measured in the changed vegetation areas: extent of the area, shrub cover, average vegetation *N* index, and forage pastoral value. Soil cover and vegetation variables between supplement and their control sites were compared using paired-samples *t* tests (Sokal and Rohlf 1995).

Results

One collar per farm failed, so tracking data were obtained from 6 collared cows for each pasture. During the study, 92 % (11 out of 12) of collared cows visited MMS, and 90 % of MMS sites (nine out of 10) were visited by collared cows. Visits per cow to MMS sites (4.09 ± 0.913 visits) were greater ($P < 0.01$) than those to paired control areas (1.13 ± 0.332). Sites with MMS were visited approximately once every six days (0.16 ± 0.031 visits day^{-1}). Minimum convex polygon areas were 320.5 ± 7.61 ha. Number of GPS locations within 100 m of the MMS sites (288 ± 54.0) was greater ($P < 0.001$) than the expected number of locations based on average cattle use of the minimum convex polygon area (205 ± 24.8). The overall number of cattle visits to supplement sites (ranging from zero to 53 visits) was strongly related ($r = 0.806$, $P < 0.01$) to the extent of changed vegetation areas measured in 2012, which ranged from 0.0 to 98.9 m^2 (45.2 ± 9.51 m^2).
No statistical differences in variables of visually estimated cover were detected between MMS and control sites in 2010. Two variables of cover around supplement-deployment sites differed from corresponding control sites in 2012: shrub cover was lower ($P < 0.001$) at the MMS sites (12.1 ± 7.20 %) than at the control sites (55.6 ± 4.50 %) and the percentage of bare ground was higher around MMS sites ($P < 0.001$).
No differences in vegetation variables were detected between the MMS and control sites in 2010. It was assumed, therefore, that supplements and control sites had roughly the same vegetation and ecological features before cattle used the MMS. In 2012, a reduction ($P < 0.001$) in both frequency and relative abundance of shrub species was detected near MMS placement sites. Oligotrophic herbaceous species cover declined ($P = 0.05$) at MMS sites, whereas no differences in relative abundance were detected between supplement and control sites. No changes in mesotrophic species were detected around MMS locations. Percentage of eutrophic species on the total of species was higher ($P < 0.01$) around supplement-deployment sites, although their frequency did not increase significantly. An increase in average vegetation *N* index ($P < 0.01$) and forage pastoral value ($P < 0.01$) was detected around supplement-deployment sites. These two

vegetation variables were also related ($P < 0.05$) with the overall number of cattle visits to MMS sites (r = 0.740 and r = 0.658, respectively).

Discussion

Cattle regularly travelled to the MMS and the data support the hypothesis that strategic placement of MMS on steep and shrub-encroached locations can increase cattle use up to 100 m from placement sites. Considering that supplement placement areas were historically underused and located in extremely steep and rugged terrain, these results are promising and suggest that cattle can be successfully used on similar landscapes and vegetation mixes.

Cattle impacts on cover around placement sites were localized and never exceeded 100 m^2. Near sites of MMS placement, cattle trampling and grazing reduced shrub cover. Two years after MMS placement, bare ground gaps created by cattle were mostly not covered by herbaceous vegetation, showing that recolonization by herbaceous vegetation is a slow process.

The forage pastoral value approximately doubled near MMS sites. The strong correlation between cattle visits to MMS and forage pastoral value provides additional evidence that targeted grazing by cattle may be useful for restoring shrub-encroached grasslands in this region. The vegetation *N* index increased near MMS placements and was correlated with cattle visits to the MMS. This may be a result of the deposition of faeces and urine which can increase nutrient availability in the soil.

Nonetheless, the vegetation data do not allow validation of all the restoration hypotheses made about changes in herbaceous species. Cover of oligotrophic species decreased but that of mesotrophic and eutrophic species did not increase on the areas of bare ground. Vegetation changes observed in this study were short-term. Long-term studies are needed to determine if strategic placement of MMS can result in sustained reductions in shrub cover and subsequent establishment of desired herbaceous vegetation in these steep and high altitude alpine grasslands.

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Use of pastures by cattle in a Pyrenean ski station: Diagnosis and recommendations for improved preservation of natural resources and snow condition

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Abstract

Ski stations are commonly located in alpine pastures where livestock graze during part of the year, providing a synergy in which animals benefit from the grazing resources while their consumption guarantees the stability of the snowpack during the winter. The current study was conducted on a 297-ha ski station grazed by 314 cows during the summer and early autumn. The patterns of space use were studied on 8 days throughout the grazing season, by scan-sampling at 30-min intervals during daylight hours. The number of heads, activity and position of the different groups were recorded and entered into a Geographic Information System (ArcGis Desktop 9.3). For each observation polygon a vegetation class and pastoral value, altitude, slope, exposure, distance to tracks, station infrastructures, water points and salt areas where calculated or assigned. Abiotic factors where compared between grazed and non-grazed areas, Ivlev's electivity index was calculated for the different vegetation types and land use categories (n=12). Cattle grazed on 190 ha (64% of the total area) and rejected areas of lower pastoral value (16.4 *vs.* 24.3 points in non-grazed and grazed areas), with higher slope (23 *vs.* 16%), located at higher altitude (1895 vs. 1695 m), and farther from salt supply (1004 *vs.* 461 m), buildings (402 *vs.* 237 m) ($P<0.001$) and roads, but unexpectedly closer to water (381 vs. 442 m, $P<0.05$), therefore water availability was not a limiting factor for pasture use in this area. Ivlev's electivity index was negative for rocky areas (-0.60), lower forests (-0.24) and *Festucion eskiae* pastures (-0.24), while preferences were observed for *Festucion gautieri, Nardion strictae, Caricion nigrae* and *Bromion erecti*, related either to their pastoral value or to their geographical location. After a diagnosis of current use, recommendations were made for a more homogeneous distribution of livestock on the area, either by modifying temporal and spatial management or by providing infrastructures (fences, salt distribution areas) to ensure a proper use of each vegetation type.
Keywords: livestock, ski resort, space use, management.

Introduction

Ski stations are commonly located in high alpine pastures where livestock graze during part of the year, providing a synergy in which animals benefit from the grazing resources while their consumption guarantees the stability of the snowpack during the winter. Livestock can therefore be used as a tool for environmental management in these areas, provided their pasture use is adequate for this purpose. This may not be the case in free-ranging herds, which is now the common management in many mountain areas.

Several studies have shown that spatial use of unguarded animals is not homogeneous, because livestock select their grazing sites according to different biotic and abiotic factors (Bailey, 2005). This can lead to high stocking density in some areas while others are underutilized, both having negative effects on pasture preservation, i.e. overgrazing may lead to soil compaction or excessive accumulation of dejections, while too low grazing pressure can result in pasture invasion by shrub species and reduction of herbage quality (Casasús *et al.*, 2007).

In the case of cattle, slope, distance to water sources and vegetation community, which affects the amount and quality of available herbage, are among the most important factors conditioning pasture use (Senft *et al.*, 1985). Several studies have also highlighted the role of distance to salt or mineral supply, to roads and fences, the existence of shadowed or protected areas, or exposure to dominant winds (Pinchak *et al.*, 1991; Bailey *et al.*, 1998). Moreover, livestock patterns of space use are not constant throughout the grazing

season; preferences change according to pasture characteristics and animal nutritional needs, thermoregulation and well-being (Casasús *et al.*, 2009).
Knowledge of livestock patterns of pasture use is crucial to determine if interventions are needed to enhance a more adequate use of the available resources, in order to optimize their utilization and to obtain the expected positive outcome from grazing, particularly when other land uses concur (Casasús *et al.*, 2013). Therefore, the objective of this study was to determine the factors influencing pasture use by livestock in the area of a ski station, and to suggest correcting measures where needed.

Material and methods

The study was conducted in Aramón-Panticosa ski station, in the Spanish Pyrenees. A herd of 314 adult cows and their offspring grazed during 71 d in the early summer (14/6 to 28/7) and early autumn (30/9 to 27/10) of 2011 on the 297 ha occupied by the ski station. During the rest of the summer they were transferred to other alpine pastures according to the traditional practice in the valley.
The patterns of space use in the study area were analyzed on 8 days throughout the grazing season, at weekly intervals. The number of heads, activity and position of the different groups were visually registered by instantaneous scan-sampling (Lehner, 1996) each 30 min during daylight hours. This method involves collecting data of the entire herd at regular intervals and extrapolating for the time separating two successive scans. Data were recorded on-site on a map and database and later entered into a Geographic Information System (ArcGis Desktop 9.3) (n=278 observations). Previously, a Digital Elevation Model had been derived from a georeferenced map, and by the combination of photo-interpretation and field research the available pastures had been classified into 8 vegetation types according to the phytosociological method (Braun-Blanquet, 1965) *(Bromion erecti* (37% of the area), *Festucion eskiae* (22%), *Nardion strictae* (8%), *Primulion intrincatae* (4%), *Festucion gautieri* (3%), hygronitrophylous pastures (1%), dense forest pastures (2%), open forest pastures (1%); 230 ha), the rest being other land use categories (bare rock areas, lakes, roads/ski tracks and buildings (Barrantes *et al.*, 2013)). Salt and drinking troughs were located on the map.
For each polygon, stocking rate (livestock units (LU)*month/ha) was calculated from field data. The original 278 polygons were merged into a single layer, resulting in 217 cells with a given stocking rate, for which vegetation type, pastoral value, altitude, slope, exposure, distance to roads, buildings, water and salt areas where assigned or calculated from the coordinates of the polygon centroid. The same parameters were calculated for non-grazed vegetation types/land use polygons (n=73).
Ivlev's electivity index (Jacobs, 1974) was calculated for the different vegetation types and land use categories (n=12), in order to detect which were preferred or avoided relatively to their availability (values from +1: highly preferred to -1: completely avoided).
Abiotic factors were compared between used and avoided areas by variance analysis (proc GLM, SAS 9.1), where livestock use (grazed vs. non-grazed) was the fixed effect. The patterns of use through the grazing season were compared by proc GLM, with season (summer vs. autumn) as fixed effect. Within grazed areas, Pearson correlations were established between stocking rate and pastoral value and site abiotic characteristics. These aspects were compared among vegetation types (proc GLM, vegetation type as fixed effect). Least Square means (± SE) are presented, with differences tested with a t-test.

Results and discussion

Cattle used 190 of the 297 ha of the ski station (64% of the area), at an average stocking rate of 0.646 LU*month/ha on 190 ha during 2.3 months. Therefore, 282 LU used these pastures in the grazing season, which is exactly the carrying capacity proposed by Barrantes *et al.* (2013) for the pastures of the ski resort. This is the result of a long grazing tradition and reflects an accurate knowledge by local farmers, who have adjusted animal needs and censuses to pasture offer (Casasús *et al.*, 2013).
Grazed and non-grazed areas were different in many aspects related to terrain characteristics and pastoral value (Table 1). Grazed sites were in lower areas of the station, with lower slope, mostly of W exposure, and closer to salt placements, buildings and roads, and with higher pastoral value. Surprisingly, non-grazed areas were closer to water troughs or lakes, therefore this was not a factor limiting pasture use here, differing with other areas (Bailey, 2005; Putfarken *et al.*, 2008).
Ivlev's electivity index differed among vegetation types and land use categories: some of them were preferred (*Festucion gautieri +0.23, Nardion strictae +0.19, Caricion nigrae +0.16, Bromion erecti +0.14*)

while others were avoided (*Primulion intrincatae* -0.14, *Festucion eskiae* -0.24, open forest -0.24, and especially bare rock -0.6). This agrees partly with the quality and carrying capacity of each pasture type (Barrantes *et al.*, 2013), although some high quality areas (*Primulion intrincatae*) seem to be underutilized due to their higher altitude and distance from salt.

Table 1: Characteristics of grazed and non-grazed areas.

	Grazed	Non-grazed	Sign.
Altitude, m	1695 ± 127	1895 ± 209	***
Slope, %	16 ± 7	23 ± 10	***
Aspect, º from N	254 ± 114	156 ± 120	***
Distance to salt, m	461 ± 402	1004 ± 563	***
Distance to water, m	442 ± 233	381 ± 215	*
Distance to buildings, m	237 ± 175	402 ± 213	***
Distance to roads, m	63 ± 67	88 ± 73	**
Pastoral value, points	24.3 ± 10.1	16.4 ± 14.1	***

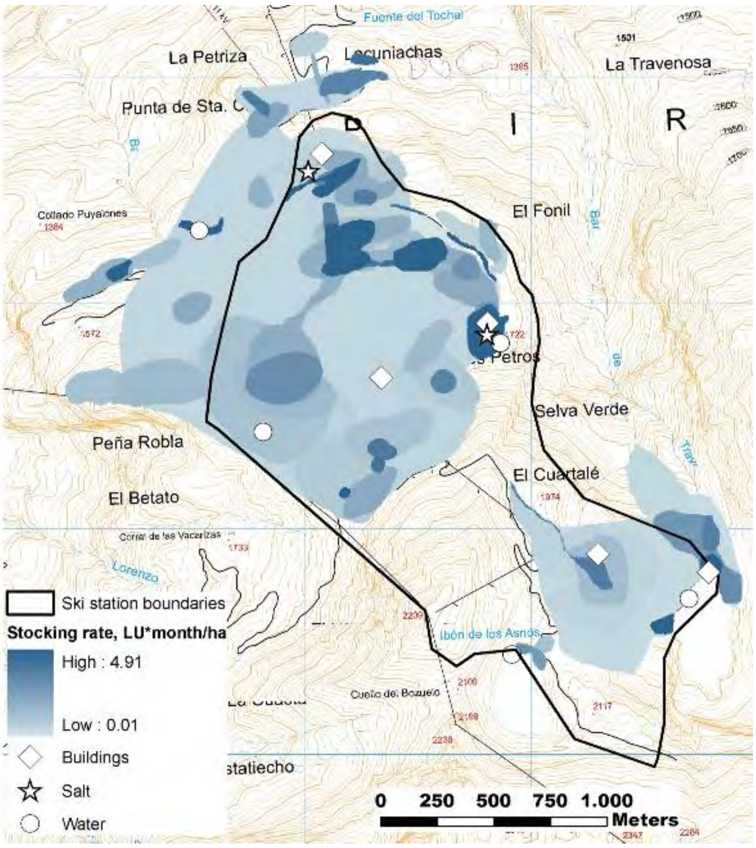

Figure 1: Cattle distribution and stocking rates.

Within grazed areas, cattle distribution was not homogeneous (Figure 1). Stocking rate was negatively related (P<0.001) to slope (r=-0.23), distance to roads (-0.32), buildings (-0.34), salt (-0.35), altitude (-0.38) and, surprisingly, to pastoral value (-0.38). The later was associated to the fact that the higher quality vegetation type (*Primulion intrincatae*, 34 points) was less used due to the aforementioned abiotic aspects, while cattle were often concentrated at very high stocking rates (average 1.86 LU*month/ha) close to roads or bare areas close to ski infrastructures with null pastoral value. Average stocking rates on the different vegetation units and other categories of land use ranged between 0.01 and 0.51 LU*month/ha. When cattle activity was considered, rest areas were more conditioned by topographic factors than grazing areas, as observed by other authors (García-González *et al.*, 1990; Aldezábal *et al.*, 2012).

Table 2: Livestock use and characteristics of the main vegetation types and land use categories in the sites where cattle was located.

	Bromion erecti	*Festucion eskiae*	*Nardion strictae*	*Primulion intrincatae*	*Festucion gautieri*	*Caricion nigrae*	*Roads, infrastruct.*	Sign.
Stocking rate, LU*month/ha	0.428 ^{b}	0.291 ^{b}	0.519 ^{b}	0.172 ^{b}	0.013 ^{b}	0.162 ^{b}	1.857 ^{a}	***
Altitude, m	1675 ^{de}	1992 ^{ab}	1857 ^{bc}	2080 ^{a}	1786 ^{cd}	1764 ^{cde}	1619 ^{e}	***
Slope, %	17.2 ^{a}	8.5 ^{b}	18.2 ^{a}	15 ^{ab}	11 ^{ab}	6.8 ^{b}	12.1 ^{ab}	***
Aspect, º from N	249	252	233	308	311	227	285	NS
Pastoral value, points	29 ^{a}	20 ^{b}	21 ^{b}	34 ^{a}	3 ^{c}	16 ^{b}	5 ^{c}	***

^{abcd}: within the same row, means with different superscript differ at $P < 0.05$.

Cattle showed distinct seasonal patterns of site use, as observed by Senft *et al.* (1985). In the summer the herds were concentrated in smaller areas, with higher stocking rates than in the autumn (0.747 vs. 0.362 LU*month/ha in summer and autumn, respectively, P<0.001); closer to salt (406 vs. 615 m, P<0.001) and tracks but farther from water (482 vs. 329 m, P<0.001) and buildings, and of higher slope (16.6 vs. 14.4%, P<0.05) but lower altitude (1672 vs. 1759 m, P<0.01).

Barrantes et al. (2013) suggested the best grazing management for each vegetation type in the ski station, considering both livestock performance and an adequate consumption of pasture that would not compromise the permanence and security of the snowpack in the winter. The actual use indicates that *Bromion erecti* pastures are grazed according to those recommendations (at the start and end of the grazing season), and *Festucion eskiae* and particularly *Festucion gautieri* pastures are naturally avoided (as suggested, to prevent from soil erosion). On the opposite, the high quality *Primulion* pastures should be grazed throughout the summer, and *Nardion* pastures, that are grazed at an early development stage (at the start of the grazing season) should also be grazed at the end of the summer, in order to avoid biomass accumulation and, hence, to improve the permanence of the snowpack in the ski runs in winter. The use of both pasture types could be forced by supplying salt in the target areas, and temporally fencing access to others. Although distance to water did not have a major influence on pasture use, in order to avoid the establishment of hygronitrophylous pastures, detected by a leaking water trough, these should be placed in steep areas, float valves should be used and periodic maintenance should be done.

In conclusion, the current stocking rates on pastures in the ski station are adjusted to their carrying capacity. However, the use of space by livestock is not homogeneous but conditioned by different biotic (vegetation type) and abiotic factors. Among the abiotic ones, some are natural (altitude, slope), but others, such as location of salt supply, are of anthropic origin, and could be easily improved for enhanced livestock performance and ecosystem preservation.

Acknowledgements

Farmers and staff from Aramón-Panticosa are acknowledged. Research funded by contract PCTAD Aramón-CITA-UniZar (089-10AC2 2011), INIA (research project RTA2010-057) and ERDF.

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Innovative monitoring of goat grazing effects on landscape structural properties

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Abstract

Introduction of goats into a Mediterranean nature park leads to changes in woody vegetation cover as well as changes in landscape properties. As part of the "adaptive management" approach, this management action should be accompanied by a monitoring program to assess the impact of grazing on various landscape parameters, and the extent to which management objectives have been accomplished. This study provides insight into the effectiveness of combining the interpretation of aerial photos with ground surveys to monitor changes in woody cover and landscape structure caused by goat grazing. Measuring woody cover by both methods has led to similar results, although data analyzed from aerial photo classification were more accurate, when applied to the whole site level. Changes in landscape structure indices, such as patch size, patch density, or edge density can be more easily measured by aerial photo classification, but they supply a two-dimensional image and overlook the fact that goat browsing influences vegetation mainly beneath the canopy. More relevant parameters, such as vegetation height distribution, cover of the understorey layer, dimension of gaps, or shifts in community composition can be detected exclusively by detailed ground surveys. In order to evaluate the extent to which the landscape was visually altered by goat browsing, an index (BLD) was developed and applied to data obtained from ground and aerial photography. Changes in woody cover and landscape structure were measured on both a spatial and temporal basis. A combination of parameters and methods was proposed to obtain maximum efficiency of the monitoring program. The complexity of the landscape, together with the wide range of uses and functions, requires monitoring techniques to be directed towards the perspective of the human eye.
Key words: controlled grazing, woody cover, monitoring, classification

Introduction

Controlled grazing is an important tool in the management of Mediterranean landscapes which may cause significant changes in landscape spatial patterns (Bar-Massada *et al.*, 2008) and plant community composition (Hadar *et al.*, 1999). As opposed to other livestock species, which concentrate mainly on the herbaceous component of the pasture, goats are considered browsers, and tree foliage constitutes the major portion of their diet (Glasser *et al.*, 2008). The exclusion of goats from shrublands enabled many adapted woody species to encroach and become dominant over large areas (Naveh and Kutiel, 1990). This process has caused an increase in fire hazard, a decrease in plant richness (Le-Houerou, 1993; Perevolotsky and Seligman, 1998) and in landscape structural diversity (Henkin *et al.*, 2007). The introduction of free-grazing livestock into a natural ecosystem must be accompanied by a monitoring program. Obviously, detailed ground surveys on large areas are time- and budget-consuming and, in patchy landscapes, do not always represent the whole managed area. These are usually based on measurements of individual plants or along fixed transects. Their main advantage is the ability to relate to species composition and to describe the landscape's "human scale" attributes, such as accessibility, visibility or plant structural diversity (Henkin *et al.,* 2007). On the other hand, interpretation of aerial photography is apparently a more practical and "straightforward" tool, which refers to the scale of the management units (e.g. a grazed site). The search for a reliable yet practical monitoring tool had challenged us to compare different approaches in order to determine the monitoring level (landscape, site, patch or plant level); the resolution and frequency for detecting landscape changes and the trade-off between remote sensing and detailed field measurements.

The aim of this study was to compare indices and data obtained by aerial photography interpretation vs. detailed ground surveys and to find the most informative and cost-effective combination of tools for detecting changes in landscape structure and visual qualities that result from goat grazing.

Methods

This study was conducted at Ramat Hanadiv, a 500-hectare nature park in southern Mt. Carmel, Israel (32° 33' N, 34° 56' E). The Ramat Hanadiv area has been subjected to traditional grazing for thousands of years, but livestock were excluded when the park was established in the early 1950's, resulting in a continuous increase in shrub cover. Due to fire hazard, and in order to manage the landscape to increase amenity values and support biodiversity, several management strategies were developed to control shrub encroachment. A key factor was the introduction of livestock grazing, including a herd of beef cattle that graze most of the park for 3-5 months every year. Since 2004, targeted grazing by a herd of 140 goats was added. The goat herd grazes all year round, at certain GIS-defined polygons (sites) of various sizes (1-20 hectares). Monitoring was based on the grazing program, which itself was designed to support the park's needs. Hence, the experimental design could not be built as a pre-planned research, but is composed of sets of comparisons in time and/or space, that reflect the goats' effects (e.g. cattle and goats vs. goats only; goats vs. control; before/after introducing goats). Two approaches were applied in order to assess the different effects of goat grazing on the landscape: interpretation of aerial photography and detailed ground surveys. All analyses were conducted in time and in space, on four sites of different management regimes: (1) goat grazing; (2) cattle grazing; (3) combined goat and cattle grazing; (4) no grazing. Ground survey data were analyzed for the sites on a spatial basis only, due to the lack of data from previous years.

Aerial photo interpretation: An aerial photo is produced every year during the summer (dry season). This timing facilitates discrimination between herbaceous and exposed soil patches, and patches of woody vegetation. Pixel size in orthophotos is 0.25X0.25 m. Classification was conducted by maximum likelihood supervised classification, using ERDAS IMAGINE 10.0 software. The orthophoto was classified into two classes on the basis of RGB color: (1) trees and shrubs (woody patch); (2) herbaceous vegetation/bare soil (open patch). Validation of our classification was conducted by 100 random points. Accuracy was found to be 94.1% and 93.9% for 2004 and 2010 classifications, respectively. Classified maps were analyzed using Fragstats 3.3 software (McGarigal *et al.*, 2002) for the landscape, class (woody/open) and patch scale. The metrics calculated were the percentage of landscape cover of different classes (woody vs. open), the mean woody patch area, woody patch density and patch edge density, reflecting the length of edge per unit area. Hence, these four metrics reflect the basic spatial processes that we seek to monitor.

Ground surveys: Sampling was conducted along 26 transects, 25-30 meters each, in four sites of different management regimes: goat grazing (four transects), cattle grazing (six transects), a combination of goat and cattle grazing (ten transects), and no grazing (six transects). Cover and canopy height of each woody species were measured, and a "structural profile" (*sensu* Henkin *et al.* 2007) was drawn in situ.

Herd performance (BLD index): An index composed of three parameters was developed: B-Browsed proportion of leaves; L-browsing Line intensity, i.e. a distinct line in the lower part of the canopy, reflecting the height above which goats cannot reach to graze; D-Debarking intensity (Table 1). Each indicator was visually evaluated and a rank from 0 - 4 was assigned (with higher scores demonstrating higher browsing pressure on vegetation). The plants evaluated are those which fall within the above mentioned transects. The BLD index final score is calculated as follows:

BLD Score = Σ_{BLD}(RANK *FREQUENCY)/total plants sampled

Table 2: BLD Index Scoring Definitions

Parameter	Rank	Definition
Browsing intensity (browsed proportion of leaves)	0	No browsed leaves or twigs
	1	25% of twigs browsed (no leaves)
	2	50% of twigs browsed (no leaves)
	3	75% of twigs browsed (very few leaves)
	4	All twigs browsed, no leaves, twigs or re-growth
Browsing **L**ine intensity	0	Browsing line not distinct
	1	Leaf density lower than 1.8 meters; a gradual change exists

		between top and bottom of shrub
	2	Browsing line distinct, without clear limits
	3	Browsing line clearly distinct, with some leaves below the line
	4	Browsing line distinct from a distance, no leaves below the line
Debarking intensity	0	No debarking of trunks or branches
	1	Some scraping signs of bark sporadically distributed on trunk
	2	Scraping signs of bark concentrated in certain locations
	3	Removal of bark up to half of trunk/branch perimeter
	4	Removal of bark over half of trunk/branch perimeter

Results

The first data set comprised two similar sites. One subjected to goat and cattle grazing, the other to cattle grazing alone. This comparison revealed the additive effect that goats have on landscape properties. The second data set compared temporal changes that occurred in a site subjected to goat grazing. A “control” site, i.e., without grazing, was used to evaluate changes caused by natural succession and climate. All sites were compared over time through interpretation of aerial photos from different years. A detailed ground survey was only conducted in the first set of sites described above.
Spatial and temporal results for the different sites are presented in tables 2 and 3.

Table 3: Spatial comparison of two grazed sites using aerial photo classification and ground surveys

	Goat & Cattle		Cattle	
	Ground survey	Aerial photo classification	Ground survey	Aerial photo classification
Woody cover (%)	63.2 (SD=14.4)	63	69.0 (SD 18.4)	67
Multiple cover (%)	79.5 (SD=21.7)		89.1 (SD 17.2)	
Mean woody patch area (m^2)		8.54		15.99
Woody patch density (Patches ha^{-1})		735		417
Edge density (km ha^{-1})		10.9		8.2
Average height (cm)	120.5 (SD=75.7)		120.5 (SD=73.4)	

Table 4: Temporal changes in landscape parameters between 2004 and 2010

Aerial photo classification					
Parameter	Year	Goat	No grazing	Goat temporal change (%)	No grazing temporal change (%)
Woody Cover (%)	2004	56.1	74.6	8.26	9.5
	2010	64.4	84.1		
Woody patch area(m^2)	2004	2.98	31.20	50	-11.2
	2010	4.47	27.70		
Woody patch density (Patches ha^{-1})	2004	1,849	238	-23.3	26.9
	2010	1,418	302		
Edge density (m ha^{-1})	2004	36,550	6,555	-1.8	-6.3
	2010	35,903	6,141		

Three landscape pattern indices: woody patch area, woody patch density and edge density were used to evaluate the change in landscape diversity. Additional parameters such as browsing intensity, browsing line distinctiveness and debarking intensity were calculated from ground survey data and are presented as the BLD index score. All parameters of aerial photo classifications analyses enable the calculation of important, but two-dimensional features only. In order to add the third dimension (height) to better understand the landscape structure, vegetation height and structural profile, including visual and functional aspects of goat browsing, were measured and drawn during the ground survey. A comparison of shrub heights distribution between goat and cattle vs. cattle-only grazing, revealed very similar averages and standard deviations of 120.5 cm (SD=75.7) and 120.5 cm (SD=73.4), respectively. BLD indices were calculated for goat-grazed sites only. The BLD score was 1.12for goat and cattle grazing versus 0.45 for goat grazing alone. This index ranges from zero (lowest forage exploitation) to four (highest forage exploitation) and will be most relevant in evaluating the changes in the long term.

Discussion

Capturing a comprehensive picture of a landscape is a complex task. It depends, naturally, on the eye of the beholder, whether it be a land manager, an ecologist or a farmer. The study presented here attempts to combine different perspectives and techniques in order to provide a reliable picture of the state of a grazed area and to find the right 'recipe' that incorporates different methods to fully meet the challenge. The first and most fundamental measure of landscape "opening" is the percentage of woody cover (Naveh and Carmel, 2003). From our results, it can be clearly seen that measurements of landscape woody cover from aerial photo classification are similar to those achieved by detailed and costly ground surveys (table 2). Furthermore, while aerial photo classification deals with the entire site area, ground surveys sample only a small proportion of the area being studied and infer it to the whole site level. As can be clearly seen from the structural analysis, the use of aerial photography does not reflect the complexity of the understorey. Another layer "hides" beneath the shrub canopy, contributing an additional 18% to total woody vegetation cover (table 2). The understorey layer plays a major role in determining the functionality, biodiversity and amenity value of a rangeland (Holzapfel *et al.,* 2006), shade, accessibility, visibility, or human scale dimensions of vegetation "gaps" (Henkin *et al.,* 2007). The properties of this layer change with grazing regime and can only be measured by a detailed ground survey that represents the vegetation profile or "façade".
The importance of structural diversity on the landscape scale, and its relation to various ecological attributes, has been widely explored (Honnay *et al.,* 1999; Christopher and Jelinski, 1999). Several approaches can be used to quantify browsing intensity and its effect on vegetation (Bilyeu *et al.,* 2007; McNaughton *et al.,* 1996). Calculating grazing pressure as the number of animal units per area is a very common approach, but does not take ecological and structural impacts into account. Furthermore, it does not assess visual and aesthetic consequences of the browsing activity, such as trampling, debarking or defoliation. Therefore, we suggest employing an index, the BLD, which comprises three visible parameters that relate very strongly to visual aspects of this kind, while at the same time representing the degree of woody component exploitation by the browsing goats.
Different effects of grazing on landscape properties are apparent at different time scales (Turner, 1989). Some parameters, such as the woody vegetation cover, are not noticeable in the short term, and it may seem that grazing does not have a significant effect on these measures. On the other hand, parameters such as edge/area ratio or BLD index, may be evident after a short period. Monitoring these parameters more frequently would help optimize grazing management and prevent the development of an undesired landscape. It is therefore recommended to conduct a ground survey to assess the BLD level at the end of each grazing season. A scheme of the different parameters and the scales in which they operate is presented in Figure 1.

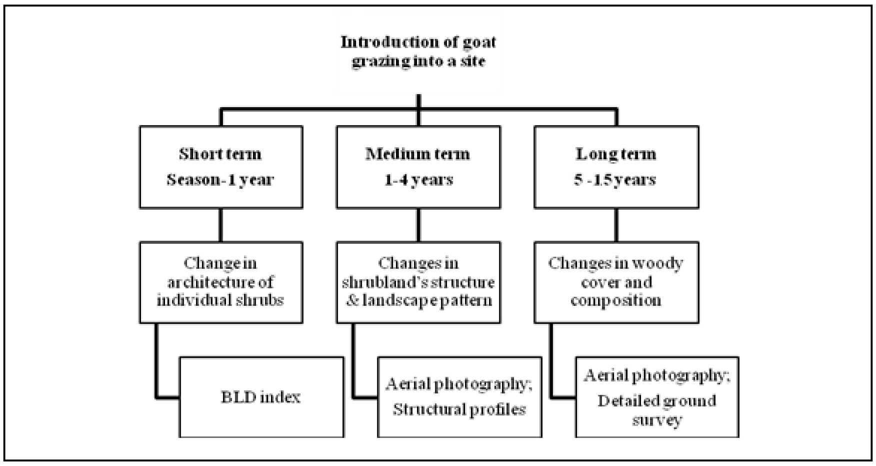

Figure 1: Different monitoring methods at different time scales

When considering the effects of goat grazing on ecosystem function and biodiversity, calculating landscape pattern indices from aerial photos would give a better estimation of the potential influence of grazing. These can be detected on a yearly basis, which would represent an intermediate interval between the short (seasonal) and long-term changes. When fire risk or potential uses are the focus of interest, field measurements must be combined with aerial photo interpretation so as to complete the picture.
Therefore, our conclusion is that the technical field work conducted by personnel can be only partially replaced by remote sensing data. Any shrubland, field or forest managed for human use must include the perspective of the human eye. Thus, only in cases where remote sensing techniques and ground surveys would produce similar information the latter method would be preferable.
In conclusion, there is no single recipe that fits all cases. Instead, there are a variety of options from which different parameters can be drawn according to site properties and management targets.

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Yak Grazing behaviour and energy expenditure under extensive grazing conditions

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Abstract
A study was conducted to measure the grazing behaviour and energy balance of free-ranging yak during the four annual seasons in order to elucidate the factors constraining energy utilization for production by grazing yak. The results showed that sward characters and allowance is the main reason to influence yak grazing behaviour. The heat production (HP, kJ) of grazing female yaks was calculated as the product of heart rate (HR, beats/minute) and the amount of O_2 delivered to the body at every heartbeat (O_2P, µl), and by the constant value of 20.47 kJ per liter of O_2 consumed. Heart rates were automatically recorded, continuously over 4 days using modified heart rate monitors. Individual daily fecal output was measured using chromium oxides an external marker. Daily intake was calculated from fecal output and digestibility of the forage determined in vitro. The greatest herbage mass measured in August (496 kg DM/ha), and the least in December and May (208 and 226 kg DM/ha). However, the herbage present in both May and August had higher crude protein contents and lower NDF contents ($P < 0.05$) than those samples in October and December. Data representative of the four annual seasons were recorded in August and December 2010, and in May and October 2011.Daily average HR (beats/minute) was significantly greater in summer (August) than during the other three seasons (68 *vs*. 49 to 52). The greatest O_2P was recorded in May. The highest metabolizable energy intake (MEI) (1084 KJ/kg MBW (metablizable body weight, $BW^{-0.75}$)/day) was measured in August when yaks grazed on lush green forage. HP was higher in August than in October and December (715, 549 and 400 kJ/kg MBW/day, respectively), but did not differ significantly from that measured in May (40 kJ/kg MBW/day).The animals were in positive energy balance only during August (369 kJ/kg MBW/day). Energy balance did not differ significantly between the other seasons: -60, -22 and -36kJ/kg MBW/day, respectively. HP was mainly affected by the forage ME content and the yaks' physical activity. HP and energy retention (ER) were highly correlated with MEI (R^2= 0.812 and 0.894, respectively).
Keywords: Grazing behaviour, Energy Metabolism, Heart Rate, Heat Production, Tibetan Plateau, Yak

Introduction
The yak (*Bos grunniens*) is a unique bovine that has survived on the Tibetan plateau for centuries under harsh alpine environmental conditions and under extensive grazing management all the year round. Because of the long period of negligible or zero plant growth each year (7-8 months) and year-round grazing management, yaks have to always go through such a cycle in one year, eating full in summer, getting fat in autumn, losing fat in winter, becoming exhaustible or dead in spring (Ding *et al.*, 2007). This situation has been exacerbated in recent years because of rangeland degradation, which has reduced the amount and quality of the herbage available, especially in the winter. However, such deterioration of pasture affects yak productivity throughout the year because of the high energy requirement for maintenance due to severe climatic conditions (long-term cold in winter, and increased temperature in summer), and the requirement to walk long distances in steep terrains to reach their pastures.

Material and methods

The experiment was conducted in Tianzhu Tibetan Autonomous County, Gansu Province, northwest China. The same twelve 4- to 8-year-old dry female yaks were used throughout the experiment selected from a farmer's large yak herd (80 yaks). The experimental yaks were integrated within a larger yak herd with 100 yaks and subjected to traditional management, which was carried out on open pastures without fencing. Measurements of grazing behaviour were determined using six sets of solid-state behaviour recorders (IGER-Recorder) (Rutter*et al*., 1997).Heat production was measured by using the HR method as described by Brosh *et al.* (2004), which is based on the measurement of HR and then relating it to the HP by calculation of O_2P through short simultaneous measurements of oxygen consumption (VO2) and HR. The VO_2 of each yak was measured over a period of approximately 20 minutes using an open-circuit system incorporating an accurate O_2 analyzer (Servomex Asia Pacific, Shanghai, China; Model 1440D). Air was sucked from the yak's face using an open face mask. A low differential pressure transducer (Setra Systems Inc, Model 269) was used for calculating air flow rate. Meantime, the live weight of each yak was measured. After VO_2 measurements, the experimental yaks with HR belt were released to the pasture including mountain and valley terrain (from 2900 to 3600 m a.s.l). Twelve non-lactating yaks were used throughout the experiment. Because we only have 6 sets of HR measuring belt, two groups (each 6 yaks) were measured alternately. The O_2P of each yak was calculated on the first day of seasonal measurement starting around at 1000 in the morning from the simultaneous measurements of HR andVO_2 (Brosh et al., 2004). HR was measured continuously using a modified heart rate monitor (Polar Electro, Kempele, Finland RS400) at 1 minute recording intervals for 4 days and held in place against the thorax with belt behind forelegs. A group of 6 yaks were equipped with GPS location and motion recorders (Lotek Engineering Inc., Canada, GPS_33000) mounted on collars. The recorders were programmed to store GPS co-ordinates and motion sensor counts at 5 minutes intervals. The yaks grazing locations on the pasture were shown by the overlays of the GPS coordinates. The horizontal distances travelled during each 5 minutes interval were calculated using ArcMap 9.2 software.

All statistical analyses were conducted using SAS software (version 9·2, SAS Institute Inc., Cary, NY). General linear model (GLM) of MIXED procedure was used with period (4 periods) as fixed effects by least square means, and yak as random effects. The Student-Newman-Keuls multiple-range test within One-Way ANOVA was applied as multi-comparison between the four seasons with season as the main effect.

Results and discussion

The total grazing time of yaks is higher in grass growing season than in non-growing season (Figure 1). Total ruminating time was higher in late summer. The bite rate was significantly higher in early summer, which is up to 68 bites per minutes. The results showed that yaks adapted their foraging behaviour in response to changes in sward conditions. In the dry periods or seasons, the yaks did not extend their grazing time because of the low quality of forage. In the grass germinating season (May), the yaks increased their bite rate and total grazing time as a response to reduced bite mass. As a result, the yaks extended much higher time for grazing and to grasp much more new germinated grass.

The average traveling distances calculated from the GPS data in December and May was shown in Figure 2. In December, yaks traveled between 10:00 and 19:00 h, with a minor peak around 12:00 h and a major peak around 1730 h. In May, yaks started to travel at about 05:30 h and continued until 0:00 h, but with two peaks of activity at around 08:30 and 18:30 h. The total daily distance traveled in December was significantly lower than in May (3.2 *vs.* 5.3 km). These results indicate that free-range yaks exerted much more energy for traveling in grass germinating period. The increased walking activity in May, in spite of the shortage in energy reserves of the yaks, was almost certainly motivated by the combination of high quality forage and low herbage mass.

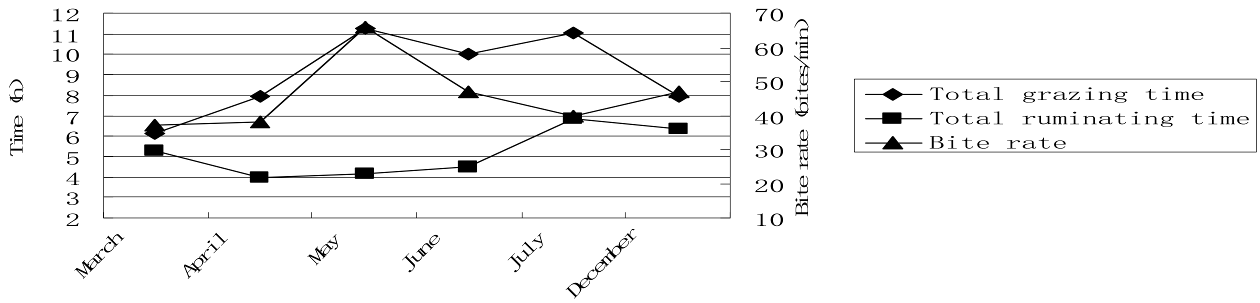

Figure 1: Total grazing and ruminating time, bite rate of free-range yaks in different months over 24 h

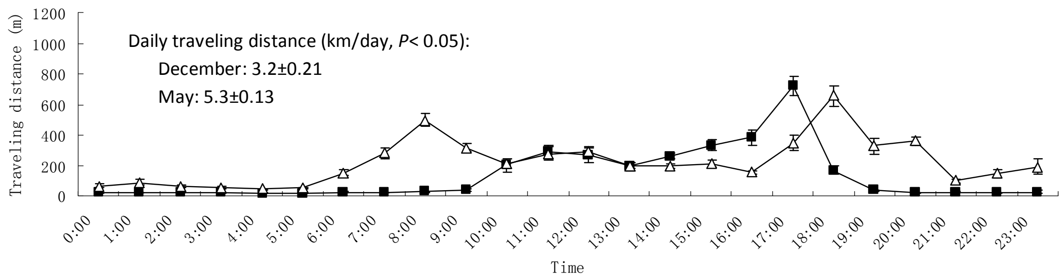

Figure 2: Mean distances traveled (±S.E. bars) by free-ranging yaks within each hour of the day during May (△, n=30) and December (■, n=22).

Yak performance and calculated energy balance variables are presented in Table 1. Mean bodyweights and DMI of the experimental yaks did not differ significantly between August, December and October, but were significantly lower in May. O_2P was the greatest in May. However, when expressed relative to live weight (LW), O_2P (µl/beat/kg LW) was significantly greater in May than in the other three months, which did not differ significantly. Mean MEI and HP per yak were significantly greater in August (summer) than during the other three months of the year, with MEI and HP being significantly higher in October than December, and values in May being intermediate. Only during August were yaks in positive energy balance, when ER was significantly greater than during October, December and May.

Table 1: Mean live weight (LW), daily herbage dry matter intake (DMI), daily average HR, O_2 per heartbeat relative to live weight (O_2P), mean daily metabolizable energy intake (MEI), heat production (HP) and energy retention (ER) per yak and relative to metabolic bodyweight (MBW), and estimated minimum HP at 0230 h (KJ/kg MBW/day) of yaks grazing on the Tibetan plateau in different months. Means within a row without a common superscript differ ($P < 0.05$)

	2010		**2011**		**SEM**	***P***
	August (Summer)	December (Winter)	May (Spring)	October (Autumn)		
LW (kg)	253^a	254^a	187^b	243^a	4.7	< 0.01
DMI (kg)	6.8^a	5.8^a	2.5^b	7.2^a	0.42	< 0.01
HR (beats/min)	78^a	49^b	52^b	52^b	2.4	< 0.01
O_2P(µl/beat/kg LW)	75.7^b	70.8^b	119.3^a	91.2^b	4.7	< 0.01
Energy balance						
MEI (MJ/day)	67.7^a	23.8^c	28.6^{bc}	30.3^b	1.78	< 0.01
HP (MJ/day)	43.9^a	24.4^c	30.8^{bc}	33.0^b	2.62	= 0.01
ER (MJ/day)	23.8^a	-0.6^b	-2.2^b	-2.7^b	2.18	< 0.01

The significantly negative energy balance in October results mainly from the low quality of the grazed forage due to seasonal senescence. However, the seasonal high wind speeds in October, before growth of a full winter coat, increase heat dissipation from the yaks' bodies. The worst survival conditions for yaks in the present study were recorded in December. This was confirmed by measurement of the lowest ambient temperature, lowest standing biomass and lowest forage quality. In spite of these extremely harsh conditions, the yaks' ER in December was statistically not significantly different from the ER measured in May and October, and was numerically greater. This unusual result can be explained by the good insulation of the yak's fur (Zhang, 1989), by a reduction in the yaks' activity in this season and by the yaks' unusual ability to reduce their HP to less than their maintenance level, which was expressed especially when resting in the cold hours of the night, when HP recorded at 2:30 was 362 ± 25.2 kJ/kg MBW/day

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Determinants of grazing intensity in summer pastures: Follow Rosie and colleagues!

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Abstract

Rosie is a dairy cow which spends summertime on a subalpine pasture. The grazing activity of Rosie and of her colleagues is a major driving factor of ecosystem services provided by summer pastures. Grazing intensity is also the primary variable of ecosystem impact influenced by the herders. The challenge with grazing intensity is that it varies substantially in space and time, especially in heterogeneous terrain such as subalpine summer pastures.
In order to determine local grazing intensity, we used GPS loggers to follow Rosie and several of her colleagues on a summer farm in Central Switzerland. Position data were recorded every 20 seconds for the entire summer season of 2011 and complemented with information about animal activity (walking, grazing, resting). These were gained through observation of the behaviour of Rosie and other tagged animals and were then related to animal movement using classification algorithms. Thus, GPS positions could be classified into the three behavioural states of walking, grazing and resting. Density distributions in space were derived thereafter.
We used linear regression with spatial autocorrelation to analyse the factors which determine the grazing intensity of Rosie and colleagues locally. Recently developed statistical techniques, namely Integrated Nested Laplace Approximation, allowed us to separate environmental explanatory variables (e.g. terrain slope and distances from sheds and water sources) and unexplained spatial trends in the data. Grazing intensity was reduced by terrain slope but only weakly by distance from the shed and from water sources. INLA further allows visualising the spatial trends in order to find covariates with potential to improve the model.
Keywords: Subalpine pastures, grazing, GPS tracking, INLA

Introducing Rosie

Rosie is a dairy cow (Figure 1). Every summer she moves from her home farm in the valley bottom to subalpine and alpine pastures, which are only grazed during three months in summer. Rosie's milk is used to produce cheese. In the entire Alpine Arch, this traditional way of pastoralism exists for centuries and the activities of Rosie and her colleagues have created ecosystems of unique characteristics and value.
Grazing by Rosie and colleagues influences ecosystem services provided by alpine pastures, but is not easy to measure. In small and topographically uniform paddocks of the lowlands, grazing intensity is well approximated by average stocking rate (e.g. Kruess and Tscharntke, 2002). However this often does not apply to large alpine paddocks, which vary in terms of topography and vegetation. In this heterogeneous environment, livestock select favoured fodder patches and avoid unsuitable areas (Adler *et al.*, 2001; Homburger, 2012). Jewell *et al.* (2005) found a pronounced small-scale pattern of grazing intensity by recording position and behavioural activity of cattle on a map several times per day on eight days dispersed throughout the growing season. The technique of Jewell *et al.* (2005) is time-consuming and suffers from an insufficient coverage of activities during the night or in areas with rugged terrain. We have therefore developped a method using Global Positioning System (GPS) in order to considerably increase the recording frequency and period. The aim of our study was to investigate the usefulness of low-cost GPS loggers as a means to determine local grazing intensity in rough terrain and analyse drivers of the observed grazing intensity.

Figure 1: Rosie on a subalpine pasture in the Lower Engadine.
The white box at the collar contains the GPS device

GPS tracking results in observations with strong spatial and temporal autocorrelation, which needs to be treated in an appropriate manner. We use the recently developed technique of Integrated Nested Laplace Approximation (INLA) allowing the estimation of regression models with various variance structures (Rue *et al.* 2009). The variance structures range from simple normal random effects for grouped observations to more complex structures of temporal and spatial autocorrelation (Fong *et al.* 2010, Illian *et al.* 2013).

How we followed Rosie and colleagues

The summer farm of Chlister lies in the Northern foothills of the Swiss Alps at 1700-2100 m a.s.l. From June 20 to August 27, 2011, 30 dairy cows were summered at the farm. The surface area grazed by dairy cows comprised 56 ha, sub-divided by fences into paddocks of different sizes (0.7 ha to 27.6 ha). The paddocks were rotated at varying intervals and smaller areas were grazed together with the two largest paddocks towards the end of the grazing period. Vegetation near the shed is of *Cynosurion* type, *Nardion* and *Seslerion* dominate steeper slopes in mixture with *Rhododendron* dwarf shrubs (Homburger *et al.* 2012). Scattered *Picea abies* trees are found in the lower areas of the farm. Dairy cows returned to the shed for milking every evening and spent the night inside. Mineral salt was supplied after milking in the shed.

We equipped Rosie and two of her colleagues with GPS loggers fixed to their collars (Figure 1). All three cows were well integrated into the herd and can therefore be assumed representative for the average cow on Chlister. The loggers were commercially available low-cost models (Qstarz Ltd., Taipei, Taiwan) with improved power supply. Position data of all three devices were collected every 20 seconds during the entire summer season. In order to assign behavioural states to GPS positions, the activities of grazing, walking, and resting of every tagged cow were protocollated by a trained observer for several hours at different dates during summer. A random forest classifier (Breiman, 2001) based on a range of distance measures along the measured sequence of positions was used to predict behavioural states for all recorded positions. Classification accuracy was 75-95 % depending on whether all three behavioural states or only grazing were considered (Homburger *et al.* 2012).

We constructed a regression model for the number of positions classified as grazing in each cell of a raster with 25 m resolution covering the entire surface of the Chlister farm (Figure 2). Explanatory variables were terrain slope, distance from the shed and distance to water sources. All variables were standardized to mean zero and standard deviation 1. In addition, distance variables were log-transformed. The likelihood of the observations was assumed to follow a Poisson distribution. Paddocks were accounted for by a normally-distributed random intercept. Spatial autocorrelation was included by the spatially structured random effect of a Gaussian Markov Random Field. Overdispersion was accounted for by a spatially unstructured random error (Illian *et al.* 2013). The regression model was fitted using INLA (www.r-inla.org).

Where Rosie and her colleagues walked

In the morning of June 26 2011, Rosie walked 3.25 km during 6.5 hours (Figure 2). The classification of the 1193 recorded positions showed that Rosie spent 50% of the time grazing, 29% were spent walking and 20% standing. Movement occurred primarily parallel to altitudinal isolines. During the entire summering season of 2011, we recorded 242000 GPS positions for Rosie and her two colleagues. 57% of the positions were classified as grazing, 21% as standing and 23% as walking. This excludes the time spent in the shed where no reliable position fixes could be obtained.

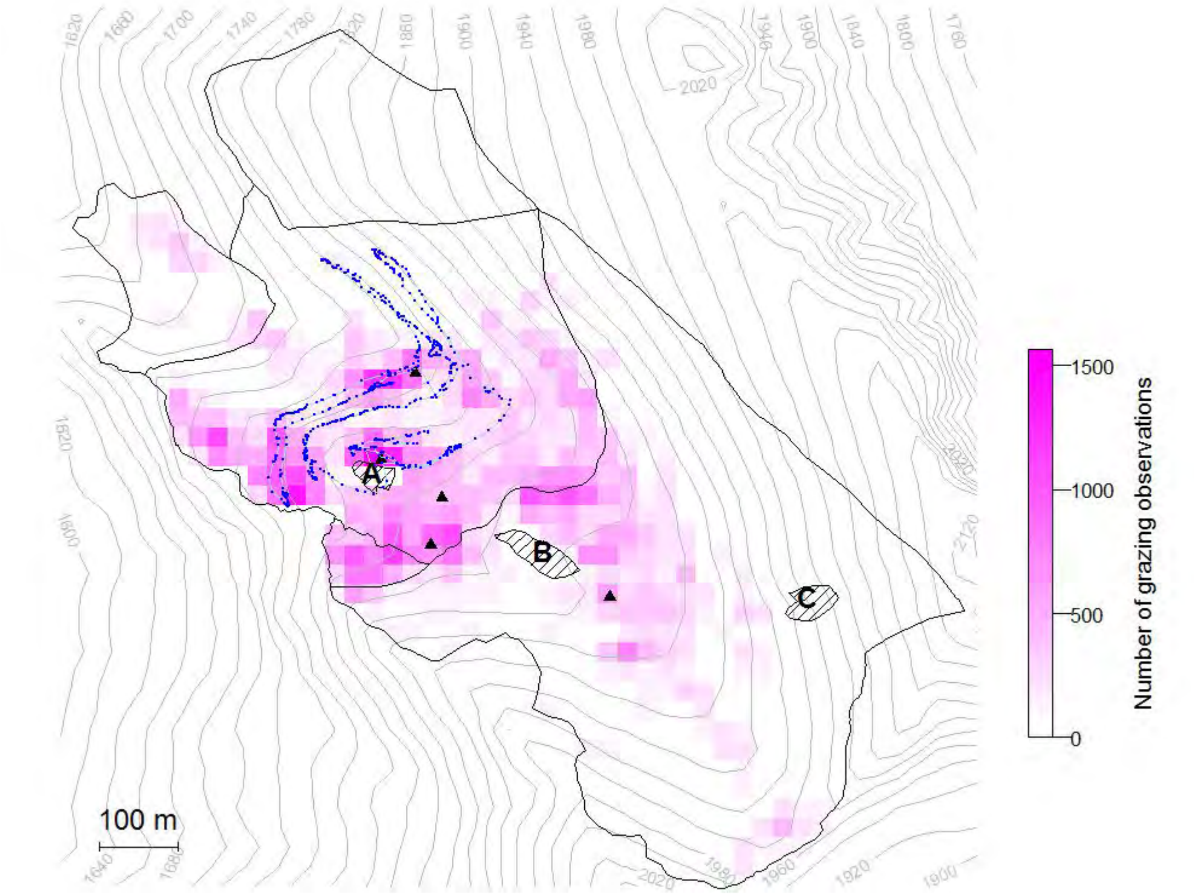

Figure 2: Rosie's walk on 2011-06-26 06:22 to 12:59 (blue points and line) and total counts of grazing observations by Rosie and two colleagues in 25 m cells during the summering season of 2011 (red shading). Black lines show fences and triangles water points. Letters indicate areas excluded from grazing (A. shed area, B. hay meadow, C. boulder area).

Figure 2 displays the spatial distribution of the observations recorded from Rosie and her two colleagues and classified as grazing thereafter. The large area visited by Rosie on just one morning and the large number of observations for the entire season indicate that the distribution of grazing points can be assumed representative for grazing intensity of the entire herd. Visual inspection suggests that grazing activities are concentrated primarily to flat areas close to the shed (A). Steep slopes and areas with long walking distance were rarely visited by Rosie and colleagues. Interestingly, Rosie explored a relatively rarely visited sector on her walk of June 26.

The two small paddocks in the North-West (top left in Figure 2) were only open for access at the end of the grazing period when fodder in the rest of the area became short.

What affected grazing by Rosie and colleagues?

The drivers of grazing intensity visually identified on Figure 2 were evaluated by the spatial regression within a rigorous statistical framework. The estimated coefficients with 95% confidence interval (in

brackets) of the three standardized explanatory variables were -0.60 (-1.07, -0.14) for % slope, 0.41 (-0.69, 1.51) for distance from shed in metres and -0.35 (-0.77, 0.07) for distance from water sources. The 95% confidence intervals are well away from zero for terrain slope indicating that the effect on grazing intensity is significantly negative at the 5% level. This is not the case for the two distance variables, which had no significant effects on grazing intensity on Chlister farm. The variance of the random intercept for the paddocks was about two orders of magnitude smaller than the unstructured random error and, hence, captured very little of the variance in the data.
The INLA methodology allows us to investigate the estimated spatially structured and unstructured random effects (Illian *et al.* 2013), i.e. the variance in the data attributable to a spatial trend and to a random fluctuation, respectively. The spatially structured effect of the fitted regression model (Figure 3a) shows a good agreement in the centre of the farm (yellow areas) but strong deviations in the top and right-hand corners (red areas). These deviations indicate spatial trends in the data not captured by the covariates included in the model. As examples, Figures 3b and 3c display two additional covariates influencing grazing intensity: (1) forage attractiveness based on a classification of vegetation types into two groups (Figure 3b) and (2) the interaction between terrain slope and distance, i.e. the fact that cows may graze steeper slopes to a stronger extent if they are close to the shed (Figure 3c). Visual comparison indicates that both covariates have potential to be included into the model in order to improve its fit to the data.

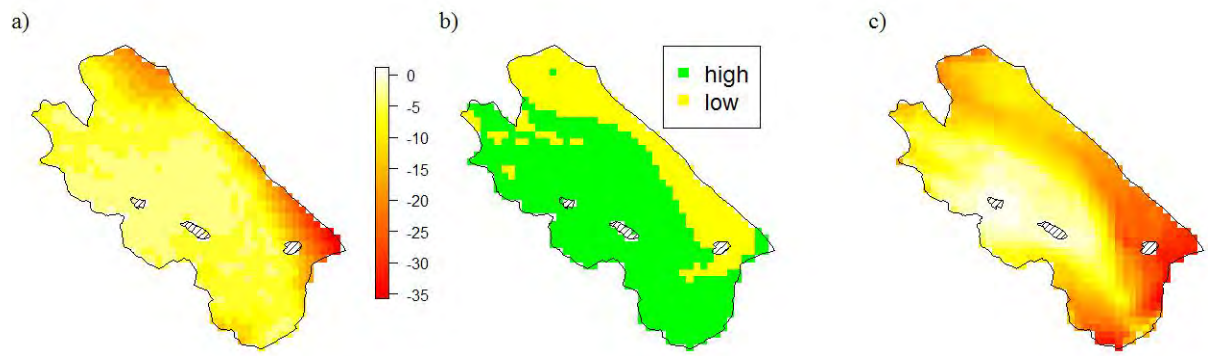

Figure 3: a) Spatially structured error of the regression model to observed grazing activity containing terrain slope and distance from shed and water sources as explanatory variables. Potential additional explanatory variables: b) forage attractiveness as a two-level factor of vegetation with high or low attractiveness to cattle and c) the interaction of slope x distance. Shaded areas are excluded from grazing.

Conclusions

High-frequency GPS tracking using low-cost GPS loggers allows monitoring grazing animals like Rosie on heterogeneous subalpine pastures. Based on the positional data, primary behavioural stages can be separated in order to filter observations depending on specific research questions. Here, interest was in grazing, whose intensity on the Chlister farm was found to strongly depend on terrain slope but not on distance from the shed or from water sources. The INLA methodology provides a statistical framework to include spatial dependencies into linear regression models in a user friendly manner. Subsequently, visualising the spatial trends can help to find covariates with potential to improve the explanatory model.

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POSTER SESSION

SESSION 1 – Ecosystem services, including quality product

Environmental performances of three Sardinian dairy sheep production systems at different levels of intensity

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Abstract

Within the CAP "greening" reform process, the optimization of environmental performances is a crucial factor to improve the competitiveness of small and medium farms, especially in marginal rural areas. Life Cycle Assessment (LCA) is the most advanced and complete computational tool for providing a widespread knowledge on the environmental aspects associated with products or production processes. This paper illustrates an LCA study carried out to assess the environmental impacts of sheep milk production obtained in three different dairy farms located in North-Western Sardinia, Italy. The main goals of the analysis were (i) to compare the performances of three sheep milk production systems at different levels of intensity, and (ii) to identify the hotspots to improve the environmental performances of each farm. The analysis was conducted using two different functional units: 1 kg of Fat and Protein Corrected Milk and 1 ha of Utilized Agricultural Area. The life cycle was assessed "from cradle to gate", including all the input and output related to sheep breeding and using farm-specific data for year 2011. The potential impacts associated with milk production were quantified using three different impact assessment methods. In addition, some options for improving the environmental performances of each farm were identified: for all farms, changing power supply strategy; for semi-intensive and intensive farms, using locally-produced feed and increasing the use of pasture resources; for extensive and semi-intensive farms, rethinking on size and number of agricultural machineries.
Keywords: sheep milk production systems; environmental performances; LCA; competitive sheep farming.

Introduction

In the current Common Agricultural Policy reform process, eco-sustainability of production systems and global climate change effect mitigation are key priorities, which will result in increasing financial support towards a more environmentally sound agriculture. Therefore, the optimization of environmental performances is a crucial factor to improve the competitiveness of small and medium farms. Moreover, recognizing and assessing the low environmental impact of production processes could represent an added value that justifies the access to financial incentives for sustainable productions, particularly in marginal rural areas. A twofold objective can be achieved: (i) one is to reduce greenhouse gas (GHG) emissions from the agriculture sector, thus improving the environmental impact of production processes; (ii) the other is to lower production costs through the adoption of methodologies and technologies that require less energy inputs and improve productivity. Consequently, it is essential to develop effective approaches to reduce GHG emissions, and to identify the different parts of food chains where to concentrate efforts. Life Cycle Assessment (LCA) is the most advanced and complete computational tool for providing a widespread knowledge on the environmental aspects associated with products or production processes (Hayashi *et al.*, 2007). In addition, LCA is also the first step towards sustainable production systems, giving information about where environmental impacts and damages take place. This paper illustrates an LCA study carried out with the purposes of (i) comparing the environmental impacts of sheep milk production from three different dairy farms in Sardinia, Italy, characterized by different production intensity, and (ii) identifying the hotspots to improve the environmental performances of each farm.

Material and methods

Data were collected from three different dairy farms located in North-Western Sardinia, Italy. These farms were chosen since they are representative of three sheep milk production systems in the region, with different levels of intensity, as summarized in Table 1.

Table 1: Main production system characteristics of dairy farms F1 (extensive), F2 (semi-intensive), and F3 (intensive). Data are referred to year 2011.

	F 1 - extensive	F 2 – semi-intensive	F 3 - intensive
Utilized Agricultural Area (ha)	125	70	67
Heads (number)	120	320	370
Stocking rate (ewes ha^{-1})	1.0	4.6	5.5
Milk production (kg year^{-1})	25000	79655	110000
Milk pro-capita annual production (kg ewe^{-1} year^{-1})	208	249	297
Natural grazing area (ha)	95	52	12
Arable land – cereals and annual forage crops (ha)	30*	18	55
Concentrate feed annual consumption (t) **	1	121	204

*10% of the arable land production is used for sheep feeding, the remaining part is sold as hay and grain.
** F1 produces all concentrates on farm, F2 imports them all and F3 imports the 86%.

The methodology used to carry out the LCA study is consistent with the international standards ISO 14040-14044 (2006). The analysis was conducted using two different functional units (FU): 1 kg of Fat and Protein Corrected Milk (FPCM) and 1 ha of Utilized Agricultural Area (UAA). The use of two FU permitted to define and to combine productivity and economic results with depletion of natural resources and to conduct a more objective impact analysis taking into account the different production intensity (Haas et al., 2000). The life cycle was assessed "from cradle to gate", including all the input and output related to sheep milk production: the livestock subdivided by gender, age, physiological and production phases; the fodder and feed production, transport and consumption; the breeding operations (shearing, milking, milk cooling, health care, etc.); the fuel, energy and water consumption; the devices and agricultural machineries; the consumable items (medicines, washing detergents and all minor stable supplies). Modes and distances of all transportations within the system were also taken into account. All the resources (materials, energy, etc.) needed by each process were determined, as well as the amount of waste and emissions to soil, water and air. Most life cycle processes' data (e.g. animal performances, forage productions, fuel consumption, etc.) were collected through visits *in situ*, interviews and a specific questionnaire (farm-specific data for year 2011). The other data (e.g. methane enteric emissions, supplement chemical composition, etc.) were collected from available literature and databases (mostly Ecoinvent v. 2.2, 2004-2010). Since all three farms produced not only milk but also meat and wool, all "inputs" and "outputs" included in the LCA analysis performed using 1kg of FPCM as functional unit were partitioned (impact allocation) between milk and the other by-products, on the basis of the economic value of products (economic allocation). When co-products were obtained from the same plot (e.g. triticale-barley grain and stubble), mass-based allocation was applied. Three different evaluation methods were used: 1) IPCC (2007), which provides estimates on greenhouse gases emitted in the life cycle of products, expressed in kilograms of CO_2-equivalents with 100-year time horizon; 2) Blue Virtual Water that estimates the (virtual) water content incorporated into a product (the volume of water, expressed in l-equivalents, consumed or polluted for producing the product during the entire life cycle) (Hoekstra *et al.*, 2011); 3) Recipe, that provides a more comprehensive assessment of life cycle environmental performances, considering 17 different categories of environmental impact which are calculated and harmonized obtaining a single eco-indicator (ecopoint) (Goedkoop et al., 2012). The life-cycle analysis was performed under the following simplification conditions: farm crops were included in the analysis only when used as forage, and taking into account only the amount consumed by flocks, after crosschecking estimated and/or measured forage production and estimated nutritional needs based on gender, age, weight, physiological stage and production level of animals. Moreover, national inventories of emissions by ISPRA (2011) for CH_4 and by IPCC (2007) for N_2O were used to quantify flocks' enteric emissions. LCA calculation was made using LCA software Sima Pro 7.3.3 (PRé Consultants, 2011), which contains various LCA databases.

Results and discussion

The LCA analysis based on the three methods indicated an overall environmental impact lower in the extensive farm compared to the semi-intensive and intensive ones (Table 2). These differences were more evident using the Blue virtual water method, which highlighted that the virtual water consumed by F1 per kg of FPCM was 5-9 times lower than F2 and F3. In fact, F1 showed a very low direct water consumption, mainly due to the absence of mechanical milking and irrigation. The analysis conducted using 1 ha of UAA as functional unit showed that the extensive dairy farm with a high surface area for natural grazing and crop cultivation has much lower environmental impacts compared to the semi-intensive and intensive farms regardless of the method used.

Table 2: Main LCA results for three farm management systems (F1, extensive; F2, semi-intensive; F3, intensive) using IPCC, Blue Virtual Water and Recipe methods and two different functional units (1 kg of FPCM and 1 ha of UAA).

IPCC method (kg CO_2 eq)	**F1**	**F2**	**F3**
FU: 1 kg FPCM	1.85	2.20	2.01
FU: 1 ha UAA	432	2430	3680
Blue Virtual Water (l eq)			
FU: 1 kg FPCM	7.1	37.8	65.1
FU: 1 ha UAA	1660	41700	119000
Recipe method (eco-pt)			
FU: 1 kg FPCM	0.29	0.47	0.41
FU: 1 ha UAA	67	520	745

A detailed contribution analysis is reported in Table 3, which illustrates all processes that contributed more than 1% to the total environmental impact of all the farms, using the three different evaluation methods. Data referred to 1 ha of UAA as FU are not reported. In general, the analysis of the contributions of individual processes showed a significant role of methane enteric emissions, of machinery stock (impacts derived from their production process at factory) an use (diesel engine use), of natural pasture utilization and, in farms F2 and F3, of feed concentrates in the diet. The analysis of the environmental impacts of the intensive production system (farm F3) underlines the high impact of concentrate feed and silage and their transportation. The semi-intensive farm F2 was intermediate between some characteristics of extensive (F1) and intensive (F3) farms. The incidence of contribution of each process changed according the evaluation method utilized. For example, the methane enteric emission represented an average 43% of total impacts in IPCC method (which considers the processes in order to their contribution to global warming), but only 10% in Recipe method (which includes others 15 impact categories in addition to global warming). This confirms that the adoption of the three different evaluation methods, offering a multiple analysis perspective, allowed to a more comprehensive assessment. The analysis of contributions indicates strengths and weaknesses of each dairy farm system. For instance, equipment contribution was very significant in F1 and less in F3. On the other side, sheep diet gave a great contribution especially in F3, where the self-produced feed was very low. Some options for improving the environmental performances of each farm were identified: for all farms, changing power supply strategy; for semi-intensive and intensive farms, using locally-produced feed and increasing the use of pasture resources; for extensive and semi-intensive farms, rethinking on size and number of agricultural machineries.

In conclusion, the LCA has revealed to be an interesting tool that can be applied to evaluate and to optimize the environmental performances of dairy sheep farms. But, for a more systematic interpretation leading to science-based decisions, is really important to enhance the knowledge about a Mediterranean database with site-specific emission and characterization factors which should be used in environmental hotspots (e.g. methane enteric emissions, synthetic fertilizers production and distribution, supplements production, etc.).

Table 3: Contribution of processes to the total environmental impact for all farms, using the three evaluation methods (functional unit 1 kg of PFCM). Processes with contributions lower than 1% in all the farms for the three methods are excluded.

Process	**IPCC**	**Recipe**	**Blue Virtual Water**					
	F1 F2 F3 F1	F2	F3	F1	F2	F3		
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Methane enteric emissions	49%	43%	37.5%	15%	10%	9%	-	-
Electricity, medium voltage	14%	5%	3%	8%	2%	1.5%	21%	2%
Diesel engine use	20%	5.5%	6%	14%	3%	4%	8%	-
Agricultural machinery, production	6%	2%	3%	4%	1%	-	14%	1%
Tractor, production	4%	2%	2%	3%	1%	-	8%	-
Natural grassland	2%	0.5%	0.3%	31%	8%	9%	-	-
Barley seed for sowing	1%	-	-	1%	-	-	26%	-
Ryegrass seed for sowing	-	-	2%	-	-	1%	-	-
Soy seed for concentrate feed	-	6%	6%	-	15%	15%	-	5%
Maize grain for concentrate feed	-	10%	2%	-	9%	2%	-	3%
Wheat grain for concentrate feed	-	3%	5%	-	2%	4%	-	8%
Sunflower for concentrate feed	-	1%	1.5%	-	2%	3.5%	-	3%
Hay by grassland	0%	0.5%	-	2%	8%	-	-	-
Barley-oats-clover, grazing	-	-	-	15%	-	-	-	-
Barley-oats-clover, hay	-	-	-	2%	-	-	-	-
Clover-ryegrass, grazing	-	-	5%	-	-	12%	-	-
Clover-ryegrass - hay	-	-	4%	-	-	12%	-	-
Triticale, stubble	-	-	1%	-	-	9%	-	-
Urea	-		2%	-		1%	-	-
Pyretroid-compounds	-	-	-	-	-	-	-	-
Veterinary pharmaceuticals	-	-	-	-	-	-	-	20%
Transport, transoceanic freight sheep	-	2%	2%	-	1%	1%	-	-
Remaining processes (more than 150 other processes included)	4.0%	19.5%	17.7%	5%	38%	16.0%	23%	58%

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SESSION 1 – Management of pastoral areas

Determinants of using forage resources in buffalo breeding system at the Lake Kerkini, Northern Greece

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Abstract

Determinants of using forage resources (communal rangelands, temporary pastures, stubble fields and other crop residues) were examined in the buffalo breeding system at the area of the Lake Kerkini in Serres, Northern Greece, during 2011. This particular area was selected as 2,492 buffaloes (80% of the whole country's buffalo population) are raised there. The research was conducted on the basis of standardized questionnaires (processed by Spearman test) and in-depth interviews with all buffalo breeders. The communal rangelands are used by all breeders independent of particular features. Even the eldest ones may continue to use forage resources, such as temporary pastures, stubble fields and other crop residues, alternatively to communal rangelands. Personal initiative (0.506) appears to be a much stronger motive for the use of temporary pastures. Experience of buffalo breeders (0.531) lays emphasis on the usage of financially safe practices such as stubble fields and other crop residues. Exercising buffalo breeding as complementary –not main- occupation (-0.571) seems to encourage developing temporary pastures, while family holdings with long tradition (-0.688) and many family or non family employees (-0.484 and -0.494, respectively) tend to avoid it. Keeping big-sized buffalo herds does not necessarily mean more strongly use of alternative forage resources. The diversification of economic activities encourages (0.505) the use of temporary pastures. Critical comments and issues for further research are proposed.

Keywords: Buffaloes, rangelands, temporary pastures, crop residues, breeders

Introduction

Water buffaloes (*Bubalus bubalis*) have been an integral part of livestock agriculture in Greece since the beginning of 20th century. Their population has dramatically decreased from 70,000 animals counted at the end of '50s (NSSG, 1960) to 3,128 nowadays (GBBLC, 2011). The majority of this population, 2,520 heads, is concentrated around the Lake Kerkini and is raised for milk and meat purposes (Georgoudis *et al*., 1998). Buffalo herds are pure and permanently herded.

The buffaloes breeding system in this area is traditionally based on grazing of communal rangelands, which can provide herbage to animals only for 6-7 months during the year. Breeders, in order to fill the winter - early spring feed gap, utilize alternative forage resources, such as temporary pastures with annual winter cereals (e.g. barley, wheat, rye and oats; mainly as monocultures). Additionally, cereal stubble fields remaining after harvesting and other crop residues (maize, sunflower, soya and rapeseed) are used for covering the summer - autumn feed shortage. The breeders also make intensive use of purchased feedstuffs throughout the year (Tsiobani *et al*., 2013a).

Temporary pastures are established during early autumn, in private or rented agricultural land, and are used either for grazing by buffaloes in late winter and early spring or for hay production or for cut-and-carried to the buffaloes supplemental feeding. After this short period temporary pastures are destroyed and used for summer cultivations. Despite their significant contribution to milk production temporary pastures have both

economic and environmental problems. The former are related to their establishment cost every year while the latter involve soil erosion caused by this establishment (Kosmas et al., 2001) as well as the use of nitrogenous fertilizers. Because of these issues several breeders prefer to replace temporary pastures with permanent ones or avoid using agricultural land in buffalo breeding.
In general, data about the buffalo breeding system in Greece is quite limited (Georgoudis, 1998, Ligda and Georgoudis, 2005, Tsiobani *et al*., 2013a). In this paper the determinants of using forage resources in the water buffalo breeding system in Northern Greece are studied.

Materials and Methods

The research was conducted during 2011 at the Lake Kerkini National Park in Serres, Northern Greece. The climate of the area is characterized by dry-hot summer and cold winter. Mean annual precipitation is 450 mm and mean annual temperature is 15°C. The dominant vegetation in the rangelands of this area is consisted of woody species such as *Rubus sp., Sambucus nigra, Quercus coccifera, Phillyrea latifolia* and herbaceous species e.g. *Sorgum halepense, Fragmites australis, Festuca arrundinaceae, Chrysopogon gryllus, Bromus mollis, Cynodon dactylis, Lathyrus laxiflorus*, *Clematis vitalba, Genista cardinalis* etc. Most of these species are food resource for the buffaloes (Tsiobani et al. unpublished data). This particular area was selected as 2,492 buffaloes (80% of the whole country's buffalo population) are raised there.
The study was based on standardized questionnaires and in-depth interviews with all buffalo breeders (n=17) of the area. All of them responded to the questionnaire. The questions concerned the animal capital, the features of the holdings and breeders, the utilization of communal rangelands as well as alternative forage resources such as temporary pastures, stubble fields and other crop residues.
The data was processed by using Spearman's test as the distributions were not normal (Steel and Torrie, 1980). As the quantitative correlations are not enough alone to detect causality, in-depth interviews were conducted in order to support interpretations of quantitative results. Even insignificant correlations will be presented not only for reasons of completeness but also because they in part support hypotheses or lead to subversive insights.

Results and Discussion

Rangelands, temporary pastures, stubble fields and other crop residues are the grazing options of buffaloes in the studied area. The determinants of usage of such forage resources are presented in Table 1. The communal rangelands are used by any breeder independent of personal, entrepreneurial, structural or attitude-related features. This tendency among breeders is understandable considering that the livestock production systems in Greece are traditionally based on grazing of communal rangelands. No one of the examined breeder-related features has statistically been proven to be relevant for using communal rangelands and stubble fields in contrast to temporary pastures and other crop residues which tend to be used by breeder groups of particular features as shown by the respective significant correlations
It is noticeable that the age of the breeder is irrelevant to the alternative forage resources used for breeding, though one would expect that older breeders would gradually give up being interested in developing such forage resources which necessitate work load, time or financial means and entrepreneurial risk. This can be regarded as a subversive insight.
The personal initiative for beginning buffalo breeding (0.506) seems to constitute a much stronger basis for making investment in temporary pastures, aiming at assuring entrepreneurial independence and dynamic development. Simultaneously, farmers who became buffalo breeders stimulated by the encouraging experience of other persons whom they have regarded as "experienced", mainly prefer to use in buffalo breeding stubble fields (0.489) and much more other crop residues (0.531) which at any rate remain in the field after crop harvesting. Thereby, the experience dictates this financially safer practice.
Optimistic attitudes toward buffalo breeding entrepreneurship such as the belief in sustainability, the desire for continuation, or the interest for buffalo breeding declared by the next generation would be supposed to lead into higher investment in temporary pastures. However, this hypothesis is not supported by the results of this study, as no significant correlation has been detected between attitudes and this (or any other) forage resource type usage. Thus, the entrepreneurial rationality of these attitudes is questionable.

Table 1. Determinants of usage of forage resources in water buffalo breeding in the Lake Kerkini, Northern Greece

		Communal rangelands (no use=0, use=1)		Alternative forage resources					
				Temporary pastures area (0-30 ha, average=8.73 ha)		Stubble fields area (0-20 ha, average=2.86 ha)		Other crop residues area (0-15 ha, average=1.93 ha)	
		Spearman coeff.	Sign. Level	Spearman coeff.	Sign. Level	Spearman coeff.	Sign. Level	Spearman coeff.	Sign. Level
Breeders' features	Age of breeder	-0.380	0.132	0.204	0.432	0.095	0.737	0.311	0.260
	Breeders motivated by personal initiative	-0.112	0.668	0.506(*)	0.038	-0.295	0.285	0.047	0.868
	Breeders motivated by others experience	0.091	0.728	0.411	0.101	0.489	0.065	0.531(*)	0.042
Attitudes toward buffalo breeding	Considering buffalo breeding as entrepre-neurially sustainable	-0.091	0.728	0.154	0.555	0.209	0.454	0.133	0.637
	Breeders desire to continue buffalo breeding	-0.091	0.728	0.154	0.555	0.209	0.454	0.133	0.637
	Next generation desire to continue buffalo breeding	-0.165	0.527	-0.332	0.193	-0.276	0.320	0.125	0.658
Entrepreneurial features	Exercising buffalo breeding as a main occupation	0.310	0.226	-0.571(*)	0.017	0.307	0.265	0.195	0.487
	Family holding	-0.022	0.935	-0.448	0.071	-0.140	0.620	-0.177	0.528
	Family tradition (generation number)	0.065	0.803	-0.688(**)	0.002	0.036	0.900	-0.315	0.252
	Family employees	0.022	0.935	-0.484(*)	0.049	-0.314	0.254	0.133	0.637
	Non family employees	-0.066	0.801	-0.494(*)	0.044	-0.135	0.631	-0.006	0.983
Structural farm features	Buffaloes number	0.149	0.568	-0.218	0.400	0.064	0.819	0.107	0.704
	Diversified economic activities apart from buffalo breeding	-0.123	0.638	0.505(*)	0.039	0.464	0.081	0.373	0.171

Moreover, using temporary pastures seems to depend on entrepreneurial features. Specifically, those who exercise buffalo breeding as complementary – not main - occupation seem to be more strongly motivated to develop temporary pastures (-0.571) as they probably expect to use these for practicing other husbandry (e.g. sheep breeding) simultaneously to buffalo breeding. The family holdings (-0.448) seem to slightly avoid using of temporary pastures, especially after a long family tradition (-0.688). This tendency seems to become stronger in the case of occupying many family members as employees (-0.484) or even non family employees (-0.494). Evidently, big and long-tradition family holdings tend to provide purchased feedstuffs to their animals instead of establishing temporary pastures. However, to what extent this is a rational entrepreneurial option or just a custom established through a long-term family practice or a necessary practice due to inadequacy of agricultural land available for buffalo breeding is a question for further research.

Concerning structural farm features, buffaloes number seem not to be strong enough to stimulate breeders to use alternative forage resources. Thus, the nutrition of buffaloes appears to depend on purchased feedstuffs. Thereby, the buffalo breeding system is gradually converted from extensive to semi-intensive, following the case of small ruminants in Greece (Zarovali *et al.*, 2006). This conversion fosters the dependence on EU subsidies as well as on the feedstuff industry. The diversification of economic activities apart from buffalo breeding (such as simultaneous practicing of other husbandry) seems to strengthen the use of temporary pastures (0.505). This is in accordance with the afore-mentioned results about (non) main occupation (-0.571) as well as with previous findings of Tsiobani *et al.* (2013b).

In conclusion, using communal rangelands as well as stubble fields mainly depend on traditional practices and not on any particular breeder-related features. On the other hand, the use of temporary pastures and other crop residues depends on various determinants. Issues for further research are the rationality (or not) of optimistic attitudes as well as of the avoidance of establishing temporary pastures by family holdings characterized by long tradition and occupying many employees.

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Desertification control in Algerian arid overgrazing area with Atriplex canescens plantation

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Abstract

The growing demographic pressure and motorization of stocks transport led to an increasing use efficiency of forage patches and thus faster overgrazing of these fragile systems. The degradation of steppes led the government to set up measures to protect the fertility of threatened ecosystems. One of solutions used was forage plantation of *Atriplex canescens* to combat desertification and support the needs of the livestock. This study was conducted on *Atriplex canescens* plantation in 9 departments. In these plantations, we evaluated the impact of shrubs on fixing the sediment, floristic diversity, elements of the soil surface and soil physicochemical parameters. The results show that the effect of planting, are significant for all parameters tested four year after planting.

Keywords: desertification, soil fertility, biodiversity, overgrazing, arid, Algeria

Introduction

The main factors impacting the plant communities in semi-arid ecosystem are climatic conditions and anthropogenic activities (Reynolds & Stafford Smith, 2002). In Algeria, the drought effect is combined with the impact of sheep grazing (Slimani *et al.,* 2010). The Algerian steppes, which extend over 20 million hectares, harbour a human population estimated at 12 million among which numerous shepherds. Steppes are grazed by 16 million sheep. This key activity for the development of this area magnified degradation of vegetation, sometimes up to an irreversible desertification of arid and semi-arid ecosystems (Mainguet, 1991). The degradation of steppes led the government to set up measures to protect the fertility of threatened ecosystems. In November 1994, plans for preserving these ecosystems from desertification were drawn up. Among techniques implemented, revegetations to stabilize the sediment, planting of forage species and fencing have been extensively used in the Maghreb and Middle East (Amiraslani & Dragovich, 2011). Forage plantation has been adopted by several countries in North Africa, West Asia, America, the Middle East and Australia, especially in the case of very advanced degradation (Mulas & Mulas, 2004). This technique was employed over large areas since 1994, managed by the High Commission for the Development of the Steppe (HCDS). This study aimed at characterizing the effects of forage plantation on (i) floristic diversity, (ii) pastoral value (iii) soil fertility and (iiii) soil surface element.

Methodology

For this study we used the systematic sampling. This sampling is done along a transect of 500 m for grazed area and 1500 m for planted area in order to show floristic and ecological changes. For all stations (inside and outside the plantation) we determined a minimum area of 64 m^2 using Braun-Blanquet & De Boulos (1957) method. Vegetation cover was described with pin-point technique, met by a pin descending to the ground on 100 points separated by 10 cm along a 10 m long line within the 64 m^2 plot. Description of the soil surface (with the following typology: litter, bare silty crust, sand, bare ground, coarse) and that of vegetation cover were carried out by the same pin-point sampling technique used by (Jauffret & Visser, 2003). The frequency of plant species and abiotic elements at the 100 points is used to estimate the frequency that can be treated as a percentage of surface cover (Godron, 1968). In order to identify possible changes in the soil environment, in each of the 145 plots a sample of soil, from the surface horizon, was 2 mm sieved and air-dried before chemical analyses. The chemical parameters analysed were conductivity, pH, total and active calcium carbonate, organic matter and total nitrogen. Conductivity and pH was determined using a 1:5

soil water suspension. Total calcium carbonate was determined by back-titration and active calcium carbonate using the Bernard calcimetry method. Organic matter (OM) was determined using the Anne method and total nitrogen was determined using the Kjeldahl method. We used C/N ratio as a proxy for soil organic matter mineralization status in each plot.

To estimate biodiversity, the species richness (R), Shannon index (H') and evenness (E), were computed for each plot using the software R version 2.13.1 (package Vegan). The pastoral value (PV) of each plot was obtained using formula adapted from (Daget & Poissonet, 1971).

The mean of R, H', E, PV, the condition of the soil surface and chemical descriptors of the surface horizon were measured for each of the 145 plots. The differences between the indices computed, the measured surface elements and chemical descriptors determined inside and outside the plantation were tested by the nonparametric Kruskal-Wallis test due to unbalanced model. Post hoc comparisons between different treatments were made using the Wilcoxon rank sum test. Both tests were conducted using R version 2.13.1 software (R Development Core Team, 2007).

Results and discussion

Table 1 shows that the plantation species richness (R) is greater in planted areas with a richness that is twice the wealth of pastureland ($\chi 2 = 272.89$, $P < 0.001$). As for the two calculated diversity indices we note that the planted areas are more diversified and covered than the unplanted areas ($P < 0.05$). When regarding the pastoral value, we note that it follows the same trend as that of the diversity indices, with values significantly higher in the planted areas ($\chi 2 = 259.91$, $P < 0.0001$).

For the elements at the surface we find that the rate of vegetation cover, litter, as well as bare silty crust are significant in planted areas, while the rate of sailing wind, bare soil and coarse increase with grazed areas ($P < 0.05$). Chemical analyses of some companies show a non-significant difference ($P > 0.05$) while for the size difference is important to be noted for other elements in the soil. Consequently, the calculated C/N ratio has showed good mineralization of the planted soil.

The greatest species richness recorded in plantations is the result of the subtraction of these spaces livestock. This has allowed the plant to complete their phenological cycles and produce seed, thus increasing the soil seed bank. By contrast, in grazed areas, species with high specific quality index are grazed at different phenological stages, resulting in the diminishing of soil seed bank. Additionally, trampling bound to overgrazing causes soil compaction, preventing water infiltration and therefore seed germination. This latter is to be translated into a low vegetation cover (Schlesinger *et al*., 1990; Van de Koppel & Rietkerk, 2000). Overgrazing changes the structure of plant communities and their floristic composition (Fleischner, 1994; Olff *et al*., 1999). The grazed areas are characterized by a dominance of perennial chamaephytes that initiate the phenomenon of desiccation (Floret *et al*., 1990) and overgrazing (Kadi-Hanifi, 1998). These areas are mostly dominated by chamaephytes with low quality specific index repelled by livestock such as: *Atractylis caespitosa*, *Herniaria fontanesii*, *Peganum harmala* and *Thymelaea microphylla*. Plantations have a much higher floristic composition than those pastoral areas. Indeed, the floristic richness in plantations varies between 11 and 23 species and between 7 and 10 species outside plantation. These plantations are characterized by the development of species including therophytes, with high forage value as *Astragalus corrugatus*, *Erodium glaucophyllum*, *Erodium crassifolium*, *Medicago litoralis*, *Trigonella polyceratia* and *Xeranthemum inapertum*. According with Vickery *et al*. (2001), overgrazing reduces biodiversity. Discriminating the development of palatable species to the detriment of thorny species rejected by livestock such as *Atractylis caespitosa* and *Atractylis serratuloides* species with low forage value as *Adonis dentate*, *Filago pyramidata*, *Peganum harmala*, *Thymelaea microphylla*.

The analysis of the soil surface has highlighted a significant improvement in vegetation cover of plantations marked by the density and the diameter of *Atriplex canescens* shrubs. In degraded areas the plant contribution to the soil is low, less than 25% on average, due to overgrazing (Huntly, 1991).

Grazed areas are characterized by high proportions of bare soil more than 50% on average due to overgrazing (Schlecht *et al.*, 2009). The proportion of coarse particles to the surface is small in plantations.

Plantation increase the rate of carbon and nitrogen compared to the overgrazed areas. Subtraction of the plantations to the livestock contribute to increase the floristic richness and soil organic matter improving soil physic-chemical allowing water infiltration and germination of seeds bank.

The low levels of these two elements in the grazed areas is the consequence of the reduction of biomass by grazing affects floristic composition and reducing the rate of litter in the soil (Hai *et al*., 2007). In addition to such a phenomenon the wind erosion removes the fine particles of soil rich in organic carbon and nitrogen making these areas poorer in these elements (Pei *et al*., 2008).

Table 1: *Atriplex canescens* plantation effect on floristic diversity, pastoral value, soil surface and soil chemical analysis. Means ± SE are given. The differences among the treatments were tested by nonparametric Kruskal-Wallis test (X_2 and p-value), signification levels (* = p < 0.05; ** = p < 0.01; *** = p < 0.001; ns = non significant). Different letters indicate differences between inside and outside plantation (Wilcoxon test, p <0.05). PL: Inside Plantation; HPL: Outside Plantation.

	Plantation		X2	P-Value
	PL	HPL		
Floristic diversity index				
Floristic Richness R	24.52 ^{a} ± 2.21	12.8 ^{b} ± 2.34	272.89	< 0.001***
Shannon index H'	2.98 ^{a} ± 0.1	2.42 ^{b} ± 0.18	59.63	< 0.001***
Evenness E	0.65 ^{b} ± 0.01	0.66 ^{a} ± 0.01	8.58	< 0.0355*
Pastoral value PV	39.09 ^{a} ± 3.74	9.51 ^{b} ± 3.18	259.91	< 0.0001
Soil surface elements (%)				
Plant cover (RGV)	75.25 ^{a} ± 5.87	26.6 ^{b} ± 5.98	214.97	< 0.001***
Litter (LT)	6.62 ^{a} ± 2.47	5,00 ^{b} ± 2.76	62.43	< 0.001***
Bare silty crust (PG)	6.12 ^{a} ± 3.89	1.75 ^{b} ± 1.92	147.95	< 0.001***
Sand (VE)	8.52 ^{a} ± 4.61	8.6 ^{a} ± 4,00	3.37	> 0.05 ns
Bare ground (SN)	1.6 ^{b} ± 2.22	50.38 ^{a} ± 8.19	204.17	< 0.001***
Coarse elements (EG)	1.98 ^{b} ± 3.6	9.05 ^{a} ± 4.22	120.85	< 0.001***
Soil chemical analysis				
pH	8.12 ^{a} ± 0.28	7.89 ^{b} ± 0.32	17.10	< 0.001***
Conductivity	0.26 ^{a} ± 0.30	0.16 ^{b} ± 0.26	52.86	< 0.001***
Total calcium carbonate	5.67 ^{b} ± 6.52	8.14 ^{a} ± 8.13	10.42	< 0.01*
Active calcium carbonate	9.78 ^{a} ± 8.81	5.34 ^{b} ± 3.97	25.24	< 0.001***
% Organic matter	3.96 ^{a} ± 0.61	0.74 ^{b} ± 0.17	77.71	< 0.001***
% Total nitrogen	0.24 ^{a} ± 0.06	0.09 ^{b} ± 0.02	52.96	< 0.001***
C/N	10.04 ^{a} ± 1.60	4.60 ^{a} ± 0.84	45.20	< 0.001***
Clay	7.32 ^{a} ± 4.75	8.71 ^{a} ± 7.61	6.70	>0.05 ns
(CEC)	7.06 ^{a} ± 5.94	6.44 ^{a} ± 8.31	4.53	>0.05 ns
Sand	85.71 ^{a} ± 7.79	84.85 ^{a} ± 13.08	2.77	>0.05 ns

The calculated C / N ratio for the inside and the outside of the plantation is comprised between 10.04 and 4.60, showing a good mineralization of the studied soils. According with Pouget (1980) the low carbon in the soil is rapidly mineralized. The results obtained in this research show that four years of *Atriplex canescens* plantation improves quantitatively and qualitatively the vegetation and the soil surface, with small changes in soil chemical properties.

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Long term influence of methods to improve subalpine *Nardus stricta l.* grasslands in the Carpathian Mountains

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Abstract

The research regarding the improvement of degraded *Nardus stricta* L. subalpine grasslands, started 8 decades ago, has underlined a series of methods, usually studied for 3-5 years in an experimental cycle, that is too short period to observe the full effect of the methods used. On this short term observation period the investment required for their improving proves to be uneconomical.
A better knowledge of the long term effect of improvement methods used, justifies the economical efficiency and the encouragement of investments for improving these degraded grasslands.
A tri-factorial long term experiment (1995-2012), was conducted on semi-natural grassland invaded by *Nardus stricta* located at 1800 m altitude, in mountain pine (*Pinus mugo*) level of Bucegi Mountains. The effects of fertilizer type (mineral, organic-mineral and organic), sward type (semi-natural, over sowing, and re-sown) and liming up to 2/3 hydrolytic acidity of the soil were investigated.
The results from the 2012 experiment, after 17 years of liming combined with fertilization have revealed the really good and durable effect of liming, a process less known in specialized literature. The residual effect of liming would be estimated around 20-25 years.
Likewise the sown species were , the *Phleum pratense* species has maintained at 22-30% in sward composition on limed plots. In the improved plots, after 17 years it stands out the emergence of *Agrostis capillaries* (20-48%) and *Poa pratensis* (16-38%) as well as the expanding of *Trifolium repens* (8-33%) species. After this long period since the intervention, in this very drought 2012 year, the highest DM yield was obtained with organic fertilization thru paddocking method and the lowest with chemical fertilization where the plots have suffered the most.

Keywords: *Nardus stricta* grasslands, fertilization, liming, sowing, maintenance

Introduction

In the Romanian Carpathians the *Nardus stricta* L. grasslands cover approximately 300.000 hectares from 400-600 m up to 2.000-2.200 m a.s.l., on poor acid soils, calloused and unventilated (Cernelea E. and Bistriceanu C., 1977). The grasslands dominated by *Nardus stricta* have replaced good grasslands of species of higher value, especially the *Agrostis capillaris* and *Festuca rubra* ones, as a result of an improper grazing use, lack of maintenance and fertilisation for decades or even centuries (Bărbulescu C. and Gh. Motca, 1983).
For the subalpine grasslands the package with grazing livestock units (with cows and sheep) represent one of the most proper improving methods, with a slight inconvenient that it can be used only on small surfaces (approximately 10-20% of the pasture surface). Likewise the radical measures like the destruction of vegetal carpet and sowing the grassland are harder to be applied on large scale, due to some restrictive factors like the presence of rocks on surface, the triggering of the erosion on slopes and the reduced economic efficiency.
In the present paper we present results regarding the combined effect of fertilisation type, the improving method of grass sward and the liming on the *Nardus stricta* subalpine pastures from the Bucegi Mountains.

Material and methods

The study was carried out at the Research Base for Mountain Grasslands (R.B.M.G) Blana Bucegi located at 1.800 m altitude. In this location the initial vegetation was dominated by *Pinus nugo* and *Picea abies*. After

the deforestation they have been replaced by grass vegetation dominated by *Festuca nigrescens*, *F. ovina* and *Agrostis rupestris,* which has been invaded by *Nardus stricta,* as a result of an improper use (Marusca T. and Frame J. 2003).
The lithologic substrate is composed of typical Bucegi conglomerates. The soils are acid browns, podzols, with low quantities of nutritive elements.
The climatic conditions are characteristic of the subalpine floor, with an annual mean air temperature (1961-1990) of 1.6°C. The rainfall during the vegetation period (June-September) is approximately 451 mm, and the annual rainfall is of 1.061 mm. In 2012 the mean annual temperature was of 2.2°C that is 0.6°C more than the multiannual mean and the rainfall was of 276 mm, with 175 mm lower that the multiannual mean.
The research has been set up in 1995, is an experiment with three factors split-split plot type, with 4 replicates. The three factors are: A – fertilisation type, -with following treatments: a1- mineral fertilization (1996 - 1998 - P_2O_{5-50} K_2O_{-50}; 2004 -N_{-150} P_2O_{5-100} K_2O_{-100}; 2005 - N_{-100}; 2006 - N_{-50}; 2012 - N_{-150} P_2O_{5-100} K_2O_{-100}); a2- mineral and organic fertilization (1996 - N_{-150} P_2O_{5-50} K_2O_{-50}; 1997 - N_{-100} P_2O_{5-50} K_2O_{-50}; 1998 - N_{-50} P_2O_{5-50} K_2O_{-50}; 2004 and 2011- package with a stocking rate of 1 cow/ 6 m^2 for 5 nights + P_2O_{5-100}); a3 - organic fertilization (1995 - package with a stocking rate of 1 sheep/ 1 m^2 for 5 nights; 2004 and 2011- package with a stocking rate of 1 cow/ 6 m^2 for 5 nights + P_2O_{5-100}); B –sward type with following treatments: – b1 natural (*Nardus stricta* 60%); b2 – over sowing in 1996, after spraying in 1995 and harrow (1-2 cm); b3 - re sowing in 1996 after spraying 1995 and milling (10-12 cm); C- calcic liming, with following treatments: c1 - no liming and c2 – liming at 2/3 of the hydrolytic acidity (approximately 7,5 t/ha CaO). The seed mixture used for over and re sowing contained the following species: *Phleum pratense* Favorit variety (40%), *Festuca pratensis* Transilvan (25%), *Lolium perenne* Marta (5%), *Trifolium hybridum* - local Brasov variety (15%) and *Lotus corniculatus* Livada variety (15%).
In order to determine the green mass yield and his quality for each individual small plot (18 m^2) samples have been prevailed from a surface of $1m^2$. The samples were done once a year in the last decade of July.
The floristic composition was determined using the KLAPP – ELEMBERG method of percentage appreciation of the each species participation on the grass carpet.

Results and discussion

A radical change has been identified in the floristic composition of the grass sward after 17 years grasslands improvement with the almost complete disappearance of the invasive *Nardus stricta* species and its replacement with valuable species like *Agrostis capillaris*, *Poa pratensis*, *Festuca nigrescens* and others (Table 1). In the same period the *Trifolium repens* species contribution increased from 8% to 18%. *Phleum pratense* was maintained after 17 years since sowing and contributed to 5-15% of the grass carpet, and reached 30% on the over sowed and limed plots 222 and 322, a result not reported in the literature. It can be noticed the increase of the proportion of *Poa pratensis* species with 8%, *Festuca nigrescens* with 6% in the natural grass carpet and of *Agrostis capillaris* species with 19% of the mean proportion of the grass carpet from 1995. Regarding the influence of the calcic liming on the grass carpet it can be seen that the *Trifolium repens* species increased with 8%, *Poa pratensis* with 4% and *Taraxacum officinale* with 3% leading to an improvement of the pastoral value compared to the plots that were not limed. Liming decreased the proportion of rustic species, with a low forage value like *Agrostis rupestris*, *Deschampsia flexuosa, Potentilla ternata* and others, of about 4-6% compared to the plots that were not limed.
The results are underlining the long term effect of liming on subalpine grassland composition. In our opinion this effect, would be more than 20 years, a fact not so well known in the literature.
The improving methods of the subalpine grasslands affected dry matter yield of the plots. By a statistical analysis of the results of the dry matter obtained in 2012 it was found that there are very significant differences between the three fertilisation treatments (A - fertilisation) and between the two liming treatments (C - liming).
The mean dry matter yield was of 1.23 t/ha, on the plots with chemical fertilization; in the case of the plots with the combined fertilisation the yield obtained was of 2.57 t/ha, 109% higher the plots that received the chemical fertilisation and in the case of the organic fertilization the DM yield reached 2.82 t/ha, 129% higher than the plots that received the chemical fertilisation.

Table 1: The influence of the improvement factors on floristic composition after 17 years (1996–2012)

Plot	Control 1995	Fertilization			Grass carpet			Liming		Mean 2012	Dif. 1995-2012
		a1 100	a2 200	a3 300	b1 010	b2 020	b3 030	c1 001	c2 002		
GRASSES total	**80**	**70**	**62**	**73**	**70**	**64**	**73**	**73**	**65**	**68**	**-12**
Sown											
Phleum pratense	(40)	5	13	15	5	13	15	7	15	11	(-29)
Festuca pratensis	(25)	-	+	+	-	+	0	-	1	+	(-25)
Spontaneous											
Nardus stricta	40	4	-	-	4	+	+	2	+	1	-39
Festuca nigrescens	+	7	4	6	7	4	6	5	6	6	+6
Festuca ovina	8	3	+	1	3	+	1	1	1	1	-7
Agrostis rupestris	12	20	3	3	21	3	3	12	6	8	-4
Agrostis capillaris	-	13	21	23	13	21	23	21	17	19	+19
Phleum alpinum	+	2	2	2	2	2	2	2	2	2	+2
Poa media	17	3	6	6	3	9	6	8	4	6	-11
Poa pratensis	-	1	9	13	1	9	13	6	10	8	+8
Poa annua	-	-	+	-	-	-	-	-	+	+	+
Anthoxanthum odoratum	+	3	1	1	3	1	1	2	1	2	+2
Deschampsia flexuosa	3	9	3	3	8	3	3	7	2	4	+1
Deschampsia caespitosa	-	+	-	-	+	-	-	-	+	+	+
LEGUMES Total	**8**	**6**	**28**	**18**	**6**	**27**	**18**	**13**	**21**	**18**	**+10**
Trifolium repens	8	6	28	18	6	27	18	13	21	18	+10
OTHER FAMILIES Total	**12**	**24**	**10**	**9**	**24**	**10**	**9**	**14**	**14**	**14**	**+2**
Potentila ternata	4	8	2	2	8	2	2	5	2	4	0
Ligusticum mutellina	7	10	5	3	11	5	3	7	6	6	-1
Ranunculus montanus	+	+	+	+	-	-	-	-	-	-	0
Polygonum bistorta	-	-	+	+	-	+	+	-	+	+	+
Hieracium aurantiacum	+	1	+	+	-	+	+	+	+	+	0
Campanula abietina	+	+	-	+	-	+	+	+	+	+	0
Campanula napuligera	+	2	1	1	2	1	1	1	1	1	+1
Viola declinata	+	+	-	+	-	+	-	+	+	-	+3
Taraxacum officinale	-	3	2	3	3	2	2	1	4	3	+
Rumex acetosella	-	-	-	+	-	+	-	+	-	+	0
Achillea millefolium	+	+	+	+	1	1	-	+	1	+	+
Alchemilla sp.	-	+	-	+	-	-	+	+	+	+	0
Other species	+	+	+	+	+	+	+	+	+	+	+
Pastoral value	18	38	63	61	39	63	61	48	62	55	+37

The effect of liming on dry matter yield was also very significant, with a production of 1.79 t/ha on the non limed plots and of 2.62 t/ha on the limed plots. This difference occurred after 17 years since the liming.
The crude protein content (CP) of the vegetation sampled on the plots varied in a large range between 9.9 and 17.6 %. The mean of crude protein content on plots with interaction effect (organic fertilisation – liming) was 10.70 % on the limed plots and 9.69% on the no limed plots.
The mineral content varied between 6-9%, higher values were obtained on the plots with chemical fertilization.
After 17 years since the liming and the chemical and organic fertilization a series of profound changes and on the soils agrochemical indices have occurred (Table 2).
The soils are maintaining a strong acid reaction, with a pH of 4.0, a high mobile Aluminium content (2.44 me/100g soil), medium basic (36.5%) high humus content (15.5%) with good nitric indices (5.66) the content in P-AL being medium to good supplied (37.7 ppm) and the one of K-AL medium (150 ppm) which indicates a degree of fertilization adequate for the climatic condition from the subalpine floor.
In terms of the fertiliser influence on the soils agrochemical indices it is found there are better values than the mean values at the chemical and organic fertilization plot.

The organic fertilization by package (plot 300) registers a small decrease in N, P, and K than the others plots (100 and 200), proving that this fertilization method is not as complete as it is considered, lacking the additional elements from the others chemical and mineral sources.

Table 2: The soil agrochemical indices according to the experimental plots after 17 years (1996-2012)

Indicators	UM	Experimental plots								Mean
		a1 (100)	a2 (200)	a3 (300)	b1 (010)	b2 (020)	b3 (030)	c1 (001)	c2 (002)	000
pH	ind.	4.0	4.1	4.0	4.0	4.1	4.0	3.7	4.4	4.0
Al mobil	me/100g	2.55	2.05	2.71	2.10	2.37	2.84	3.89	0.98	2.44
Hydrolytic acidity	%	39.5	37.3	32.7	37.6	39.0	33.0	27.1	46.0	36.5
Humus	%	16.4	15.7	14.5	15.6	16.3	14.6	16.2	14.8	15.5
NI	ind.	6.5	5.9	4.6	5.8	6.3	4.8	4.4	6.9	5.66
P-Al	ppm	44	42	27	45	40	28	42	33	37.7
K-Al	ppm	125	188	137	156	166	128	156	144	150

The type of the grass carpet had a low influence on agrochemical indices.
From all the studied factors, the liming has the highest influence on to the agrochemical indices. So, after 17 years the soil reaction (pH) grows with 0,7 and the nitrogen indices (NI) with 2.5.
The most important decreasing is registered in the case of mobile Aluminium with 2,91 me/100g/soil, P-Al - 9,2 and K-Al – 12 ppm, due to a higher trophic process and the higher proportions of these elements in the yield.
The results are underlining the value of the long term researches on the permanent mountain grasslands that can bring scientific and practical contribution of the highest level from our domain.

Conclusions

- From the analysis of the data obtained it can be concluded that under a long term influence of the improvement factors the percentage of the valorous species like *Agrostis capillaris, Poa pratensis, Festuca nigrescens, Trifolium repens* etc. is increasing, and the percentage of the *Nardus stricta* species has reduced. We can talk even about the transformation of *Nardus stricta* grasslands into *Poa pratensis* grasslands, with a higher nutritive value.
- After 17 years since the liming, on the subalpine grasslands have been obtained significant differences in terms of dry matter yield. The mean yield obtained at the not limed plot was of 1.79 t/ha and of 2.62 t/ha at the limed plot.
- The liming has an influence on to the soils agrochemical indices even after long period. As a result, after 17 years the soils reactions increases with 0.7 and the nitrogen indices with 2.5.

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SESSION 1 – Vegetation assessment

Improving grassland in the Southern side of the Swiss Alps

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Abstract

Meadows and pastures play a vital economic role for both agriculture and tourism along the Southern side of the Alps. The main objective of the PRAMIG (Miglioramento dei prati a Sud delle Alpi) project was to promote sustainable farming and herding systems based on a fodder production adapted to local conditions, as well as to animals' needs. Therefore it is not a fundamental research project, but rather applied research. For three years key stakeholders (AGRIDEA, APF, Agroscope, Agricultural Extension of Ti, Agricultural School of Mezanna, SEREC) ran demonstrative tests and trials on ten farms, consisting in the characterization of the vegetation (botanical composition, phenology and grass growth) of permanent grasslands. Disseminated through the usual extension channels, such as information journeys, specialized agricultural press and technical leaflets, the results led to better evaluate the main characteristics of forage areas in the Southern Alps, and to identify operating practices and interventions that best suited to develop their fodder potentials. This project has revived the debate on forage (especially in mountain areas) and encouraged stakeholders to build and strengthen their network of partnerships at different levels (agricultural, institutional).
Keywords: grassland, pastures, grass-growth, phenology, typology

Introduction

According to the Statistical Office of the Canton Ticino (USTAT, 2012), the utilised agricultural area (UA) of Ticino in 2010 was 14'231 ha: 11'552 ha as permanent meadows and pastures (without summer mountain pastures) and 415 ha as leys. Grasslands occupy then the largest part of the UAA and represent the main fodder resource for dairy cows. Dairy is the most important animal production in the Canton with 17 Mio CHF gross proceeds in the third position behind horticulture and viticulture (28 and 26.5 million CHF). Grasslands have therefore a prime economic weight, not only in terms of agricultural services, but also for landscape conservation and tourism development. In 2007, AGRIDEA, Agroscope, the Canton Ticino and the Swiss Italian Section of Swiss Grassland Society (APF) have launched a project aiming at supporting herders and improving forage production in the South side of the Alps by implementing specific tools.
A survey was first conducted among thirty-five farms located in four mountain regions of the Canton. This process allowed to identify their strategies, to characterize their socioeconomic conditions and to determine the actions to be undertaken. Based on these initial results, diverse experiments and measurements were launched. Demonstrative trials were implemented on a ten-farm network, including the phenologic characterisation of grassland and the determination of grass growth. Other activities have been added during the project, such as a typological approach to assess the permanent grassland vegetation. This paper gives an overview of the project and presents the activities, the results, the difficulties encountered and the main conclusions.

Material and methods

On farm activities

Demonstrative trials have been settled time by time according to farms' situation with the objective to be used as example for dissemination and discussion point. The main action concerned topics such as weeds management, overseeding, optimization of fertilization and grazing management. All these activities have been carried out according to the recommended practices contained in the “fodder production” folder edited by AGRIDEA/ADCF (2011).

Grass growth

The experimental design consists in two plots mowed alternatively every 14 days (Corral Fenlon 1978, modified by Mosimann 2011). Within this work, it was also possible to calibrate the plate pasture meter used to estimate farm cover. Sward density values were calculated to convert height measurement into herbage mass. In 2009, two experiments have been initiated, one in Cadenazzo (Ticino) and one in Lostallo (Misox valley, Graubünden) and followed for three years. In 2011, a third one was added in Semione (Blenio valley,Ticino). These places express three different levels of production: high (Cadenazzo), medium (Semione) and low (Lostallo).

Phenology

The springtime phenology of semi-natural meadows was observed according to the method developed in Switzerland (Meisser et al., 2008). The phenological stages of ten common species differing in their earliness (grasses, legumes and forbs) were weekly monitored. Cocksfoot (Dactylis glomerata) was used as the reference species and the stages observed in other species were converted into 'equivalent cocksfoot stage' (ECS). The mean ECS, involving many species, allows the characterization of the stage of meadow development to be made on a standardized basis. About 25 meadows distributed among the principal valleys and thermic levels have been followed during 3 years.

Botanical composition

In 2008, various botanical surveys have been carried out according to the method proposed by Sahli et al. (1996) with the purpose to characterize meadows vegetation and to link it with farmers’ expectations. As a consequence, the great variability of semi-natural grassland of the South side of the Alps has been highlighted. From 2010 a more systematic approach to understand the botanical composition of meadows and pastures and their distribution has been settled on four farms, according to the Daget and Poissonet method (1971).

Results and discussion

On farm activities

Due to the great dispersion of the farms on the territory, these activities have been the most expensive in terms of resources, time and results harvesting. Even to motivate farmers to experiment good practices has not been easy and sometimes specific follow-ups have been needed, complicating comparisons between trials. Anyway, these activities have been crucial to allow the project team to improve the knowledge of the territory, to meet the farmers expectation and to implement the project.

Grass growth

In 2010, the grass growth curve had a classic shape: a production peak in spring (90 kg DM ha-1 d-1 for Cadenazzo and 47 kg DM ha-1 d-1 for Lostallo) and a second peak, less important, in summer (76 kg DM ha-1 d-1 only for Cadenazzo). In 2009, in Cadenazzo, the spring production peak was lower than in summer (80 and 110 kg MS ha-1 d-1). In 2011, in Cadenazzo and Semione, a very low productivity level was recorded in May (54 and 30 kg DM ha-1 d-1). These results are due in large part to the specific meteorological conditions of the years 2009 and 2011 characterized by a severe drought in spring, followed by a very wet summer (MeteoSwiss annual reports). In Semione and especially in Cadenazzo, the presence of millet and other C4 plants (Setaria spp., Digitaria spp., Echinochloa spp.) must be taken into account, as summer grasses with a low forage value, but high yielding potential . In conclusion, two out of three years, the weather conditions were far from average in the South of the Alps. It was therefore decided to further develop this activity in a way to obtain representative data for the Southern Alps.

Phenology

During the three years (2009-2011) of observation a great interannual variability has been registered (Tab. 1). More specifically the year 2010 has been the latest, with a delay, one to two weeks in the achievement of the “full earing stage”. This lead to serious repercussions on the harvesting that should be adapted according to the precocity of the year.

Table 1: Variations in realization dates of equivalent cocksfoot stage 'full heading' (mean ECS = 4) for the different thermal levels in Ticino – Switzerland, from 2009 to 2011

Mowing Date	2009				2010				2011			
	Cool	Warm	Hot	Torrid	Cool	Warm	Hot	Torrid	Cool	Warm	Hot	Torrid
9-11 April		1.5	2.0	2.5						2.5	2.5	3.0
12-14 April		2.0	2.0	3.0				1.5	2.0	2.5	2.5	3.5
15-17 April		2.0	2.5	3.5				1.5	2.0	3.0	3.0	**4.0**
18-20 April		2.5	2.5	3.5			1.5	2.0	2.5	3.0	3.5	4.5
21-23 April		2.5	3.0	**4.0**			2.0	2.5	2.5	3.5	3.5	4.5
24-26 April		3.0	3.0	4.5		1.5	2.5	3.0	2.5	3.5	**4.0**	5.0
27-29 April	(1.5)	3.0	3.5	4.5		1.5	2.5	3.0	3.0	**4.0**	4.5	5.5
30-2 May	2.0	3.0	**4.0**	5.0	1.5	2.0	3.0	3.5	3.0	4.5	4.5	5.5
3-5 May	2.5	3.5	**4.0**	5.5	1.5	2.0	3.0	**4.0**	3.5	4.5	5.0	6.0
6-8 May	2.5	3.5	4.5	5.5	1.5	2.5	3.5	**4.0**	3.5	5.0	5.5	6.0
9-11 May	3.0	**4.0**	5.0	6.0	2.0	3.0	**4.0**	4.5	**4.0**	5.5	5.5	6.5
12-14 May	3.5	4.5	5.0	6.0	2.0	3.0	**4.0**	5.0	4.5	5.5	6.0	6.5
15-17 May	3.5	4.5	5.5	6.5	2.5	3.5	4.5	5.0	4.5	6.0	6.5	
18-20 May	**4.0**	5.0	5.5	6.5	2.5	**4.0**	4.5	5.5	5.0	6.5	6.5	
21-23 May	**4.0**	5.5	6.0	7.0	3.0	**4.0**	5.0	5.5	5.0	6.5		
24-26 May	4.5	5.5	6.0	7.0	3.5	4.5	5.0	5.5	5.5			
27-29 May	5.0	5.5	6.5	7.5	3.5	4.5	5.5	6.0	6.0			
30-1 June	5.0	6.0	6.5		**4.0**	5.0	5.5	6.0	6.0			
2-4 June	5.5	6.0	7.0		4.5	5.0	6.0		6.5			

Scale	Grasses	Dicotyledonous plants
	1. Tillering	1. Vegetative stage
	2. Transition phase (elongation)	2. Flower buds
	3. Start of heading (10% ears)	3. Stem elongation
	4. Full heading (50% ears)	4. Start of flowering (10% flowers)
	5. End of heading (90% ears)	5. Full flowering (50% flowers)
	6. Full flowering	6. End of flowering (90% flowers)

Botanical composition

Meadows and pastures of four farms were investigated by means of 51 detailed surveys (Daget & Poissonet, 1971), and four main vegetations types have been identified according to botanical composition, ecological conditions and managing practices. Among these grasslands we recorded the low abundance and distribution of ryegrass (Lolium perenne) in comparison with cocksfoot (found in about half of the visited plots) which is the plant that most influences the agronomical characteristic of grasslands in the South side of the Alps. According to Daccord et al. (2002), the decrease of energy content following the early heading stage is more pronounced in cocksfoot than in ryegrass. Same authors reported that the levels of proteins were higher in the cocksfoot than ryegrass.

These first results highlight the particularities of grasslands composition in this mountainous region. They revealed the need for further studies in order to better understand composition, distribution, ecological and agronomical characteristics of permanent grassland and to develop correct management policies.

Conclusion

The dissemination has been carried out by the organization of one or two extension-days per year on different farms in collaboration with extension services and the agricultural school. Despite the low participation of farmers at the beginning of the project, the impact of such events has grown over time, actually reaching good scores with the continuation of extension-days.

The results of the activities have been published by the local specialized press, by internet (phenological weekly bulletin on www.agrometeo.ch) and by AGRIDEA with insertion of new technical leaflets in the “fodder production” folder.
At the end of the project it was decided to continue the development of some activities (grass growth, botanical and phenological surveys) and to reinforce dissemination strategy, especially on-farm extension-days. The demonstrative on-farm trials have been reduced and partially replaced by visits targeted on vegetation assessements.

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Comparison of two methods to calculate forage quality in natural pastures grazed by beef cattle.

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Abstract

The aim of the study was to compare two methodologies for assessing the quality of natural pastures used by beef cattle at Spanish Pyrenees: the Pastoral Value method based on floristic analysis and the quality derived from chemical analysis and INRA equations. The correlation between both methods applied on two irrigated organic meadows has been discussed.
Keywords: Pastoral Value, Stocking Rate, UFL, Meadows, Grazing.

Introduction

The extensive livestock production systems located in the Pyrenean mountains consists in grazing resources at different periods of the year. Part of the sustainability of these systems depends on the optimization of the grazing system. The use of pastures by domestic animals contributes to the reduction of feeding costs and is very important for the maintenance of landscape and biodiversity.

The meadows at the bottom and slopes of the mountain valleys have been traditionally used during short grazing periods at spring and autumn whereas high mountain pastures are grazed in summer . In some production systems, as organic farming, pastures could also be grazed from spring to autumn by fattening calves (Villalba et al., 2009). There are different tools to determine the forage quality (i.e. energy value expressed in Forage Units, UF) of pastures and to define the adequate stocking rate. Some of these tools, as the pastoral value (PV, Daget and Poissonet, 1972), are directly derived from the vegetation composition and have been widely used in researches and developments on mountain pastures (Argenti et al., 2012). Other ones, derived from yield measurements and laboratory analysis (INRA, 2007) are more used for herd management.

The aim of this study is to compare two methodologies for evaluating the nutritive value of grazing resources for beef cattle on meadows located in the Pyrenean Spanish valley.

Material and methods

Two irrigated organic meadows (approximately at 1000 m.a.s.l.), belonging to the *Molinio–Arrhenatheretea* phytosociological class, and located in the Spanish Pyrenees were experimented. The first meadow, in Alins (42º32.165'N 001º16.555'E), had a mean botanical composition of 27% *Trifolium repens L.*, 18% *Poa pratensis L.*, 17% *Rumex crispus L.*, 12% *Dactylis glomerata L.*, 8% *Taraxacum officinalis L.*, and 16 % other species under 2% of contribution. The second one, in Astell (42º24'12.8"N 000º57'45.7"E) had a mean botanical composition of 18% *Trifolium pratensis L.*, 17% *Trifolium repens L.*, 17% non identified grasses, 12% *Dactilis glomerata L.*, 8% *Plantago lanceolata L.*, 7% *Lotus corniculata L.*, 8% *Taraxacum officinalis L.*, and 20% others species under 2% of contribution. Both meadows were rotationaly grazed by fattening calves (350 kg of mean body weight) from May to October.

During this period, two samples of 0.25 m^2 were monthly taken at random with a 2 cm cutting-height. Sampling was done before the animal started to graze the paddock. Fifteen samples were collected in paddocks where animals didn't grazed previously this year and 18 in paddocks where animals already grazed and then were moved to allow the regrowth . The different species were separated, dried at 60º C, and weighted to calculate the specific composition (Cs in %). The dry matter production (kg DM/ha), the Shannon index, which gives a measure of the botanical biodiversity of the pastures, and the pastoral value (PV), using Cs and the specific Indexes (Si) of forage plants (scale 0-5) according to Daget and Poissonet (1972), were calculated. The samples were then reconstructed and analysed for dry matter (DM), organic matter (OM), crude protein (CP), fat (EE), crude fibers (CF), neutral detergent fibers (NDF), and acid detergent fibers (ADF) according to Association of Official Analytical Chemists (AOAC) methods. Each sample was analyzed in triplicate.

In the first method, the nutritive value of the forage in terms of energy value (UF) was calculated using the phytologic approach. We used the Daget and Poissonet (1972) calculation with a relationship between PV and stocking rate (in livestock units per hectare and year, LU/ha.year) of 0.02. According to the same authors this stocking rate could be translated to UF considering that the energy requirements of one LU is 3000 UF/year.

The second approach to assess the nutritive value of the pasture was based on INRA tables (2007), that express the energy content of the feedstuffs as milk feeding units (UFL), which is the net energy of lactation (NEL) content of the particular feedstuff relative to that of the French reference barley (1.7 Mcal NEL/kg). The protein content of the feedstuffs was expressed as protein truly digested in the small intestine (PDI). Two PDI values were calculated, PDIE and PDIN, when rumen available energy or rumen available nitrogen were limiting for microbial growth, respectively. Finally, the INRA system uses the fill unit (FU) as the potential intake of the problem feed referred to the intake of a reference feed. To calculate the NEL, PDIE, PDIN and FU contents of the feedstuffs, the chemical value and the set of equations from INRA (2007) were used. The potential energy value of the pasture (UFL/ha) has been calculated multiplying the DM production by the UFL/kg DM obtained.

Finally, a Relative Forage Value (RFV) has been calculated following Moore and Undersander (2002). This index represents an objective evaluation of forage quality that reflects the potential of dry matter intake and it is a function of NDF and ADF: $RFV=((88.9-(0.779\cdot ADF))\cdot 120/NDF)/1.29$).

An analysis of variance (proc GLM, SAS, Cary, NC) was performed including Site (Alins, Astell), Time of cut (First Cut, Regrowth) and month in the model. Least square means were obtained to correct the unbalanced design between month and site. Correlations between variables have been performed using proc CORR of SAS. A Principal component analysis (PCA) including the floristic data, chemical analysis and calculated parameters of quality has been performed with proc PRINCOMP of SAS in order to present graphically the relationship between the different variables.

Results and discussion

Table 1 presents the results of chemical analysis, floristic parameters and quality indexes derived from empirical equations. The differences between meadows of the two sites, specially referring to CP, NDF and ADF could be related to their own historical management. Both meadows were previously sown, but the sowing year and of the species used could have been different. Nevertheless, the obtained PV were very similar, and quite high in both sites. The regrowth samples had significant higher protein content and pastoral value than ungrazed samples. The increase in PV from first cut to regrowth, despite no statistically significance due to the high variability of samples, could be explained by the change in the type of predominant species. After grazing, the number of legumes and shrubs in early growth vegetative state increased.

For 'first cut' samples the pattern of evolution of quality is clearly different comparing PV and UFL values. The 'Regrowth' samples quality was more homogeneous in time and the relationship between PV and UFL seems clearer. With all samples, pastoral value had a low correlation with UFL ($r=0.18$; $p>0.05$) and RFV (-0.19; $p>0.05$) but a positive and significant correlation with crude protein ($r=0.46$; $p<0.05$) and fat ($r=0.52$; $p<0.05$) and negative with crude fiber ($r=-0.43$; $p<0.05$).

Three dimensions obtained from the PCA analysis explained 76% of the variance. The Figure 1 presents the correlation of the variables included in the PCA analysis with two main dimensions (65% of the variability explained). The variables UFL, CP and PDIE were correlated positively with dimension 1 whereas the percentage of crude fibers and fill units of the samples were correlated negatively. The dimension 2 was not clearly related with any variable, but VFR, NDF and ADF could be assigned to the potential grass intake. According with the PCA analysis, the floristic indexes PV and Shannon were negatively correlated, but none of them were clearly related with UFL neither with RFV. 'First cut' samples seem to be more related with low values of dimension 1, high Shannon indexes, high productivity but low UFL, whereas 'regrowth' samples had more PV, UFL and CP.

Table 1: Site and time of cut for chemical analysis, floristic parameters and quality indexes derived from INRA equations (means values ± s.e.) .

	Site		Time	
	Alins	Astell	First cut	Regrowth
Chemical analysis				
Crude Protein (%)	15.6 ± 1.4	18.2 ± 1.0	14.9 b ± 1.3	18.9 a ± 1.2
Crude Fiber (%)	25.1 ± 1.7	26.8 ± 1.3	29 a ± 1.6	22.8 b ± 1.5
Neutro Detergent Fiber (%)	45.4 b ± 1.9	52.2 a ± 1.4	49.6 ± 1.8	47.9 ± 1.6
Acid Detergent Fiber (%)	26.1 b ± 1.2	30.5 a ± 0.9	30 a ± 1.1	26.6 b ± 1.0
Floristic analysis				
Pastoral Value	61.3 ± 4.8	61.7 ± 3.5	57.7 ± 4.5	65.2 ± 4.0
Species richness	11.6 b ± 1.9	15.9 a ± 1.4	14.7 ± 1.8	12.8 ± 1.6
Shannon Index	1.8 ± 0.1	1.8 ± 0.1	1.9 ± 0.1	1.7 ± 0.1
Quality indexes				
UFL/kg DM	0.79 ± 0.04	0.86 ± 0.03	0.76 b ± 0.04	0.89 a ± 0.03
Relative Forrage Value	142 a ± 6.8	117 b ± 5.0	125.7 ± 6.4	133.8 ± 5.7

Within site and time, means with different letter are statistically different ($p<0.05$)

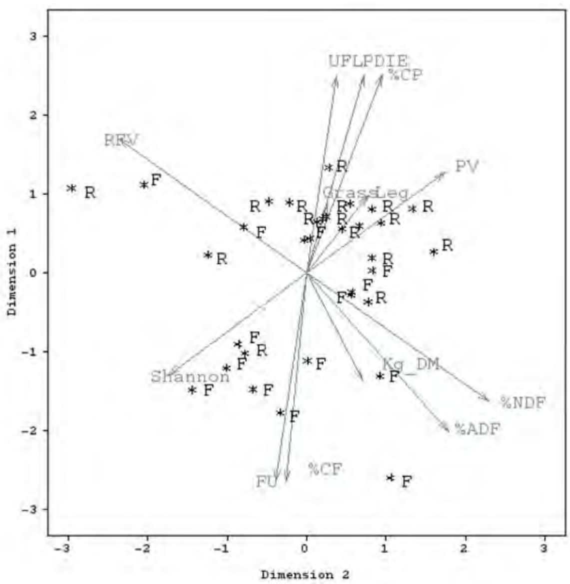

Figure 1: Principal component analysis including floristic and quality indexes obtained from 'first cut' samples (F) and 'regrowth' samples after grazing (R).

PV:Pastoral Value; %NDF; Neutro Detergent Fiber; %ADF: Acid Detergent Fiber; Kg_DM: DM production;%CF: Crude Fiber; FU: Fill Unit INRA; Shannon: Shannon Index; RFV: Relative Forage value; UFL: Forrage Unit INRA; PDIE: Digetible Protein; %CP: Crude Protein; Grass: % Grasses; Leg: % Legumes.

Table 2 presents the potential stocking rate and UF yield depending on the type of sample, month, and method. PV gives higher potential stocking rates and total energy produced in terms on UF than the results obtained using the INRA forage units (UFL) and the DM yield. The translation from PV to UF yield and then to potential stocking rate proposed by Daget and Poissonet (1972) was obtained for mountain pastures validated in the Spanich Pyreenes (Amella and Ferrer, 1979). For the validation, Amella and Ferrer obtained a good correlation (r=0.88) between PV and forage units calculated following the work of Tisserand (1968). The low correlation obtained in our case could be explained in part by the difference in the forage unit we used, namely the newest UFL, but mainly by the difference between mountain pastures and valley meadows. All analysed samples had a PV over 50 similarly to the values obtained in other meadows in the same region (Fanlo and Chocarro, 2013), while in the work of Amella and Ferrer (1979) all are bellow this value. According to Loiseau et al. (1998) beyond the value of 50, the diagnosis of PV loses most of its effectiveness. The same author argues that the allocation of specific indices often requires an update in each region. On another hand, the UFL yield derived from chemical analysis and productivity has some handicaps. Finally, the harvested DM gives information of the initial offer but takes not into account the growth during the period of grazing , and this could infraestimate the total UF pasture production. As a conclusion, the floristic approach had a low correlation with the chemical analysis in the studied meadows. The translation of potential stocking rate derived from pastoral value could lead to some differences in the grazing management decisions compared with the DM production and chemical analysis approach.

Table 2: Comparison of the stocking rate derived from the use of pastoral value or INRA quality indexes base on chemical analysis.

		Stocking Rate based on Pastoral Value (Floristic)				Stocking Rate based on laboratory analysis and INRA tables			
Type	Month	**Pastoral value**	LU /ha/year[1]	LU /ha/period[2]	UF produced	DM production (kg DM/Ha)	UFL /kg DM[3]	LU /ha/period[4]	UFL produced[5]
First cut	MAY	**61.61**	1.2	4.9	3697	3143	0.57	2.6	1816
	JUN	**58.59**	1.0	3.9	3515	3505	0.76	2.9	2504
	JUL	**50.37**	1.6	6.4	3022	3831	0.82	3.2	3278
	SEP	**78.50**	1.1	4.5	4710	2475	0.80	1.8	1988
	Average	***56.49***	*1.4*	*5.6*	*3389*	*3540*	*0.77*	*2.9*	*2739*
Regrowth	JUN	**67.79**	1.1	4.5	4067	2444	1.00	2.1	2451
	JUL	**68.47**	1.2	4.9	4108	1780	0.89	1.4	1587
	AUG	**70.76**	1.2	4.7	4246	2544	0.96	2.1	2402
	SEP	**57.67**	1.2	5.0	3460	2309	0.90	1.7	2099
	OCT	**62.54**	1.1	4.3	3753	2766	0.98	2.3	2727
	Average	**63.86**	1.1	4.5	3831	2377	0.94	1.9	2243

LU: Livestock Unit; UF: Forrage Unit; UFL: Forrage unit INRA
[1]Stocking rate = 0.02* PV (Daget and poissonet, 1972); [2]Considering a 90 days period; [3]Equations proposed in INRA tables (2007);[4]Productivity/ (Predicted DM intake UGB· 90 days); [5]Productivity·UFL obtained at laboratory

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Assessing population maturity of three perennial grass species: Influence of phenology and tiller demography among mountain and plain pastures

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Abstract

The quality of forage grass production is related to sward maturity, i.e. the average level of development of the tiller population, and sward phenology is commonly used to guide management practices. To assess the whole-sward maturity, we studied three forage grass species with contrasted phenology among mountain and plain pastures in 8 locations across France. Two main questions were addressed: (1) Is temperature accumulation a good index to describe phenological development for different latitudes or altitudes? (2) How is grass population maturity related to population phenology? We report that phenological development rate was constant among sites for each species, but a given phenological stage required less accumulated temperature to occur in higher latitudes and altitudes. Synchronous tiller development led to an increase in sward maturity that was closely tied to phenology for *Phleum pratense* but that was buffered by the percentage of vegetative tillers for *Alopecurus pratensis* and *Dactylis glomerata*. Percentage of non-flowering tillers varied among sites without any clear pattern related to latitude or altitude. The GDD method can describe species phenological development in different locations across latitudes and altitudes but, considering tiller development synchrony together with phenology is needed to assess sward maturity.
Keywords: Phenology; perennial grasses; growing degree days; tiller development synchrony; sward maturity; sward morphological structure.

Introduction

Taking into account grassland vegetation phenology is critical to assess appropriate management practices (Pontes *et al.*, 2007; Gaujour *et al.*, 2012). However, plant phenology can vary widely between species and is influenced by environment (Rathcke and Lacey, 1985). Air temperature is a major environmental factor for plant phenology in temperate systems (Sparks *et al.*, 2000) which led to the use of growing-degree days (GDD) to assess the timing of phenological events. The quantity and quality of forage grass production is affected by variations in plant morphology during growth and phenological development (Moore and Moser, 1995). Flowering coincides with the peak of biomass production (Robson *et al.*, 1988), whereas many forage quality traits change unfavourably for animal feeding as vegetation gains in maturity (Duru *et al.*, 2000; Baumont *et al.*, 2007). Population-scale sward phenology is therefore used to guide management practices (Huyghe *et al.*, 2008). However, developmental morphology can vary strongly within a tiller population, notably with the presence of a percentage of non-flowering tillers (Matthew *et al.*, 2000,) and the occurrence of main phenological peaks is not necessarily a pertinent descriptor of sward maturity when defined as the average level of development of the tiller population. In this study (Rossignol *et al.*, 2013), we considered two main issues: (1) Is sum of temperatures a good index to describe phenological development under contrasted climates? (2) How is grass population maturity related to population phenology? We described the phenological development of populations of three grass species along latitude and altitude gradients. We used a numerical index of phenological stages to quantify phenological distributions and to assess the relation between phenological peak and average maturity of populations.

Material and methods

The experimental design was established in 8 locations in France. Six sites formed a latitude gradient (43°36'N, 45°40'N, 45°46'N, 46°25'N, 48°18'N and 48°44'N). Three close-by sites formed an altitude gradient (350, 850 and 1100 m a.s.l.). In each site, three perennial grass species with contrasted phenology were sown in pure stands in autumn 2008, i.e. Meadow Foxtail (*Alopecurus pratensis* (L.) cv. 'Levocska'), an early-flowering species; Cocksfoot (*Dactylis glomerata* (L.) cv. 'Starly'), an intermediate species, and Timothy (*Phleum pratense* (L.) cv. 'Rasant'), a late-flowering species. In 2010, samples of grass biomass were collected in each site using a thermal calendar around 400°, 500°, 600°, 800°, 1000°, 1200° and 1400° GDD cumulated from the 1st February. In each site, plant biomass was sampled when the GDD thresholds were reached. Tiller development was described using a numerical index (Table 1) adapted from Moore *et al*. (1991). For each sample, 40-50 tillers were randomly chosen and sorted by phenological stage, and characterized by phenological index value. Sampled tillers were then dried (60°, 72h) and weighed. Mean Stage by Weight (MSW) of the populations was calculated by averaging the index value attributed to each individual tiller weighed by individual tillers biomass. We performed distribution analysis (Rossignol *et al.*, 2013) to assess the value of the MSWr index (r for 'reproductive') defined as the average value of reproductive tillers only (phenological peak). MSW was used to assess whole-sward maturity on a weight basis, and MSWr was used to assess the actual phenological stage reached by reproductive tillers.

Table 1: Numerical indices of 12 phenological stages recorded on individual tillers. (Adapted from Moore et al. 1991)

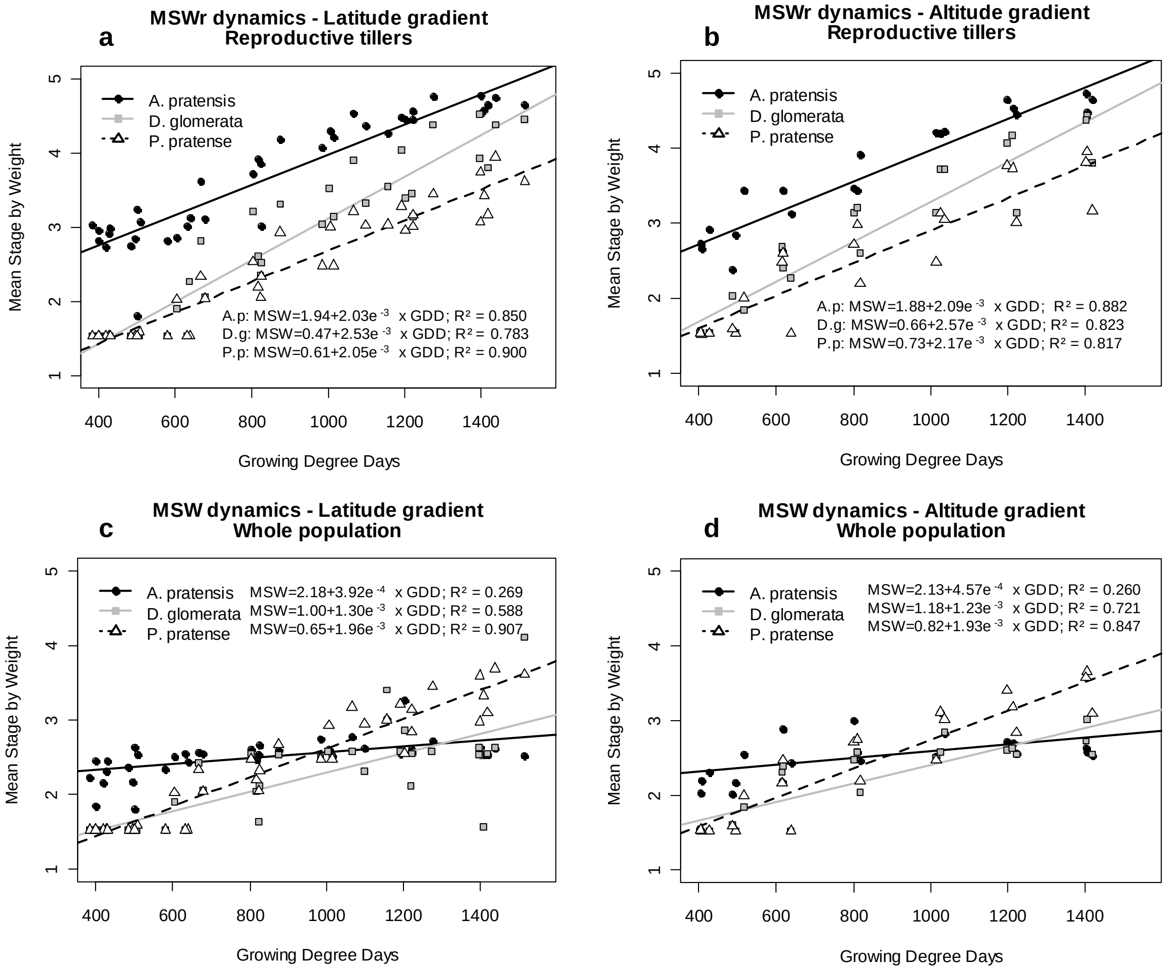
Numerical Index			
Phase	Stage	Index	Description
Vegetative (Leaf development)	V	1.5	Presence of leaves
Elongation (Stem elongation)	E1	2.0	First node palpable
	E2	2.5	Two or more nodes palpable
	E3	2.9	Flag leaf emergence
Reproductive (Floral development)	R1	3.1	Inflorescence emergence/ Spikelets enclosed or partially emerged
	R2	3.3	Spikelets fully emerged, peduncle not emerged
	R3	3.5	Spikelets fully emerged, peduncle fully elongated
	R4	3.8	Anther emergence / anthesis
Seed ripening (Seed development)	S1	4.0	Caryopsis visible
	S2	4.1	Milk
	S3	4.4	Soft dough
	S4	4.8	Physiological maturity and seed ripe

Results and discussion

For each species studied, MSWr values were linearly related to GDD with a significant effect of sites on intercepts but not on slopes of linear regressions. Phenological development of reproductive tillers was thus linearly related to temperature accumulation. The species ranking observed at the beginning of the experiment was maintained until the end of the experiment (Fig 1a,b). On average, at 1400° GDD, *A. pratensis* was close to seed maturity (range: 4.47–4.77), *D. glomerata* was approaching mid-seed development phase (range: 3.80–4.51), and *P. pratense* was approaching mid-floral development phase (range: 3.06–3.95). These results confirm that GDD method can predict the occurrence of phenological events in plant populations as shown in previous studies (Sparks et *al*., 2000).

For a given species, linear regressions showed similar slopes among sites which evidenced that phenological development rate of reproductive tillers was constant among sites. Intercepts of the regressions differed however significantly among sites (data not shown): a given phenological stage required less accumulated temperature to occur at higher latitude than at lower latitude for all three species and at higher altitude than at lower altitude for *D. glomerata* and *P. pratense*.

Figure 1: Relations between phenological development of reproductive tillers (Mean Stage by Weight indexes of reproductive tillers, MSWr, fig. a and b) or for whole sward maturity (Mean Stage by Weight indexes, MSW, fig. c and d) and GDD among all sites along a latitude gradient (fig. a and c) and an altitude gradient (fig. b and d) in the three species studied. Parameters for linear regressions are given within the figures.



Analysis of tiller biomass distribution among development stages revealed that *P. pratense* populations were characterized by a high development synchrony among tillers whereas *A. pratensis* and *D. glomerata* populations showed weak development synchrony among tillers. This was mostly due to the occurrence of two tiller groups with distinct average development stages within populations. For instance, at 1000° GDD, *A. pratensis* and *P. pratense* populations both showed a maturity (MSW index, Fig. 1c,d) corresponding to the flower emergence stage (stage 3). But, while most tillers of *P. pratense* were effectively nearing the flower emergence stage, reproductive tillers of *A. pratensis* populations were approaching the seed maturity stage (stage 4, Fig. 1c,d) and a part of tillers was still in vegetative stage (stage 1.5). The use of the phenological peak (MSWr) can lead to an overestimation of whole sward maturity compared to the MSW index, thus underlining the importance of taking into account both phenology and tiller demography parameters such as percentage of flowering tillers (Jonsdottir, 1991) for understanding how grass population maturity evolves over time. In this study, percentage of vegetative tillers of *A. pratensis* and *D. glomerata* populations were highly variable among sites and GDD alone was not a good predictor of MSW (Fig. 1a,b).

Previous studies with *Lolium perenne* suggested that in temperate areas, higher latitude promotes a higher proportion of flowering tillers (Bahmani *et al.*, 2000). However, we did not find any clear pattern in flowering tiller percentages related to latitude or altitude for the three species studied, which may make this percentage difficult to predict.
In conclusion, the GDD method can describe species phenological development in different locations across latitudes and altitudes but, considering tiller development synchrony together with phenology is needed to assess sward maturity.

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Relationships between chemical composition and *in vitro* digestibility or fermentation kinetics of mountain hays from Piedmont (Italy)

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Abstract
Hay samples of Italian forages were used to study relationships between chemical composition, *in vitro* ruminal fermentation kinetics and digestibility. There was a strong positive correlation among parameters related to *in vitro* digestibility and gas production. Stepwise multiple regression analysis of *in vitro* digestibility with chemical composition showed the best prediction equations for *Lolium multiflorum* followed by *Medicago sativa* and permanent meadow grass.
Keywords: Piedmont mountain hays, chemical composition, *in vitro* gas production, *in vitro* digestibility

Introduction
There are many factors that affect the amount of forage that can be included in the rations for ruminants (e.g. animal requirements, level of intake, quality and type of the forage source, fibre content, particle size). Moreover, the rate and the extent of fermentation in the rumen vary with the nature and chemical composition of the ingredients of the ration. As for the forages, their chemical composition depends on the forage species, variety or hybrid, state of maturity, harvesting practices and environmental (agronomic) factors (Shaver et al., 2002), making forage quality highly variable among and within forage types (NRC, 2001). The challenge for dairy cattle nutritionists is to provide guidance in ration formulation for a high incorporation of forages in the ration to enhance rumen function without compromising milk yield and composition. Laboratory methods have been developed and refined to provide information on forage quality and to obtain accurate predictions of intake and digestibility from *in vitro* procedures. A filter bag technique for analyzing *in vitro* dry matter and neutral detergent fibre digestibility was developed by ANKOM Technology Corporation, allowing a large number of samples to be analyzed in a short time (Damiran et al., 2008). Kinetics of rumen fermentation of feedstuffs can be studied *in vitro* by means of the gas production technique (Mauricio et al., 1999). The aim of this work was to study the relationships between chemical composition, *in vitro* gas production kinetics and digestibility of mountain hays from Piedmont (Italy), comparing different samples of alfalfa, Italian ryegrass and grass from permanent meadows.

Material and methods
The study was carried out on 28 hay samples of Italian ryegrass (LM, *Lolium multiflorum L.*, n=6), alfalfa (ME, *Medicago sativa L.*, n=8) and first cut grass from permanent meadows (PM, n=14), collected from 20 farms located in Piedmont region (N-W Italy). Samples were oven dried at 60°C for 48 h, then ground in a Buhler mill to pass a 1 mm screen and analysed for dry matter (DM), ash, crude protein (CP) ether extract (EE) and crude fibre (CF) following the methods of AOAC (1997). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined with the ANKOM fibre analyser (Ankom Technology Corp., 1997) following the procedure of Van Soest et al. (1991). Six rumen-fistulated Merino sheep, fed alfalfa hay and with free access to water, were used as donors of rumen inoculum for the *in vitro* assays. Rumen contents

were collected before the morning feeding in thermos flasks, taken to laboratory, strained through cheesecloth, kept at 39°C under CO_2 and diluted (1/4 v/v) with a culture medium containing mineral and buffer solutions as described by Van Soest et al. (1966). *In vitro* dry matter digestibility (IVDMD) was determined using the ANKOM-DAISY procedure following the approach proposed by Van Soest et al. (1966). After 48 h of incubation the jars were emptied and the bags were gently rinsed and dried in an oven at 60°C. Bags were then washed with a neutral detergent solution at 100°C during 1 h and rinsed with distilled water into the fibre analyzer. *In vitro* NDF degradation (IVNDFD) was estimated considering the amount of NDF that disappeared during incubation. Four incubation runs were carried out in different weeks giving four single observations per sample. *In vitro* gas production measurements were conducted using a pressure transducer as described by Opsi et al. (2012). *In vitro* gas production technique was used to determine 24 h gas production (G24), extent of DM degradation in the rumen (ED), potential DM disappearance (D144) and parameters related to gas production kinetics: asymptotic gas production (A), fractional rate of fermentation (c) and lag-time (L). Gas volume was estimated from pressure measurements using the equation suggested by Lopéz et al. (2007). Three incubation runs were performed in different weeks, using in each of them two bottles per sample. Blanks were used to compensate for gas production in the absence of substrate. ANKOM-DAISY procedure with 144 h of continuous incubation was used to estimate the potential DM disappearance (D144). The exponential model proposed by France et al. (2000) was fitted to gas production data: $G = A\,[1 - e^{-c(t-L)}]$, where G (ml/g DM) is the cumulative gas production at time t, A (ml/g DM) the asymptotic gas production, c (h^{-1}) the fractional rate of fermentation and L (h) is the lag time. The ED parameter, for a rate of passage (*k*) of 0.033 h^{-1} (characteristic of sheep fed a forage diet at maintenance), was estimated using the equation suggested by France et al. (2000): $ED = (D144 \times c \times e^{-kL}) / (c + k)$. All relationships were analyzed by regression procedures, and variables were automatically removed from the stepwise regression model if their *P*-values were > 0.10. Analyses used the general linear model procedure of Statistical Package for Social Science (v 17.0, SPSS Inc., Chicago, IL, USA) by regression equations between the independent variables (chemical composition) and the dependent variables (*in vitro* digestibility and gas production parameters), and the goodness-of-fit was assessed based on proportion of variance accounted for by the predictors (coefficient of determination, R^2). The association among all variables was evaluated by correlation analysis.

Results and discussion

The average chemical composition of each group of hays was published by Opsi et al. (2011). The ME hays had the highest CP (39.0% and 24.0% higher than in LM and PM, respectively), ADF (19.0% and 9.4% higher than in LM and PM, respectively) and ADL (49.8% and 24.6% higher than in LM and PM, respectively) contents. PM hays had the highest ash (7.7% higher than in ME and LM) and EE contents (24.4% and 14.6% higher than in ME and LM, respectively). The greatest value of NDF was observed in LM hays, with 2.9% and 4.9% more NDF than ME and PM, respectively.

Table 1 shows the stepwise multiple regression equations of *in vitro* digestibility and gas production parameters from chemical composition across hays and divided into groups. When PM data was subjected to regression, only IVDMD, D144 and c could be predicted from chemical composition. IVDMD and D144 decreased as ADF contents increased, with R^2 above 0.75. R^2 for c was very low (0.36), this parameter increasing with CP contents. For LM data, prediction equations were achieved for all the parameters intended, R^2 being above 0.85 in all the cases. DM contents influenced negatively most of the parameters (IVDMD, IVNDFD, D144 and c) and positively L, while the increase in fibre contents (represented by CF, NDF or ADL) caused a decrease in ED, G24, A and L. Prediction equations were obtained for most of the parameters excluding ED and G24 when ME data were used. R^2 were, in general, not as high as those observed for LM data, except for A (R^2=1.00). IVDMD diminished with ADF contents and increased with DM, while IVNDFD varies inversely to CP contents. D144 is negatively influenced by CF, while A increased with EE and diminished with CF, CP and ash contents. L increased with EE, whereas c decreased with EE and increased with NDF contents. The best prediction equations were observed for LM, followed by ME and PM. When all samples were included in pooled regression analyses, R^2 were lower than those observed when data sets were assayed separately for each group of hays. The general trend observed was that IVDMD diminished with ADF and CP, and increased with CF and ash contents. Unexpectedly, the relationship between CP and *in vitro* digestibility was negative. Across the different forage types this could be due to the fact that LM were the most digestible hays with a low CP content, whereas ME showed the highest CP content and the lowest digestibility (probably because of their high lignin content). IVNDFD was negatively influenced by ADL contents. D144 and ED seemed to decrease in response to ADF and NDF, respectively, whereas D144 also decreased as CP contents increased. Asymptotic gas production was negatively influenced by ADL and CP contents; c decreased proportionately to NDF and increased in response to ADL contents, while L diminished in response to DM contents. A proper overall prediction equation was not obtained due to the heterogeneity of samples included in the study (data not shown).

Table 1: Stepwise multiple regression analysis of *in vitro* digestibility and gas production parameters with chemical composition of total hay samples (n=28) and divided into groups (PM, permanent meadows, n=14; LM, *Lolium multiflorum L.*, n=6; ME, *Medicago sativa L.* , n=8)

	PM			LM		
Item	Equation	R^2	SEE	Equation	R^2	SEE
IVDMD	109.826-1.066(ADF)	0.859	2.194	237.820-1.926(DM)	0.930	2.174
IVNDFD	No regression			262.062-2.320(DM)	0.857	3.887
D144	113.674-0.975(ADF)	0.756	2.892	224.525-1.699(DM)	0.926	1.971
ED	No significant regression			90.795-0.824(NDF)	0.876	1.380
G24	No significant regression			477.931-8.573(CF)	0.958	3.937
A	No significant regression			377.495-15.874(ADL)	0.930	4.074
c	0.023+0.002(CP)	0.359	0.006	0.178-0.002(DM)	0.952	0.001
L	No significant regression			-65.752+16.323(EE)-4.933(ADL)+0.713(DM)	0.998	0.181

	ME			Overall pooled		
Item	Equation	R^2	SEE	Equation	R^2	SEE
IVDMD	21.722-0.482(ADF)+0.688(DM)	0.870	9.289	86.838-1.967(ADF)-0.85(CP)+2.107(Ash)+1.351(CF)	0.519	5.010
IVNDFD	64.150-1.724(CP)	0.589	4.298	61.025-1.925(ADL)	0.195	9.693
D144	101.178-0.770(CF)	0.819	1.986	96.053-0.753(ADF)+1.645(Ash)-0.541(CP)	0.626	4.148
ED	No significant regression			68.189-0.455(NDF)	0.156	4.183
G24	No significant regression			No significant regression		
A	389.478+8.342(EE)-3.381(CP)-2.200(CF)-0.883(Ash)	1.000	0.296	358.957-6.322(ADL)-3.364(CP)	0.522	22.337
c	0.146-0.022(EE)+0.000(NDF)	0.880	0.005	0.090+0.003(ADL)-0.001(NDF)	0.568	0.006
L	-0.317+0.387(EE)	0.761	0.094	18.804-0.208(DM)	0.177	1.076

SEE = Standard Error of Estimate

Table 2: Pearson's correlation coefficients between chemical data and *in vitro* digestibility and gas production parameters of total hay forages (n=28)

Item	DM	Ash	CP	EE	NDF	ADF	ADL	CF
IVDMD	-0.333*	0.287	-0.286	0.273	-0.317*	-0.592**	-0.573**	-0.542**
IVNDFD	-0.173	0.258	-0.330*	0.203	-0.023	-0.408**	-0.465**	-0.383*
D144	-0.477**	0.360*	-0.330*	0.394*	-0.400*	-0.697**	-0.686**	-0.678**
ED	-0.064	0.285	0.118	0.077	-0.395*	-0.216	-0.054	-0.169
G24	0.160	0.118	-0.058	-0.111	-0.172	-0.100	-0.044	-0.071
A	-0.074	0.121	-0.535**	0.140	-0.044	-0.513**	-0.652**	-0.529**
c	0.226	0.016	0.456	-0.315	-0.162	0.423	0.628	0.512
L	-0.420**	0.118	-0.128	0.098	-0.067	-0.152	-0.174	-0.071

* = $P \leq 0.05$; ** = $P \leq 0.01$

There was a strong positive correlation among parameters related to *in vitro* digestibility and gas production. As shown in Table 2, fibre contents (ADF, ADL, CF) were negatively correlated to IVDMD, IVNDFD, D144 and A. However, the importance of fibre contents in determining digestibility and gas production parameters seem to be lower for alfalfa than for LM and PM hays (Table 1), which, in agreement with previous studies (Getachew et al., 2004), demonstrates that the effect of NDF on fermentation becomes less important as the level of fibre declines. Regarding gas production, the strong correlation between A and chemical composition and the poor correlation between c and chemical composition is in agreement with Nsahlai et al. (1994). However the negative correlation between CP and DM and NDF digestibility is not consistent with that reported by Getachew et al. (2004). Samples with high CP contents, such as ME, could have had slightly lower digestibility values than PM or LM samples (Opsi et al., 2011), which could have accounted for this negative correlation.

Generally speaking, IVDMD and IVNDFD decreased as ADF and ADL contents increased, CP and EE contents also showing a negative impact on *in vitro* digestibility. CP highly influences prediction equations for ME, and A increased with EE and decreased with CP, CF and ash contents. Equations derived herein are purely empirical and were selected exclusively on the basis of statistical goodness-of-fit. As a result, some of the equations are of controversial interpretation (e.g., negative relationship between CP and digestibility, or an equation with negative effects of ADF and positive effects of CF on digestibility). Considering the biological significance of the regression coefficients, it would be sensible to revisit these equations considering only those relationships between chemical composition and digestibility of hays with a plausible nutritional meaning. In regards to coefficients of determination, lower values were observed when all samples were considered together than for each group of forage separately, probably due to the heterogeneity of hays (different botanical composition with varying plant maturity stage, different harvest seasons or cutting dates within a season).

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Grassland typological characterisation: a case study in Romania

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Abstract

Nowadays grasslands have to be considered as multifunctional resources, their importance being expanded from the animal feed resource to landscape, tourism, biodiversity *etc*. The purpose of this work is to highlight the suitability of the typological approach for the assessment of mountain grassland vegetation. The typological approach is one of the most complete approaches because it brings pieces of information both from phyto-ecological and agronomical point of view that can be used for the proper planning of exploitation and conservation management. Two subalpine grasslands from Muntele Mic Massif, a Natura 2000 site, part of Retezat – Godeanu Mountain, sector of the South Carpathians chain, have been assessed. The analysed grasslands are placed at different altitudes, respectively 1800 m and 1600 m a.s.l. Both grasslands are framing in a *Nardus stricta* typological series. Biodiversity is higher at 1800 m level in comparison with 1600 m. From the point of view of the life forms, both the grasslands are dominated by hemicryptophytes. The most dominant chorotypes are European species followed by the circumpolar (boreal) ones. Both the grasslands are characterised by low pastoral value and potential carrying capacity.
Keywords: grassland, typology, vegetation, *Nardus stricta*, ecological indexes.

Introduction

Grassland assessment is a challenge and for a comprehensive understanding of grassland agro-ecosystems the choice of the proper methodology must have in view interdisciplinary approaches. The typological approach is probably the most complex as it gives pieces of information both from the phyto-ecological and agronomical points of view. Typological characterization has to be the background of the planning of the management and conservation works on permanent grasslands.

This system is widely used in several regions of the world, notably continental Europe where it was first developed by Braun-Blanquet (Peeters *et al*., 2004). The typological unit is an herbaceous vegetation unit that comprises the totality of the phyto-coenoses sharing similar floristic composition, site conditions and productivity, which under the influence of certain management practices have in general specific evolutionary trends. Thus, the grassland type concept is not entirely uniform (floristic composition, relief, soil *etc*.), but it is characterised by similar bio-productive, ecological and management features (Ţucra, 1987). The availability of this kind of tool is useful to plan the management of marginal mountain grasslands taking into account the increase of the interest for these natural resources and the opportunity of their conservative management (Argenti *et al*., 2011). Mowing, stocking rate, mineral or organic fertilisation, animal species and exploitation timing are the main variables of the management that directly influences the vegetation dynamics of a pasture (Durău *et al.*, 2008). The goal of this paper is to apply the typological approach for the comparison of the agro-ecological features of two subalpine grasslands dominated by *Nardus stricta* L.

Material and methods

The research was carried-out at Muntele Mic Massif, a part of Retezat – Godeanu Mountain, sector of the South Carpathians chain. The highest altitude of this massif is 1802 m a.s.l. The entire massif is included in Munţii Ţarcu, Natura 2000 site which has a total surface of 58,840 ha, where permanent grasslands account

for 18,465 ha, i.e about 31% of total surface. The natural and the semi-natural grasslands from the massif are almost exclusively grazed by sheep and dairy cows. Hayfields cover small areas, generally isolated. Being most of the surfaces abandoned, the semi-natural grassland area is decreasing continuously and the vegetation is at different stages of the succession process towards woodlands. At the moment, the grazed surfaces are exploited extensively and maintenance practices are not applied, mainly because of the distance from permanent settlements, except the small ski resort at the mountain top.
The vegetation of the permanent grasslands at two altitudes (1800 m and 1600 m a.s.l) was analysed using Daget and Poissonet methodology (1971). The typological characterisation was performed on the background of the work on Romania grassland types (Ţucra *et al.*, 1987). Ecological indexes were used for grassland ecological characterisation: humidity (U), temperature (T), and soil pH (R), using Landolt indices (1977); light (L) and nutrients (N) using Ellenberg indices (1974), and forage value or specific quality index (IS) using Daget and Poissonet indexes (1971). Those indexes were used for the calculation of the synecological indexes of the analysed swards. Also, the Raunkiær's plant life-forms and chorotypes were used to characterise studied vegetation. The indexes used in this work were adapted for Romanian flora by Kovacs (1979) and Sanda *et al*. (1983). The Shannon biodiversity index (*H'*), pastoral value (*PV*; Daget and Poissonet, 1971), and potential carrying capacity (LU ha^{-1}) were also compared (Sărăţeanu *et al.*, 2011).

Results and discussion

The vegetation at the highest altitude (1800 m) is framed in the *Nardus stricta* typological series, and the dominant species was *Nardus stricta*, followed by *Festuca rubra*. Other species with important contribution in the sward were *Deschampsia flexuosa* and *Vaccinium myrtillus*. At 1600 m the typological framing was similar to previous one, the sward being dominated by *Nardus stricta*. Also *Festuca rubra*, followed by *Deschampsia flexuosa* and *Geum montanum* remarkably contributed to sward composition. The floristic lists of the two grassland types are reported in table 1.

Table 1: List of the main species from the two investigated types by contribution

1600 m	**1800 m**
Nardus stricta L.	*Nardus stricta* L.
Deschampsia flexuosa (L.) Trin.	*Festuca rubra* L.
Agrostis capillaris L.	*Deschampsia flexuosa* (L.) Trin.
Geum montanum L.	*Vaccinium myrtillus* L.*Anthoxanthum odoratum* L.
Anthoxanthum odoratum L.	*Ligusticum mutelina* L.
Luzula luzuloides (Lam.) Dandy *et* Willmott	*Campanula rotundifolia* L.
Potentilla brauniana Hoppe ex Nestl.	*Geum montanum* L.
Antennaria dioica L.	*Alchemilla xanthochlora* Rothm.
Campanula rotundifolia L	*Plantago atrata* Hoppe
Potentilla aurea L.	*Juniperus communis* L.
Campanula patula L.	*Hieracium aurantiacum* L.
Juniperus communis L.	*Hieracium pilosella* L.
Festuca rubra L.	*Potentilla aurea* L.
Bruckenthalia spiculiflora (Salisb.) Reichenb.	*Scorzonera rosea* Waldst *et* Kit.
Vaccinium vitis-idaea L.	*Luzula luzuloides* (Lam.) Dandy *et* Willmott
Trifolium repens L.	*Agrostis capillaris* L.
Silene nutans L.	*Polygonum bistorta* L.
	Bruckenthalia spiculiflora (Salisb.) Reichenb.
	Avenula versicolor (Vill.) Lainz
	Viola canina L.
	Trifolium repens L.
	Polytrichum communae Hedw.

Six common species were identified in the two *Nardus* grasslands types (*Nardus stricta, Festuca rubra, Agrostis capillaris, Anthoxanthum odoratum, Trifolium repens,* and *Bruckenthalia spiculiflora*). The same species were found by Maruşca (2010) in Braşov County.

The Shannon indices highlighted a higher average diversity at 1800 m (*H'*= 2.52) as compared with 1600 m value (*H'*= 1.94).
According with Hortal *and* Lobo (2006) the synecological approach brings technical and theoretical advantages in the study of composite biodiversity variables. The table containing average synecological indexes allowed a synthetic comparison among the statuses of the analysed vegetation samples. The greatest difference between the analysed grasslands concerned IS; at 1800 m the species with forage value accounted for a larger contribution than at 1600 m (Table 2).

Table 2: Mean values of the ecological indexes for the investigated types

Specification	1600 m	1800 m
Humidity (U) - (0-6 scale)	1.73	1.62
Temperature (T) – (0-5 scale)	0.37	0.62
Soil pH (R) – (0-5 scale)	1.23	1.49
Light (L) – (0-9 scale)	1.50	1.75
Nitrogen (N) – (0-9 scale)	0.59	0.67
Specific quality index (IS) – (0-5 scale)	0.32	0.93

At both the altitudes grasslands were dominated by hemicryptophytes, which accounted for the largest species number and coverage (contribution to composition) (figure 1). Concerning the chorotypes, the European species accounted for the largest contribution, closely followed by the circumpolar (boreal) species, the last one being more numerous (figure 2).

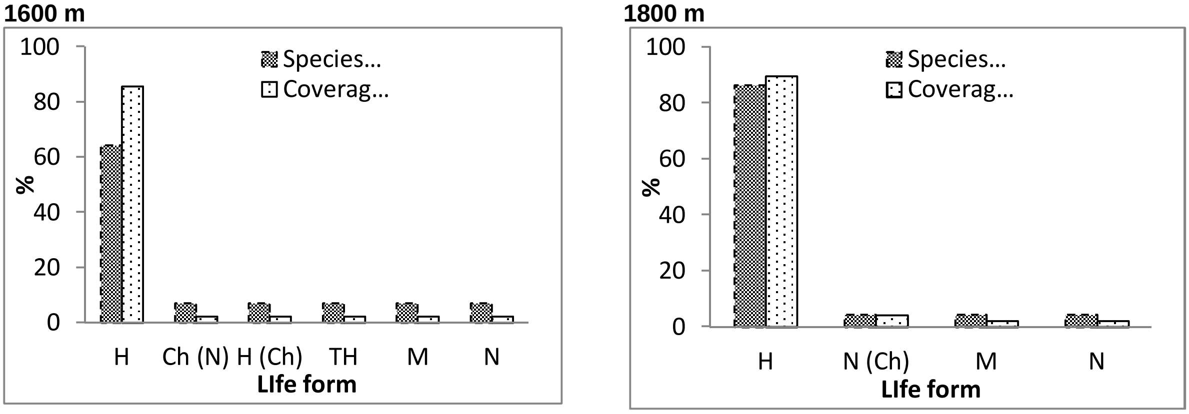

Figure 1: Life form spectres for the investigated types (life forms abbreviations: H – Hemicryptophyte; Ch (N) – Chamaephytes (Nano-phanerophyte); H(Ch) – Hemicryptophyte (Chamaephytes); N(Ch) - Nano-phanerophyte (Chamaephytes); Th – Therophyte; M – Micro-phanerophyte; N - Nano-phanerophyte.)

The pastoral features of two grassland types are compared in Table 3. The pastoral value on 0-100 scale was low at 1800 m (18.6) and very low at 1600 m (10.8), this being dependent by the contribution of the species with forage value, which is greater at 1800 m. As a consequence also the carrying capacity was greater at 1800, but both values were low. Even the economic value of the grassland was low from the productive point of view (low pastoral values and carrying capacity) but other important intrinsic benefits contributing to the grassland multifunction, such as landscape value, ecological value *etc.* still have to be properly assessed.
The combination of methods to survey vegetation, ecological and agronomical indexes and other parameters (not reported here) can lead to a proper characterization of the grassland, which is a starting point to design sustainable management and conservation practices, with the adapting of the calculation of the ecological and agronomical indexes and other parameters, here not taken into account, can be considered to perform a proper characterisation of the grassland. This has to be the starting point in the design of sustainable management and conservation.

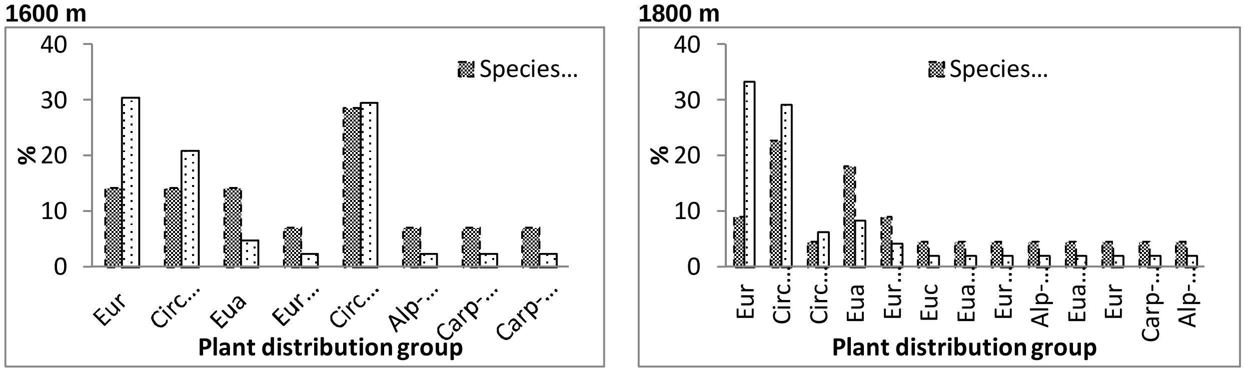

Figure 2: Chorological spectres for the investigated types (chorotypes: Eur – European; Circ (arct-alp) – Circumpolar (arctic-alpine); Eurasiatic; Eur (alp) – European (alpine); Circ (bor) – Circumpolar (boreal); Alp-Carp – Alps-Carpathians; Carp-Balc – Carpathians-Balkan Peninsula; Carp-Balc-Anat – Carpathians-Balkan Peninsula-Anatolia; Euc – Central European; Eua (arct-alp) – Eurasiatic (arctic-alpine); Eur (Med) – European (Mediterranean); Eua (cont) – Eurasiatic (continental); Alp-Carp-Balc Alps – Carpathians - Balkan Peninsula.

Table 3: Comparative pastoral characterisation for the investigated types

Specification	1800 m	1600 m
Pastoral value	18.6 (low)	10.8 (very low)
Potential carrying capacity	0.47 LU ha^{-1}	0.27 LU ha^{-1}
Grazing period	June - August (about 85 days)	June - August (about 100 days)

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Monthly variations of herbage production and mineral content in the sub-alpine grasslands of Jena Mountain in northern Greece

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Abstract

Herbage production and mineral content were determined in the sub-alpine grasslands of Mountain Jena (altitude of 1770m – 1900m) in northern Greece, during the growing period of 2011. These grasslands are grazed by cattle herds and sheep flocks only during the growing period (May to September) as for the remaining months they are usually covered by snow. Herbage production was determined by harvesting the aboveground biomass at monthly intervals, from twelve sampling sites (plot size: 4x4 m). The collected samples were oven-dried at 60^{o}C, weighed, ground and analyzed for calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K) and sodium (Na) content. Mineral content of herbage was compared to the recommended requirements for maintenance of cattle and sheep. Herbage production ranged from 314 kg/ha to 2062 kg/ha for May and August, respectively. Ca, Mg and K content of herbage were adequate to meet the cattle and sheep requirements for maintenance and growing. However, Na and P contents were sufficient only for some of the months both for cattle and sheep. The Ca/P ratio (3:1 to 7:1 for July and September, respectively) and the grass tetany index (<2.2) were in accordance with the corresponding threshold values necessary to avoid potential metabolic disorders. On the other hand the high values (>20) of K/Na (bloat index) ratio increase incidence of bloat. It is recommended that additional Na and P should be supplied in order to cover the maintenance requirements and improve health and productivity of the grazing cattle and sheep in the study area.
Keywords: sub-alpine meadows, minerals, grazing season, ruminants

Introduction

Livestock production is an important activity in the sub-alpine grasslands of Greece. These areas cover 7.3% of the total area of grasslands (Papanastasis and Pittas, 1984).
Herbage production in the Greek rangelands varies greatly and is a function of the area and the type of the grassland as well as the local conditions. It is also affected by livestock grazing and management practices (Papanastasis 1981, Smith et al. 2008). Mountousis *et al.* (2009) reported that herbage production was higher in the sub-alpine grasslands compared to grasslands in the lowland.
Grazing animals rely on pasture for 25–75% of their total annual feed requirements (Zervas *et al.*, 1999). The ability of a grassland to sustain animal growth depends on its biomass production and herbage nutritive quality, affected both by abiotic and biotic environmental factors including soil type, climatic regime and botanical composition (Pérez-Corona *et al.*, 1998). The evaluation of feed quality is important for the prediction of animal performance (Tatli Seven and Cerci 2006). Herbage nutritive quality is associated with protein, mineral concentrations and digestibility (Pérez-Corona *et al.*, 1998; Bertrand *et al.*, 2008) which in turn are strongly affected by the stage of maturity and botanical composition (Bruinenberg *et al.*, 2002; Karn *et al.*, 2006).
The animals require inorganic elements to support normal life processes. The minerals cannot be synthesized by living organisms therefore animals must acquire adequate amounts of required elements to be maintained. However, less attention was given to mineral content although it is known that unbalanced mineral content in animal diet can greatly affect their performance (Yiakoulaki and Nastis 1993). In general, research

concerning mineral content of forage species in Greece is quite limited (Yiakoulaki and Nastis 1993; Roukos *et al*., 2006; Mountousis *et al*., 2009).
The aim of this research was to study the monthly variations of mineral content in the above-ground biomass of sub-alpine grasslands of Mountain Jena, North Greece.

Materials and Methods

The study was conducted in 2011, at Mountain Jena (longitude: 22° 13′, latitude: 41° 09′) in northern Greece. In Mountain Jena the sampling sites were located at an altitude of 1770m – 1900m. Jenna's soil parent material has volcanic origin, mostly trachyte, and andesite. The soil in the grasslands falls into the category of sandy loams, with a mean pH of 5.45. The studied grasslands are grazed by cattle and sheep in the period from May to September. Their productivity and readiness are mainly affected by climatic and soil conditions.
Most of the taxa belong to Caryophyllaceae (14), Asteraceae (12), Rosaceae (11), Poaceae (10) and Fabaceae (9) families. The percentage of plant coverage of functional groups was grasses 53%, forbs 41% and legumes 6% (Mpokos et al unpublished data).
In October 2010, twelve sampling plots (4x4 m) were selected and wire-fenced up to 1.5 m. in order to obstruct free–range grazing. The plots were placed in representative areas of uniform botanical composition, taking into account topographic factors such as elevation, slope and exposure. In the second week of each month, from May to September, herbage production was determined by harvesting the aboveground biomass. The collected samples from each plot were stored in paper bags and weighed in situ to determine fresh weight. After transportation to the laboratory all samples were oven-dried at 60°C and ground to pass a 1-mm screen of a Willey mill. Samples were analyzed for, calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K) and sodium (Na). Phosphorus was measured by spectrophotometeric methods and Ca, Mg, K and Na determined by atomic absorption spectrophotometry (AOAC, 1999).
All the necessary statistic parameters were calculated using JMP ® 8 (Sall *et al*., 2007). The average and standard deviation were determined. ANOVA analysis (students'–*t* test) was used to determine statistically significant differences between months. The herbage production, Ca, P, Mg, K and Na contents were assessed for a significance level of $P \leq 0.05$.

Results and Discussion

In the sub-alpine grasslands of Mountain Jena the peak of herbage production occurs in August, while in the following month the high temperatures and low precipitation result in the rapid decrease of yield (Table 1). Herbage production of August was significantly different ($P \leq 0.05$) than that of all months except of July. It is known that precipitation and temperature determine the duration of plants' growth and the production of biomass (George *et al*., 2001). The results of this study are higher than the findings of Papanastasis (1982) for sub-alpine grasslands of Menoikio Mountain in Northern Greece.
Calcium content showed a gradual increase from the beginning to the end of the growing season (Table 1) with a peak during the month of August. Calcium is the most deficient of the mineral nutrients in concentrate feeds, in contrast to pasture plants where it is quite abundant. Calcium requirements for growing cattle of 200-250 kg and for maintenance for sheep of 50 kg are in the range of 0.30% DM and 0.20% DM, respectively (NRC 1985, 1996). It is obvious that Ca concentration of herbage in the area of study exceeds the Ca requirements for both cattle and sheep.
Phosphorus concentration ranged between 0.09% and 0.20% for May and July, respectively (Table 1). P levels were similar to those of other sub-alpine regions (García-Ciudad *et al*., 1997 and Mpokos *et al*., 2012). However, Mountousis *et al*. (2008) found higher values of P (0.16%-0.37%). Phosphorus requirements for grazing growing cattle of 200-250 kg live weight are 0.15 % DM and for sheep of 50 kg are 0.16% DM (NRC 1985, 1996). In the study area phosphorus content was enough to cover the maintenance requirements of sheep and growing cattle during the months of July and August. For the remaining months phosphorus supplements are necessary.
The Ca:P ratio ranges between 3:1 to 7:1, and although it exceeds the threshold (2:1), due to increased intake of vitamin D this ratio might rise up to 7:1 without negative impacts on the ruminants (Liamadis, 2003).
The concentration of Mg in the herbage ranged from 0.12-0.16% with the peak appearing in July. The Mg needs of growing cattle are 0.10% DM (NRC 1996), while the proposed Mg content in the feed of sheep

ranges between 0.12 - 0.18% DM (NRC 1985). So it is understandable that the Mg requirements of both cattle and sheep grazing in Mount Jena are covered during the entire grazing period.

Table 1: Monthly variations of herbage production, minerals, Ca/P ratio, K/Na ratio (bloat index) and G.T.I. (Grass Tetany Index =K/Ca+Mg in meq); Data are average values±S.D. (n=12); Different letters in rows indicate significant difference (*P*≤0.05)

	May	June	July	August	September
Herbage Production (kg/ha)	314^{c}±212	974^{b}±461	$1939^{a,b}$±1180	2062^{a}±1006	1195^{b}±398
Ca %	0.34^{c}±0.15	$0.42^{b,c}$±0.20	$0.60^{a,b}$ ±0.36	0.80^{a}±0.22	0.78^{a}±0.30
P %	0.09^{c}±0.02	$0.11^{b,c}$±0.04	0.20^{a}±0.13	$0.15^{a,b}$±0.06	$0.12^{b,c}$±0.09
Mg %	0.12^{b}±0.02	0.13^{b}±0.04	0.16^{a}±0.03	0.15^{a}±0.05	$0.14^{a,b}$±0.04
K%	1.84^{a}±0.41	2.08^{a}±1.13	1.87^{a}±0.73	2.93^{b}±0.87	2.07^{a}±1.03
Na %	0.04^{b}±0.01	0.04^{b}±0,02	0.05^{b}±0.01	0.05^{b}±0.03	0.07^{a}±0.02
Ca/P	3.78^{b}	3.81^{b}	3.0^{b}	5.33^{a}	6.5^{a}
G.T.I. meq	1.77^{b}	1.70^{b}	$1.12^{a,c}$	$1.45^{b,c}$	1.05^{a}
K/Na (bloat index)	$25^{b,c}$	22^{b}	$21^{a,c}$	30^{b}	20^{a}

Herbage potassium content ranged from 1.84% to 2.93%, with the highest value appearing in August (Table 1). High values of K concentration during the growing period are confirmed from other researchers (Roukos *et al*., 2006; Mountousis *et al*., 2009 and Mpokos *et al.*, 2012). The daily K requirements of growing cattle are 0.6-0.7% DM (NRC 1996) and of sheep are 0.5-0.8% DM (NRC 1985). Therefore, K requirements of both cattle and sheep are covered for the entire grazing period. However, provided that the grass tetany index (Table 1) is below 2.2, this may not be a problem. At higher index levels, high potassium reduces the availability of calcium and/or magnesium so that grass tetany risk is increased, (hypomagnesaemia) (Grunes *et al*., 1970).
Sodium content in the herbage reached its peak during the period of September 0.07% (Table 1). Daily requirements in Na are around 0.07% DM for beef cattle (NRC 1996) and 0.09 % DM for sheep (NRC 1985). In the study area Na content of herbage does not cover the requirements of growing cattle during all the months of the grazing period except September. Sheep do not cover their requirements in Na during any of the months of the grazing period. Therefore, high values (>20) of K/Na (bloat index) ratio increase incidence of bloat. It is recommended that additional Na should be supplied in order to cover the maintenance requirements and improve health and productivity of the grazing cattle and sheep in the study area.
In conclusion, harvest month has a significant effect on herbage production and concentration of most of the minerals studied (K, Ca and Mg) was found to be adequate for both cattle and sheep requirements, while Na and P contents were sufficient only for some of the months. The Ca:P, G.T.I. and K/(Ca + Mg) ratios of the herbage were in accordance with the corresponding threshold values necessary to avoid potential metabolic disorders. On the other hand the high values (>20) of K/Na ratio in the months of May, June and August increase incidence of bloat. Therefore, additional P and Na should be supplied in order to cover the maintenance and growing requirements of the grazing cattle and sheep.

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SESSION 2 – Agro-pastoral practices for environmental conservation

Researches on pastoral activities and biodiversity in the Bucegi Natural Park

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Abstract

Numerous of protected areas located in the Romanian mountain area have been recently designated and include large surfaces of grasslands with primary vegetation at the alpine level (1.900-2.500 m alt.) and secondary vegetation resulted after the deforestation at lower levels.

One of the most important protected areas is the Bucegi Natural Park (BNP) located in Romania's Southern Carpathians, from 640 m altitude up to 2505 m (Omu Peak). The total surface is 33.663 ha of which 8.750 ha are grasslands with 44% in various degrading stages (13% rocks, 15% soil erosion, 12% shrubs and 4% paddock weeds).

The pastoral value of 7 grasslands types has been determined, with a mean value of 15 points, corresponding to a potential stocking rate of 1.2 LU/ha over 85 grazing days, respectively 10.500 LU/season.

Inventories of the grazing livestock have revealed an animal load of 5.200 LU in 2005, less that 50% of the real potential and 4.400 LU in 2011. This low level and its continuous decrease have a negative effect on BNP biodiversity. According to the Red Book of IUCN, among the identified plant species, 5 are endangered at global level, 8 at European level and 21 are endemic species. In worst cases the under-load and the abandonment lead to reforestation.

Several data regarding sheepherding conditions, age and training level of herders, livestock and others important information regarding the activity are presented in this paper.

Keywords: Natural Park, pastoral value, biodiversity, transhumance, sociologic studies

Introduction

The Bucegi Massif has become a protected area in 1990, and has received the status of Natural Park in 2003 (www.bucegipark.ro). The protected surface of Bucegi Natural Park (BNP) is located on three counties: Brasov, Dambovita and Prahova. The total surface of BNP is of 32.663 hectares from which 26,8% is covered by natural grasslands (Marusca et al., 2005). The easily accessible grasslands located in Bucegi Mountains, have attracted since ancient times numerous flocks, from the near regions as well as from faraway lands. In that way Transylvanians (Scheii and Ungurenii) have practiced for centuries the transhumance in Romanian Country, by moving their flocks on the mountains during summer and on the Danube ponds in winter. The first historic documents on herding are dating from the 16th century and they are containing data regarding the pastoral activities from these Mountains (Puscaru et al., 1956). The diversity and botanical richness have drawn the attention of botanical researchers like Prodan (1923) and Borza (1944), who brought a valorous contribution to the knowledge of the flora from this area (Beldie, 1967; Bărbulescu and Motcă, 1983; Marusca *et al.*, 2010).

Material and methods

Two studies have been carried out in order to highlight the pastoral activities from Bucegi Natural Park, in 2005 and in 2011. The methods used consisted in visiting all the folds situated in the BNP area surveying livestock numbers, grazed surfaces as well as sociological aspects such as herdsmen`s age and education level. At the same time, researches have been carried out for identifying the vegetation and the pastures types located on the Park`s territory, using satellites maps. The worksheet consisted in the identification of the main plant species, and appreciations of their cover according to Tansley scale (Sârbu Anca *and al.*, 2004). The observed grassland surface identified on the field was of 6.275 ha, representing over 60% from the total surface of BNP`s natural grasslands. Soils samples have been collected for the determination of their agrochemical characteristics (pH, humus, P-AL, K-AL, mobile Al, etc.).

Results and discussion

On the studied area of 6.275 hectares, approximately 15% (935 hectares) are affected by soil erosion, 13% (810 hectares) are on rocks and 12% (770 ha) are covered in different proportion by *Juniperus sibirica* and *Picea abies* in the areas where the pastures are abandoned.

Six phyto-sociological alliances have been determined (five herbaceous and one shruby) as follows:

Potentillo ternatae – Nardion (PON), subalpine oligotrophic pastures on acid soils, with the species: *Nardus stricta, Festuca nigrescens, Festuca airoides, Poa media, Potentilla ternata, Campanula abietina, Geum montanum, Ligusticum mutelina, Deschampsia flexuosa, Viola declinata* and others. The alliance is present on 4125 ha, (65.7% from the total surface).

Seslerion bielzii (SEB), basiphilous subalpine pastures with the presence of species: *Sesleria bielzii, Sesleria rigida ssp. haynaldiana, Festuca amethystina, Festuca saxatilis, Festuca versicolor, Linum extraaxilare, Dianthus spiculifolius, Carex sempervirens, Aster alpinus* and others. The alliance is present on 1430 hectares (22.8%).

Oxytropido – Elynion (OXE), basiphilous alpine pastures, with the species: *Oxytropis carpatica, Elyna myosuroides, Erigeron uniflorus, Dianthus glacialis, Cerastium lanigerum, Pinguicula alpina, Pedicularis verticillata, Salix reticulata, Dryas octopetala, Polygonum viviparum, Gentiana nivalis* and others. The surface covered by the OXE alliance is of 435 hectares (6.9%).

Junicion trifidi (JUT), acidophilous alpine pastures, with the species: *Juncus trifidus, Carex curvula, Oreochloa disticha, Agrostis rupestris, Campanula alpina, Primula minima, Minuartia sedoides, Armeria alpina* and others. This alliance is present on 40 hectares (0.6%).

Cynosurion (CYN), mesophile hill-mountainous grasslands on well drained soils, with the species: *Agrostis capillaris, Cynosurus cristatus, Festuca rubra, Festuca pratensis, Lolium perenne, Phleum pratense, Trifolium repens* and others. The alliance is present on 25 hectares (0.4%).

Rhododendron myrtifolii-Vaccinion (RHV), *Rhododendron myrtifolium* shrubs, with the species: *Rhododendron myrtifolium, Vaccinum gaultherioides, Vaccinum myrtillus, Vaccinum vitis-idaea, Loiseleuria procumbes, Soldanella pusilla, Juniperus sibirica* and others. This alliance is present on 220 hectares (3,6 %).

The first alliance is the most important grassland type dominated by *Nardus stricta* and *Festuca airoides* species (PON), which are present on approximately 2/3 of the surface, indicating an advanced degrading stage of the sward. In this category, the mean pastoral value calculated after the method of the double meter (Daget, Poissonet, 1969) is 15, corresponding to a potential carrying capacity of 0,30 (Table 1).

Table 1: The pastoral value and the potential carrying capacity of the pastures from BNP

Nr. Cr	Pasture type (alliances)	Pastoral value appreciation	Potential carrying capacity LU/ha
1.	Alpine *Carex curvula* (JUT)	20-30	0,50
2.	Alpine *Elyna myosuroides* and *Oxytropis carpatica* (OXE)	5-10	0,15
3.	Alpine and subalpine *Sesleria bielzii* and *Sesleria rigida ssp. haynaldiana* (SEB)	5-10	0,15
4.	Subalpine *Festuca airoides* (PON)	10-15	0,25
5.	Subalpine *Nardus stricta* and *Festuca nigrescens* (PON)	15-20	0,35
6.	Mountainous *Nardus stricta* and *Festuca rubra* (PON)	15-20	0,35
7.	Mountainous *Festuca rubra* and *Agrostis capillaries* (CYN)	30-50	0,80
	MEAN	15	0,30

Among the numerous plant species identified on the studied area, 5 are endangered at global level, 8 at European level, 21 are endemic species and 10 sub-endemic. From these 44 plant species 1 is on critical endangered, 3 threatened, 34 vulnerable and 6 with low threat risk. As example we mention *Draba dornerii*, *Draba haynaldii*, *Ligularia sibirica* and *Crocus banaticus* with the maximum threat.

As indicated in table 2, in only six years the folds number has decreased from 40 to 29 (30%). The animal load is low, only 0,59 LU/ha in 2005 and 0,50 in 2011, reflecting a decrease of 15% in six years. In contrast the LU per fold and per herdsmen has grown by 17-19%, simultaneously with the improvement of optimal age and education status.

Table 2: Comparative study on pastoral activities from Bucegi Natural Park

Specification	*2005*	*2011*	*Dif. ±*	*%*
FOLDS UNITS				
Sheep	4	1	-3	25
Combined	30	25	-5	83
Cattle	6	3	-3	50
Total	40	29	-11	70
HERDSMEN				
Number of herdsmen	230	165	-65	72
Average herdsmen on fold	6	6	0	100
HERDSMEN AGE (%)				
Under 20 years	15	7.3	-7.7	48.7
21 – 30 years	17	29.7	+12.7	174.7
31 - 40 years	23	18.2	-4.8	79.1
41 – 50 years	18	21.8	+3.8	121.1
51 – 60 years	16	14.5	-1.5	90.6
61 – 70 years	7	5.5	-1.5	78.6
71 – 80 years	3	2.4	-0.6	80
81 – 90 years	1	0.6	-0.4	60
HERDSMEN EDUCATION SITUATION				
No education	2	2	0	100
Under 7-8 classes	25	45	+20	180
7-8 classes graduates	158	60	-98	38
10 classes graduates	38	33	-5	87
High school graduates	7	18	+11	257
LIVESTOCK NUMBERS				
Adult sheep	12500	15023	+2523	120
Young sheep	6700	1714	-4986	26
Adult cattle	1800	1624	-176	90
Young cattle	400	165	-235	41
Horses	200	128	-72	64
Donkeys	30	21	-9	70
Pigs	120	140	+20	117
Sheep dogs	270	263	-7	97
Total LU	**5186**	**4424**	**-762**	**85**
No. LU/fold	**130**	**152**	**+22**	**117**
No. LU/herdsmen	**22,5**	**26,8**	**+4,3**	**119**
No. LU/hectare	**0,59**	**0,50**	**-0,08**	**85**

This example shows that researches on pastoral transhumance have to be extended on the Carpathians mountains in order to know the current evolution and to take the appropriate to avoid abandonment and reforestation in the future.

The herdsmen working and living conditions are almost unchanged from centuries. As a consequence, it is being harder and harder to employ peoples for such a primitive way of life in comparison with modern and confortable civilisation. At some of the folds, electrical generators are used for one or maximum 2 hours per day, usually in the morning (at 3^{30}-4^{00} am) when the milking starts or later in the evening for the light or to charge the mobile phones.

Likewise the animal products made at the fold and their elaboration recepts are unchanged for centuries. Some improvement consists on usage of modern machinery in the making process of animal products.

Conclusions

The grasslands from Bucegi Natural Park are in an advanced degrading stage, being covered with shrubs and invasive herbaceous vegetation.

Enquiries showed that in a short term period of only 6 years a drastic decreasing of the fold numbers and of the livestock unit numbers has been recorded.

By the reduction of grazing pressure the invasive woody vegetation consisting on *Juniperus sibirica* and *Picea abies* will replace the grass sward lowering the grassland surface and leading to a decreasing of its biodiversity.

The conservation of biodiversity of this protected area will depend on a good grassland management in the Bucegi Natural Park.

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Performance of exclosure in restoring arid degraded steppes of Algeria

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Abstract

Steppes of arid Mediterranean zones are deeply threatened by desertification. To stop or alleviate ecological and economic problems associated with this desertification, management actions have been implemented since the last three decades. The struggle against desertification has become a national priority in many countries. In Algeria, several management techniques have been used to cope with desertification. This study aims at investigating the effect of exclosure on floristic diversity and chemical soil proprieties after four years of implementation. 167 phyto-ecological samples have been studied, 122 inside the exclosure and 45 outside. Results showed that plant diversity, composition, vegetation cover, pastoral value and soil fertility were significantly higher in protected areas.

Keywords: Desertification, arid, pastoral management, plant community soil fertility, Algeria.

Introduction

Two important restoration programs have been led to fight against the desertification and to improve the pastoral and the rural life. The first program began in 1972 with the green wall with mitigate results. The second one, known under the name of big steppe works initiated in 1994, targeted the development of water sources as well as the collection of superficial waters, electrification and solar pumping, promotion of rustic fruit cultivation, fodder plantations of 1.7 million ha and exclosure of 3 million ha rangelands moderately degraded. This last measure constitutes the basis for this study conducted in 9 departments with the purpose to characterize the effects of exclosure on (i) floristic diversity, (ii) pastoral value, (iii) soil fertility and (iiii) soil surface element.

Methodology

Systematic sampling (Frontier, 1983) has been done along a transect of 500 m for grazed area and 1500 m for ungrazed area in order to show floristic and ecological changes. 64 m^2 minimum areas were determined using Braun-Blanquet & De Boulos (1957) method inside and outside the exclosure. Vegetation cover was described with pin-point technique, met by a pin descending to the ground on 100 points separated by 10 cm along a 10 m long line within the 64 m^2 plot. Description of the soil surface (with the following typology: litter, bare silt crust, sand, bare ground, coarse) and that of vegetation cover were carried out by the same pin-point sampling technique used by Jauffret & Visser (2003). To identify possible changes in the soil mineral contents, in each of the 167 plots, a sample of soil, from the surface horizon, has been sieved with 2 mm mesh and air-dried before chemical analyses. Conductivity and pH was determined using a 1: 5 soil water suspension. Total calcium carbonate was determined by back-titration and active calcium carbonate using the Bernard calcimetry method (Vatan, 1967). Organic matter (OM) was determined using the Anne method (organic carbon by sulfochromic oxydation following ISO 14235) and total nitrogen was determined using the Kjeldahl method. To estimate biodiversity the species richness (R), Shannon index (H') were computed for each plot using the software R version 2.13.1(package Vegan). The pastoral value (Pv) of each plot was obtained using formula adapted from (Daget & Poissonet, 1990). The differences between the indices computed (diversity index and pastoral value), the measured surface elements and chemical descriptors determined inside and outside the exclosure were tested by the nonparametric Kruskal-Wallis test due to unbalanced model. Post hoc comparisons between the two treatments were made using the Wilcoxon rank sum test. Both tests were conducted using R version 2.13.1 software (R Development Core Team, 2007).

Results and discussion

Table 1 shows that the species richness (R) is two times greater in exclosure areas than on grazed areas (P <0.001). Shannon index (H') indicates that the exclosure areas are more diversified and covered than the grazed areas (P <0.001). The pastoral value follows the same trend as that of the diversity indices, with values significantly higher in the exclosure areas (P <0.001). For the surface characterization, we find that vegetation cover, litter, as well as bare silty crust are significantly higher in exclosure areas, while the rate of sand, bare soil and coarse elements increase with grazed areas. Chemical analyses show a significant difference between grazed and ungrazed plots (P< 0.05). The greatest species richness recorded in exclosure is the result of the lack of use by livestock. This allowed plants to complete their phenological cycles and to produce seed, thus increasing their stock in the soil as well. By contrast, in grazed areas, species with high specific quality index were grazed at different phenological stages, resulting in the reduction of seed stock in the soil. Additionally, trampling bound to overgrazing caused soil compaction, preventing water infiltration and therefore seed germination. This latter is to be translated into a low vegetation cover (Van de Koppel & Rietkerk, 2000). Overgrazing changes the structure of plant communities and their floristic composition (Olff et *al*., 1999). As a consequence, the grazed areas are characterized by a dominance of perennial plants that originate the phenomenon of desiccation (Floret et al., 1990) and overgrazing (Kadi-Hanifi, 1998). These areas are mostly dominated by chamaephytes with low quality specific index repelled by livestock such as: *Herniaria fontanesii*, *Peganum harmala* and *Thymelaea microphylla*. The floristic richness in exclosure varies between 20 and 32 species and between 9 and 16 species outside exclosure. These exclosures are characterized by the development of species including therophytes, with high forage value *like Astragalus corrugatus, Erodium glaucophyllum, Medicago minima,Medicago laciniata, Trigonella polyceratia* and *Xeranthemum inapertum.*

Outside the exclosure, overgrazing reduces biodiversity (Vickery et al., 2001) discriminating the development of palatable species to the detriment of thorny species rejected by livestock such as *Atractylis caespitosa* and *Atractylis serratuloides* as well as low forage value plants such as *Filago pyramidata,, Peganum harmala, Thymelaea microphylla.* The analysis of the soil surface has highlighted a significant improvement of vegetation cover inside the exclosures (Amghar, 2012). The plant cover in degraded areas remains low, less than 25% on average, due to overgrazing (Huntly, 1991). Grazed areas are characterized by high proportions of bare soil more than 50% on average due to overgrazing (Schlecht et al., 2009). The proportion of coarse to the surface is small in exclosure areas. The highest rate of organic matter and total nitrogen is stored in the exclosure areas. This indicates that the restoration of vegetation increases the rate of litter into the soil and improves its physical properties. Total soil porosity promotes good water infiltration by reducing runoff and thereby increasing the species richness of these areas. The low levels of these two elements in the grazed areas are the consequence of the biomass reduction and the degraded floristic composition that are reducing the rate of litter in the soil (Hai et al., 2007). In addition to such a phenomenon the wind erosion disseminates the fine particles of soil rich in organic carbon and nitrogen leading to mineral losses (Pei et al., 2008).

Table1: Exclosure effect on floristic, pastoral value, soil surface and soil chemical analysis. Means ± SE are given. The differences between the treatments were tested by Kruskal-Wallis test (p-value). Asterisks indicate significance of tests (* = p < 0.05, ** = p < 0.01, *** = p < 0.001, ns: non-significant). Different letters indicate differences between inside and outside exclosure (Wilcoxon test, p <0.05). EX : Exclosure ; GR : Grazed areas.

	EX	GR	P-Value
Floristic diversity index			
Floristic Richness R	32.3 [a] ± 2.3	14.4 [b] ± 2.8	< 0.001***
Shannon index H'	3.3 [a] ± 0.1	2.5 [b] ± 0.2	< 0.001***

	EX		GR		P-Value
Pastoral value Vp	28.3 [a]	± 5.2	10.7 [b]	± 3.18	< 0.001***
Soil surface elements (%)					
Plant cover	67.7 [a]	± 7.4	29.2 [b]	± 6.2	< 0.001***
Litter	8.0 [a]	± 2.3	5.0 [b]	± 2.4	< 0.001***
Bare silty crust	10.1 [a]	± 3.9	3.2 [b]	± 2.6	< 0.001***
Sand	8.8 [a]	± 4.2	9.9 [a]	± 3.4	> 0.05 ns
Bare ground	3.3 [b]	± 2.6	44.3 [a]	± 10.3	< 0.001***
Coarse elements	2.2 [a]	± 3.0	8.4 [a]	± 6.0	> 0.05 ns
Soil chemical analysis					
pH	8.1 [a]	± 0.3	8.1 [a]	± 0. 2	> 0.05 ns
Conductivity	0.18 [a]	± 0.2	0.16 [a]	± 0.4	> 0.05 ns
% Organic matter	3.1 [a]	± 0.6	0.8 [b]	± 0.3	< 0.001***
% Total nitrogen	0.2 [a]	± 0.04	0.09 [b]	± 0.04	< 0.001***

Conclusion

The study has shown that after four years protection the technique improves quantitatively and qualitatively the vegetation and the soil surface, with little changes in soil chemical proprieties.

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Firebreak sward restoring with native forage genotypes

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Abstract

In Sardinia the pastoralism is a key element of multifunctionality in agriculture and the landscape is characterized by the "pasture-animal system".
Natural pastures are the main source of livestock feed. The high flora biodiversity including several aromatic species provides derived products with valuable characteristics.
The careless of human activity (overgrazing, firebreaks bulldozing, abandoned quarries, etc.) causes soil degradation. In this situation sward restoring using local seed is an imperative,
This paper reports the preliminary observations of some genotypes collected in 2006 in a firebreak on a mountainous site in the centre of the island.
The site showed a high biodiversity with 195 species many of which officinal and endemic.
In 2007 the genotypes were evaluated in benches for biological cycle and forage and seed production. They showed a great variability that could be exploited for forage aims and multiuse.

Keywords: environment, local genotypes, pastures, sward restoring

Introduction

Pastoralism represents the main multifunctional agriculture. Since in the past the farmers activity preserved natural environment, the modern European Community Policy chooses to encourage the extensive farms, especially for herbivores, giving them a prominent role for the landscape protection and animal welfare.
Pasture-animal system characterizes the rural landscape of Sardinia. Sheep are the most common livestock for milk production (12 thousand farms, more than 3 million heads), cattle are bred in the northern and central part of island, while goats in the most inaccessible areas.
Natural pastures (about 1 million hectares) represent the main source of livestock feed. The high biodiversity of flora provides valuable characteristics to the livestock products. Some botanical analysis of different pasture sites list more than one hundred species, which often show a significant landscape value, especially in the flowering period (Spanu *et al.*, 1997; Vargiu *et al.*, 2002; Vargiu *et al.*, 2008).
The careless of human activity (overgrazing, inappropriate deep tillage, abandoned quarries and firebreaks bulldozing) leads to sward degradation and soil erosion especially in the slope areas. In such conditions the herbage sward restoration is an imperative (Caredda *et al.*, 2002). To ensure the environmental sustainability and the effectiveness of interventions it would be appropriate to use local seeds, as the commercial seeds are often unsuitable.
This paper reports the preliminary observations of some genotypes collected on a mountainous location regarding their suitability for sward restoring in a firebreak.

Material and Methods

The study was conducted in a forest firebreak (Tonara, NU, lat. 44°, long. 15°) between 764 and 448 m asl, on a loamy-sandy soil with a schistose substratum, absence of limestone and pH 5.7 - 6.3.
The botanical composition of sward was preliminarily assessed.
The collection of native genotypes seeds began in the summer of 2006.
In 2007, in the experimental farm of Ussana (CA, lat. 39°, long. 9°, 150 m asl) characterized by droughty climatic conditions, 16 genotypes were evaluated on benches for biological cycle, vegetative growth and seed production. Forage yield was assessed by manual cuttings until flowering time to ensure seed production. Some biotypes were repeatedly sampled, while others with scarce growing not allowed any use.

Results

The floristic analysis showed the high biodiversity of this site, with a total of 195 species, 28 of which officinal (table 1) and 23 endemic (table 2).

Table 1: Officinal species * (A= Aromatic, G= Gastronomic, L= Liqueur, M= Medical, D= Dyeing)

Achillea ligustica All. (M)	*Potentilla recta* L. (M)
Capsella bursa pastoris L. Medicus (G - M)	*Quercus ilex* L. (G - D)
Crateagus monogyna Jacq. subsp. *monogyna* (G - L - M)	*Quercus pubescens* Willd. (D)
Euphorbia caracias L. (D)	*Raphanus raphanistrum* L.subsp. *raphanistrum* (G)
Fumaria officinalis L. subsp. *officinalis* (M)	*Reseda luteola* L. (D)
Geranium robertianum L. (M)	*Rubia peregrina* L. (D)
Helichrysum italicum (Roth) G.Don subsp.*Microphyllum* (A-M)	*Rubus ulmifolius* Schott (G - L - M - D)
Hypericum perforatum L. subsp. perforatum (A - L - M - D)	*Rumex* sp. (G)
Lavandula stoechas L. (A - G - M - D)	*Senecio vulgaris* L. var. *tyrrhenus* (M)
Mentha aquatica L. subhyb. *piperita* (A - G - L - M)	*Sisymbrium officinale* (L.) Scop. (M - G)
Nasturtium officinale R. Br. (A - G - M)	*Smilax aspera* L. (M)
Papaver setigerum DC. (M)	*Stellaria media* (L.) Vill. subsp. *media* (M - G)
Papaver rhoeas L. subsp. *rhoeas* (G - L - M - D)	*Teucrium marum* L. (A)
Plantago lanceolata L. (M)	*Urginea marittima* (L.) Baker (M)

Table 2: Endemic species *

1. *Arum pictum* L. fil.	13. *Narcissus tazetta*L. subsp. Bertolonii (Parl.) Baker
2. *Bellium bellidioides* L.	14. *Pancratium illyricum* L.
3. *Bryonia marmorata* Petit	15. *Polygonum scoparium* Requien ex Loisel.
4. *Carex microcarpa* Bertol.ex Moris	16. *Ptilostemon casabonae* (L.) Greuter
5. *Delphinium pictum* Willd.	17. *Santolina insularis* (Genn. ex Fiori) Arrigoni
6. *Euphorbia cupanii* Guss.et Bertol.	18. *Scrofularia trifoliata* L.
7. *Genista aetnensis* (Rafin.) DC.	19. *Seseli bocconi* Guss. subsp. praecox Gamisans
8. *Genista corsica* (Loisel.) DC. in Lam. ex DC.	20. *Stachys glutinosa* L.
9. *Hypericum hircinum* L.	21. *Stachys corsica* Godr. e Gren.
10. *Mentha insularis* Requien	22. *Thymus herba-barona* Loisel.
11. *Mercurialis corsica* Cosson	23. *Urtica atrovirens* Requien ex Loisel.
12. *Morisia monantha* (Viv.) Ascherson ex Barbey	

* Pignatti, 1982; Arrigoni, 1976-1991

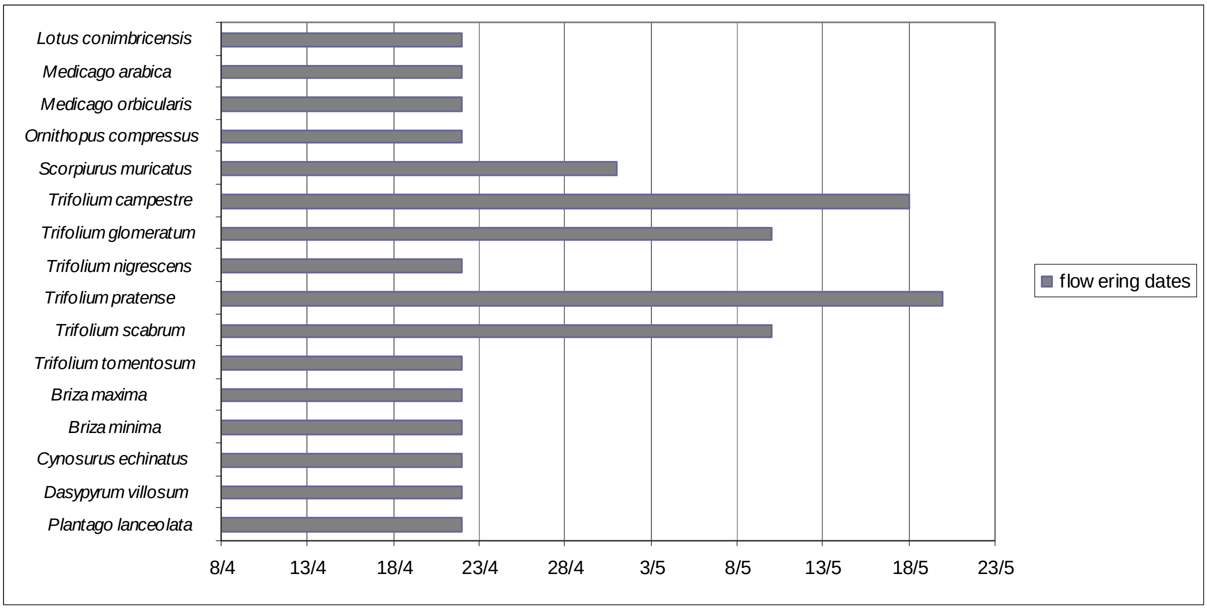

Figure 1: Flowering dates of ecotypes in benches

The genotypes planted in benches showed a great variability regarding the phenological cycle, from the emergence to flowering and fruiting time, and seeds characteristics (figure1 and figure 2).

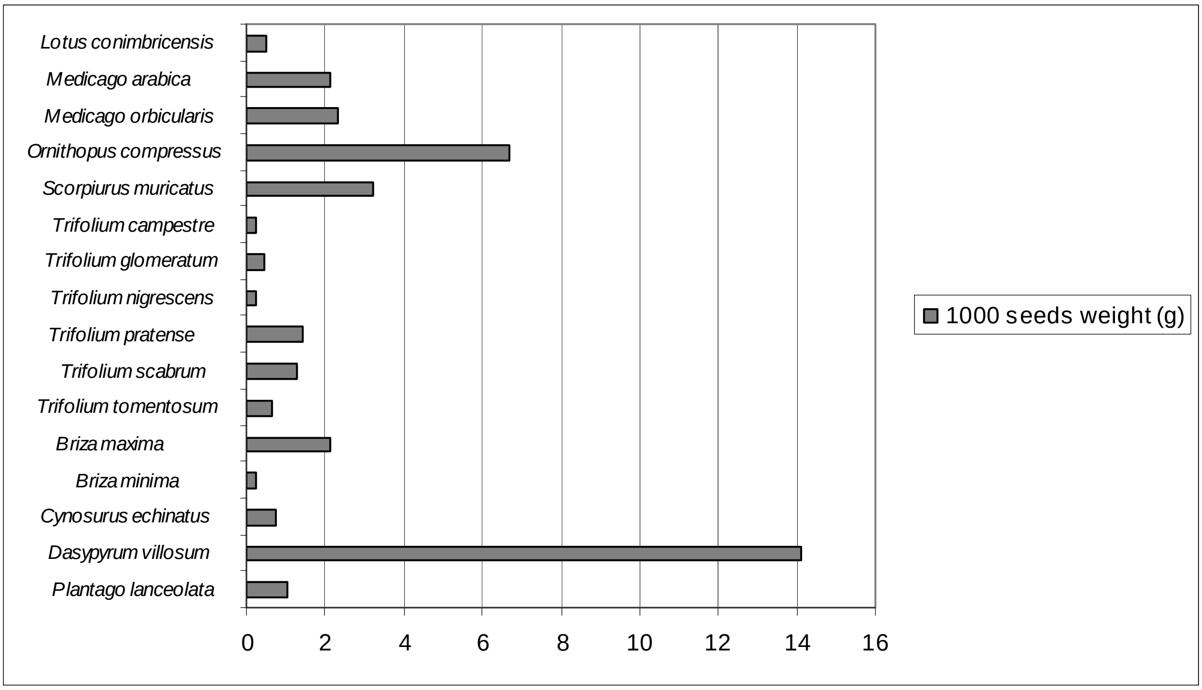

Figure 2: 1000 seeds weight of ecotypes in benches

The seed harvesting was carried out at different times because of the intra and inter-species ripening scale, from the end of May with *Briza maxima and B. minima*, until August with the poliannuals as *Trifolium pratense*, *T. ochroleucum* and *Plantago lanceolata*.

Regarding the vegetative growing pattern (fig. 3) some grasses such as *Briza maxima*, *Cynosurus echinatus*, *Dasypyrum villosum* were the earliest. The legumes species were later as their first cut was made after 45 days .

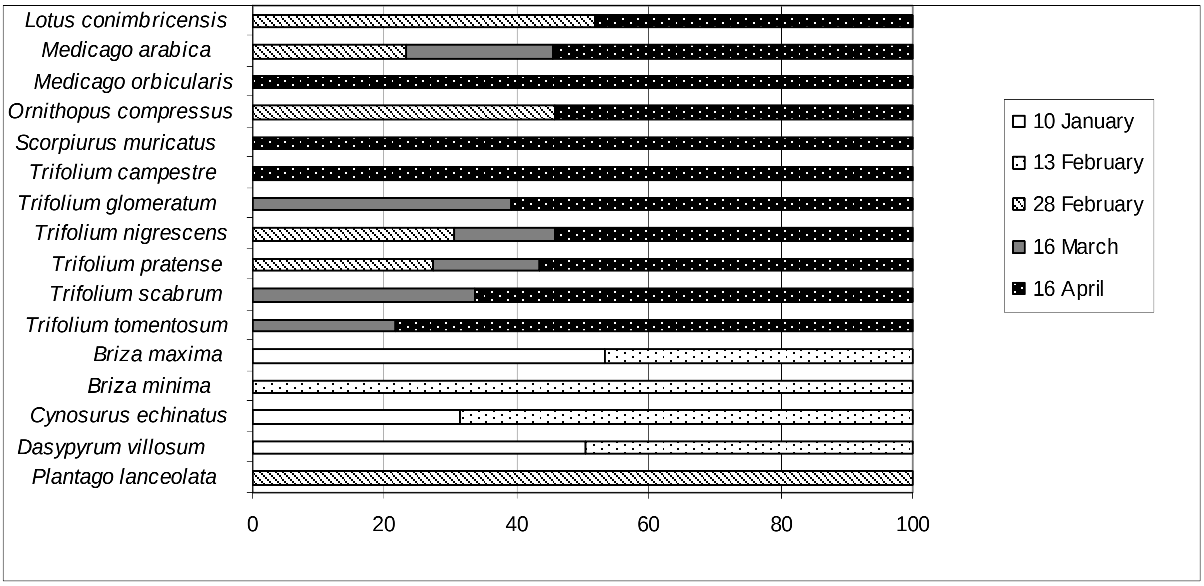

Figure 3: Vegetative pattern (dry matter yield percentage) of some genotypes evaluated in benches

Discussion

As a consequence of the continuous mechanical removing, the firebreak sward was poor of species, but the surrounding area presented the necessary high degree of biodiversity in order to find genotypes for forage and environmental aims.
Moreover the ecotypes showed a great variability in both sites of collection and evaluation, as regard the vegetative and biological cycle, which could be extremely useful to create a foraging chain.
This large variability could be exploited to select genotypes for different environments, with high pastoral value and covering capacity, suitable for swards reconstitution in grazing condition.
Furthermore during flowering period most of these species, increasing the amenity of landscape, become interesting for recreational uses, that could give the possibility of extra-incomes for the local population.
Not least the numerous endemic species and the environment health meet the even more important needs of places away from the stress of everyday life.
It should be also underlined that the important presence of species for officinal purposes could represent an additional value for the economically depressed and even more depopulated areas.
In the end is important to stress that a seed multiplication activity is essential for the availability of local genotypes (Vargiu *et al.*, 2010).

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Performances of spontaneous subterranean clover in Mediterranean natural pastures

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Abstract

Subterranean clover (*T. subterraneum* L.) is one of the most important annual self-reseeding pasture legume in Sardinia. Almost all its commercial varieties were selected in Australia starting from germplasm mainly collected in Mediterranean basin. There are few studies regarding its performances in natural swards, whereas native swards of subterranean clover represent a invaluable reservoir of germplasm. A research was started in order to study dry matter production, nitrogen fixation and self-reseeding in native swards dominated by subterranean clover. The contribution of the legumes reached 68% of total pasture DM production. The nitrogen fixation by native subterranean clover and annual legumes was quantified by the ^{15}N isotopic dilution method and reached 76% of N yield, representing an important N contribution to the pasture with. about 50 kg ha^{-1} of total N fixed in the aerial biomass. Furthermore, subterranean clover's seed yield and hardseededness were evaluated, showing that seed bank provides a satisfactory persistence of this legumes. The research showed that native subterranean clover has important agronomical and ecological traits.
Keywords: *Trifolium subterraneum*, natural swards, nitrogen fixation, ^{15}N, hardseededness

Introduction

Trifolium subterraneum L. "sensu lato" (subterranean clover) which includes the three subspecies *subterraneum* L., b*rachycalycinum* Katzn. et Morley and *yanninicum* Katzn. et Morley, is one of the most important Mediterranean annual self-reseeding pasture legumes. Until now, it has been studied with the main aim to breed it as commercial varieties, mainly in Australia, and later in Italy (Pecetti and Piano, 2002). Most of the varieties of subterranean clover have been released in Australia, starting from germplasm collected in Mediterranean basin (e.g. Leura, Gouburn, Denmark and York varieties, selected from Sardinian germplasm). This material has been made available on the European market (Collins *et al*., 1984). Experimental Institute of Fodder Crops of Lodi (Italy) started also a selection program to obtain additional varieties (Losa, Campeda, Limbara, Antas) more adapted to European Mediterranean pedo-climatic conditions (Piano *et al*. 1997). The different microclimates and soil conditions over a limited surface and the high stocking rates encountered in Sardinia provide great value to its native ecotypes (Fois *et al*., 2000). Almost all researches on subterranean clover carried out in Southern Europe (Olea *et al*., 1984; Sulas *et al*., 1993; Pardini *et al*., 1995; Piano *et al*., 1997) deal with *ex situ* bio-agronomic evaluations of both elite lines and commercial varieties imported from Australia. On the other hand, as recognized in several germplasm collections (Francis and Gillespie, 1981; Piano *et al*., 1982; Gonzales Lopez *et al*., 1992) *T. subterraneum* proved to be the most widespread spontaneous pasture legume species in Sardinia. Despite this invaluable genetic resource to be preserved and the decreasing interest for subterranean clover seed production in Southern Australia due to the high cost of *vacuum* seed harvesting, there are very few studies regarding its performances in natural swards. Within a project founded by the Sardinian Region for the valorisation of local resources, a research was started on native subterranean clover swards. This research aims at quantifying the dry matter (DM) yield, the amount of fixed N, the seed production and hardseededness of spontaneous subterraneum clover in natural swards in a way to contribute to their wider exploitation in Mediterranean agro-pastoral systems.

Materials and methods

A study was started in 2012 in Sardinia at two locations (Table 1), with different altitude, rainfall and soil type.

Table 1. Main pedo-climatic characteristics of the two locations.

Location	Bolotana	Macomer
Latitude/longitude	40°16’N / 8° 58’E	40°15’N / 8°44’E
Altitude (m.a.s.l.)	200	580
Avg.temperature. (°C)	16.6	15.5
Rainfall (mm y^{-1})	495	834
Sand/Silt/Clay (%)	68/12/20	57/35/8
pH	6.3	6.2
Soil series (Fao, 1988)	Eutric, Calcaric e Mollic Fluvisols	Rock outcrop; Eutric e Lithic Leptosols

At each location, within traditional agropastoral private farms, natural pasture areas with a valuable presence of native subterranean clover (mixed sward), and additional areas dominated by non-fixing reference species (NFS) used as a control were identified. Both treatments (mixed sward and NFS) were arranged in a randomized complete design, with three replicates in each location. The size of each experimental unit was 10 m^2. A rate of 4 kg N ha^{-1} of enriched ^{15}N fertilizer (10 atom %^{15}N enriched ammonium sulfate) was applied to both treatments. In the NFS plots, mainly represented by grasses, legumes seedlings were removed if necessary.

At the end of spring, dry matter (DM) yield were determined by cutting the aerial biomass at 5 cm above ground level over a 3 m^2 area within each experimental unit, and drying it at 65 °C in a forced-air oven until the obtainment of a constant weight. On subsamples, botanical composition was determined by separating *T. subterraneum*, annual legumes, grasses and other species biomasses. Dried samples were ground (1 mm mesh) and subjected to elemental analyzer isotope ratio mass spectrometry at the Iso-Analytical Limited laboratory (Cheshire, United Kingdom) to determine both total N content (% N) and atom%^{15}N. Nitrogen fixed by subterranean clover and annual legumes was assessed by the isotopic dilution (ID) method. The proportion of N derived from the atmosphere (%Ndfa) and the amount of the fixed N were calculated with the Warenbourg expressions (1993):

$$\%Ndfa=(1- atom\%^{15}N_{legume}/ atom\%^{15}N_{NFS});$$

$$\text{Fixed N (kg ha}^{-1}) = \text{legume N x Ndfa/100}.$$

In summer, buried subterranean clover burrs (i.e. inflorescences) were extracted up to 4 cm soil depth; the number of inflorescences per m^2, seeds per burr and seed bank size were determined. Sets of 50 seeds of subterranean clover were put in flywire envelopes (5 by 5 cm) and were placed on the soil surface at each site in a completely randomized design. At the end of summer, seeds were removed from field and put on moistened filter paper in sterile Petri dishes to germinate at 20 °C for 14 days.

Results and discussion

The mean biomass production over the two locations (Table 2) reached about 4 t DM ha^{-1} with a contribution of almost 70% of legumes. Annual legumes were annual medics (mainly *Medicago arabica* and *M. murex*) and clovers. Even if subterranean clover contribution to the total dry matter did not exceed 18%, it was the most representative single legume species in the sward. The yield of the non-fixing reference species (NFS) plots was 35% lower than that of the mixed sward. The N concentration of biomass ranged from 1 to 2.5%; it was higher in legumes, being almost double than that of grasses. The total N yield of subterranean clover and annual legumes reached 62.2 kg ha^{-1}, corresponding to 76% of the mixtures yield. The ^{15}N excess was significantly lower in legumes (Table 3) than in NFS, due to its dilution with atmospheric N. The Ndfa of *T. subterraneum* reached about 85%, similar with the annual legumes rate. The amount of fixed N was double in annual legumes than in subterranean clover, as a consequence of the higher DM yield. This estimate is quite conservative because legume below ground N was not considered in this experiment. The measured DM yields were quite similar to those reported in previous experiment on unfertilized natural pastures at the same locations by Bullitta *et al*. (1984). Unfortunately, these authors did not assess botanical composition of the sward. However, others researches often pointed out the difficulty for maintaining on long term an adequate contribution of subterranean clover commercial varieties in both sown pure swards (Sulas *et al.*, 1993) and sown mixture swards (Sölter *et al.*, 2007). This was due to a low adaptation capacity and pest tolerance of some commercial varieties. Ndfa values were double than those recorded in commercial varieties of subterranean clover by using the same ID method in southern Portugal (Carranca *et al.*, 1999). Finally, subterranean clover and annual legumes fixed 2.3 and 2 kg respectively of N per 100 kg of legume aerial biomass. These rates are very similar to other Mediterranean legume forage crops in spite of wide differences in terms of absolute DM yields (Sulas *et al.*, 2009).

Table 2. Dry matter (DM) yield, nitrogen (N) concentration and yield in the mixed sward and non-fixing reference species (NFS) during 2012 (Means of two locations ± se).

	DM yield ($t\ ha^{-1}$)	N concentration (%)	N yield ($kg\ ha^{-1}$)
T. subterraneum	0.70±0.18	2.50±0.33	17.5±2.6
Annual legumes	2.02±0.85	2.21±0.30	44.7±15.9
Grasses	0.93±0.02	1.33±0.08	12.4±0.5
Other species	0.38±0.07	1.78±0.14	6.8±1.79
Total	4.03±0.97	-	81.4±18.5
NFS	2.58±0.72	1.05±0.03	27.0±8.2

Table 3. Atom%^{15}N excess, proportion of N derived from the atmosphere (Ndfa) and amount of N fixed by *T. subterraneum* and annual legumes during 2012 (Means of two locations ± se).

	^{15}N excess (%)	Ndfa (%)	Fixed N ($kg\ ha^{-1}$)
T. *subterraneum*	0.0319±0.0030	84.7±1.2	14.8±2.0
Annual legumes	0.0317±0.0047	82.8±5.0	37.0±10.9
NFS	0.2164±0.0364	-	-

* Non-fixing reference species

The magnitude of subterranean clover's soil seed bank reached 4486±264 seed m^{-2} from which more than two third were produced during the previous spring. Inputs from current and past generations of plants are thus identified. Hard seeds content in July was about 70%± 2.9. From an ecological point of view, seed production, seed dormancy and the breakdown of hardseededness are key processes determining the adaptation of subterranean clover and other species to any climatic environment (Cocks, 1997). At the site of Bolotana, the seed bank size proved to be lower than that recorded in pure sward of commercial cultivar of subterranean clover (Sulas unpublished) but in the year of sowing only. According to observations previously made in this site, it was evident that native subterranean clover is more persistent than its commercial varieties.

In conclusion, the relative and absolute performances of native subterranean clover and annual legumes in terms of DM yield, fixed N and contribution to the seed bank should be regarded as valuable agronomical and ecological traits. They should contribute to an higher sustainability of local forage systems without any external inputs.
In the natural pasture areas under study, subterranean clover proved to be the most representative legume species and gave an important contribution in terms of DM production, N yield and fixed N. Moreover, the subterranean clover seed bank has allowed a satisfactory persistence of this legumes.

Acknowledgements

The work was funded by Regione Autonoma della Sardegna, L.R. 7/ 2007 annualità 2010 "Studio del ruolo ambientale di cotiche native a base di trifoglio sotterraneo per la loro valorizzazione in sistemi agropastorali mediterranei".

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Management techniques for reclaiming hillside pasture and woodland and their effects on soil chemical-physical characteristics

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Abstract

Experimental trials on the recovery of hilly marginal land were conducted in the NW Italy to study the interaction between coppice and pasture management. The favorable effects of the coppice used for grazing cattle were primarily physical, resulting in better herbage utilization and control for shrubs development. The more intensely grazed areas showed a lower content of organic matter and carbonate, and bulk density and penetration resistance increased.
Keywords: hillside pasture, woodland, grazing cattle, compaction

Introduction

The agricultural management techniques and mechanization adopted in sloping areas under temperate and sub-continental climate can affect the physical and hydrological characteristics of the soil, producing environmental impacts such as soil erosion rate and compaction (Opsi et al., 2012). Hilly areas always played an important role in Italian agriculture and have long been intensively cultivated for viticulture, which represents the cash crop more widespread with economic and social importance. In Piedmont (hills with 300-800 m asl) vineyards occupy an average of about 30-35% of the farm area, and the remaining lands are often divided into plots used for cereals or occupied by meadows and coppices, and part of them are underused and colonized by forest. Low-input agriculture, such as semi-extensive breeding of livestock within an integrated management of the agro-forestry resources, can be used to reclaim these marginal lands. The IMAMOTER Institute has carried over a 20 years experiment of recovering marginal land, by partially free-range cow-calf breeding in a farm located in the "Alto Monferrato" area of Piedmont region. Since Avery and Gordon (1983) stated that controlled livestock grazing improves the development of conifer woods and can be of valid help in controlling shrubs, an experiment was conducted to reclaim hill meadows and woodlands by stocking with cattle. A trial was performed to investigate the effectiveness of rotational grazing of cattle as a tool for controlling shrubs in hillslope coppices. Additionally, considering that the compaction produced by the animals seems to be linked to the frequency and location of their passage and the type and density of the herd (Zhou et al., 2010), the aim of the experiment was also to investigate the effects of trampling on the properties of the woodland soil.

Material and methods

The study was conducted in a hilly area of NW Italy (Alto Monferrato), characterized by a subcontinental climate that presents cold winter with snowfalls, and equinoctial rain distribution with drought in July and August. The experimental farm, located at 420 m a.s.l., covers an area of about 30 ha comprising vineyards, meadows and pasture land, some of them bordering on broad-leaved coppice. The coppices, with average slopes between 25% and 40%, had an arboreal flora mainly composed by association of *Quercetalia pubescentis* and in lesser extent species of *Quercus fagetea*, which were variously invaded by *Robinia pseudoacacia* L., bramble (*Rubus* spp.) and hawthorn (*Crataegus oxyacantha* L.) in the shrub layer. The soil was a sandy-silty one resting on a base of marls with sandstone layers (textural composition was 41% sand, 39% silt and 20% clay). Experimental plots were obtained fencing pasture and adjacent coppice areas with a woodland/grassland ratio ranging from 0.4 to 1.2. A herd of 22 adult Piedmontese cows weighting between 470 and 520 kg, was made graze on them over three turns for year: at the end of May, in August and in October, with variable stocking rates calculated in term of animal unit grazing days (AUGD, equivalent to 500 kg of live-weight). Three seasonal intensities were established: high (H) amounting to 80 AUGD/ha, medium (M) with 64 AUGD/ha and light grazing (L) with 48 AUGD/ha. In the autumn prior the beginning of the trial, the bushes were cut with shrub-clearing machine, and glyphosate was used for localized shrub control. The experimental trial lasted for four years and at the beginning and at the end of the period the following characteristics at 0-20 cm depths of the soil were checked in the area under test: textural and chemical composition, dry bulk density, water content at saturation capacity (SC), field capacity (FC), wilting point (WP) and cumulative water infiltration. Measurements were conducted according to the methods reported by Ferrero (1991) in the trial of compaction of woodland soil. At beginning and at the end of the grazing season, the soil penetration resistance (2 to 28 cm depth) was measured by a recording penetrometer. Some qualitative and quantitative features of the trees, shrubs and herbs were monitored on woodland. Vegetation records were performed annually by the linear analysis method of Daget and Poissonet (1969) adopted to the condition of the undergrowth.

Results and discussion

The influence of different grazing intensities on the main floral components and soil cover during the study period, is presented in Figure 1. After four years of cattle grazing in woodland, herbs with no forage value and shrubs showed a notable decrease, whereas good forage species increased their flora contribution, raising the soil cover. The greater reduction of the area occupied by shrubs, about 52%, was shown in the high grazing intensity plot. The area without vegetation was appreciably reduced especially in woods having moderate and heavy grazing intensities, with 94% and 82% of reduction respectively. These results confirm that the physical impact of animal trampling on woodland soil accelerates the destruction of the woody remains of the trees and shrubs, by the action of cattle hooves, having the effect of light surface tilling and preventing the establishment of other herbs more sensitive to trampling than grasses. In general, woodland grazing did not adversely affect the trees of more than 120 mm diameter at the beginning of the trial; where grazing intensity was high, trees less than 60 mm in diameter suffered moderate damage when located in the area most frequented by the animals.

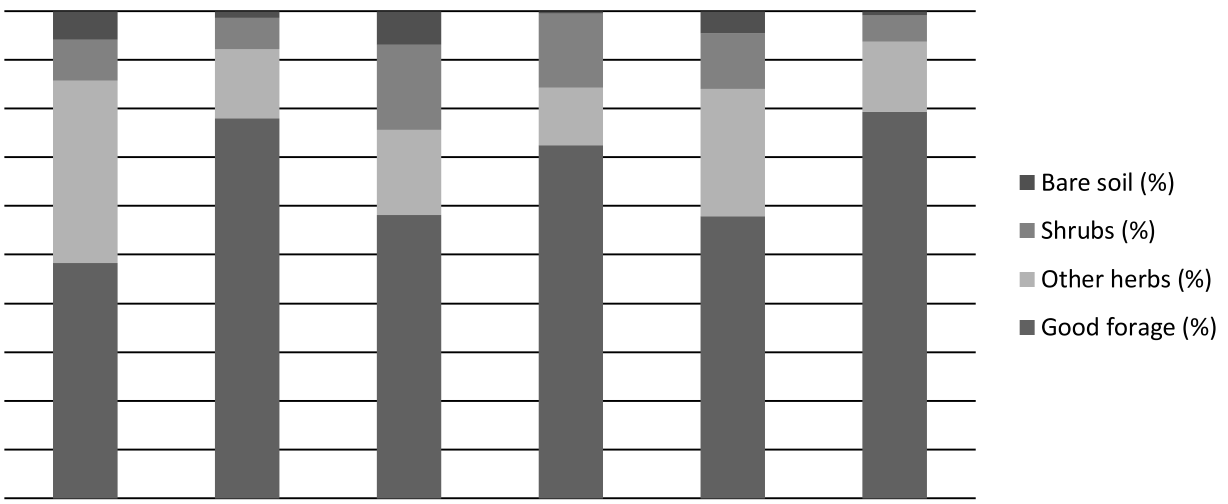

Figure 1: Influence of different grazing intensities on the main floral components and soil cover, at the beginning and end of the experiment

Chemical and physical characteristics of woodland soil measured in the layer 0-20 cm depth under ungrazed and grazed regime, are shown in Table 1. The comparison of the measurements performed at the beginning and end of the experiment showed a significant increase of the nitrogen content in the surface layer, higher in grazed plot, and a reduction of the carbonate content. The N trend could be confirmed by the results of the herbaceous flora surveys which showed an increase of the forage species components, more sensitive to manuring (Schrama et al., 2013). The bulk density and the organic matter content increased, the latter to a lesser extent at the surface of the soil in the preferred pathways of the animals. Hydrological data were quite uneven. Considering the overall results of all the blocks at the end of the trial, only saturation capacity appeared to be considerably lower in grazed woods.

Table 1: Chemical and physical characteristics of woodland soil, measured at 0-20 cm depth under ungrazed and grazed regime, during the four years experiment

Measurements	Initial		Final	
	Ungrazed	Grazed	Ungrazed	Grazed
pH (H_2O)	7.45	7.72	6.92	7.22
$CaCO_3$ (%)	7.02[a]	6.90[a]	6.33[b]	5.87[b]
Organic matter (%)	4.10[b]	4.20[b]	6.28[a]	5.93[a]
N_{tot} (%)	2.93[b]	2.73[b]	3.40[a]	3.37[a]
Bulk density (g cm^{-3})	1.09[b]	1.12[b]	1.15[ab]	1.24[a]
Saturation capacity (%)	50.32	49.22	51.10	48.30
Field capacity (%)	40.45	41.12	41.32	39.86

Means on the same line followed by the same letter (or none) are not significantly different at P=0.05

Water cumulative infiltration data from grazed and ungrazed plots are presented in Figure 2. Trends proved to be much lower in the plots having more intensely grazed areas, where the infiltration was uneven for the first two hours. The highest values were reported by ungrazed and grazed at light intensity plots, with cumulative infiltration data exceeding 1600 mm. Penetration resistance data recorded within the experimental area are shown in Figure 3. The grazed plots at different intensities and the ungrazed one have maintained similar trends up to approximately 15 cm depth, with higher values of about 1.36 MPa for the plot intensively grazed than that without grazing. Above 15 cm depth, the areas most grazed showed a variable trend, while the plots less subjected to animal trampling presented an increasing data with the increase of depth. Data did not differ sensitively at 25 cm depth. On average the maximum value did not exceeded 3 MPa, which is the critical value for the roots of sowed plant (Glinsky and Lipiec, 1990).

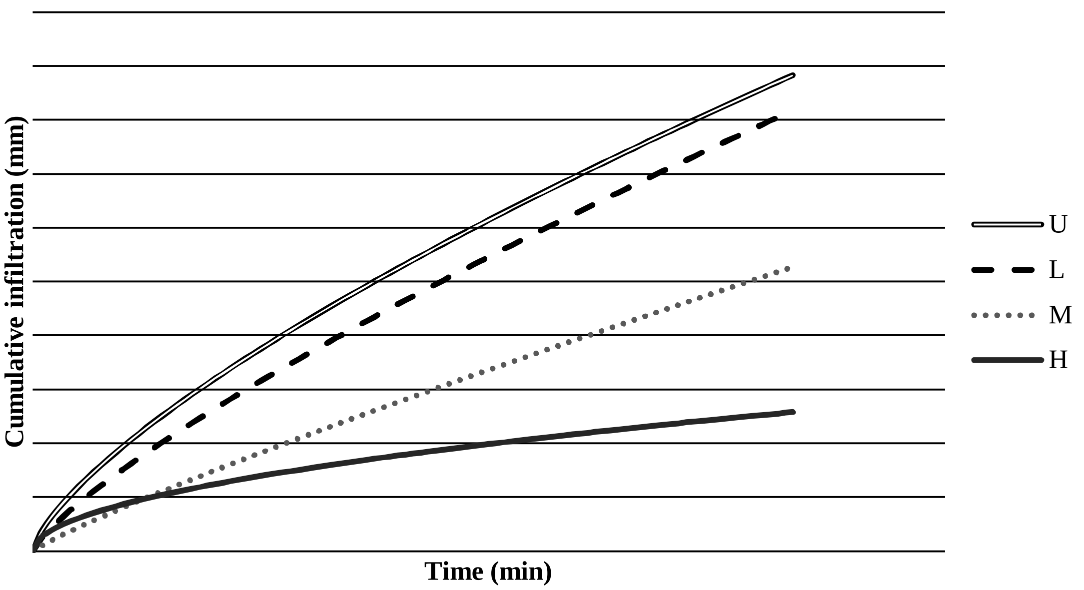

Figure 2: Water cumulative infiltration from the ungrazed (U) woodland plots and after four years of grazing at light (L), moderate (M) and high (H) intensities.

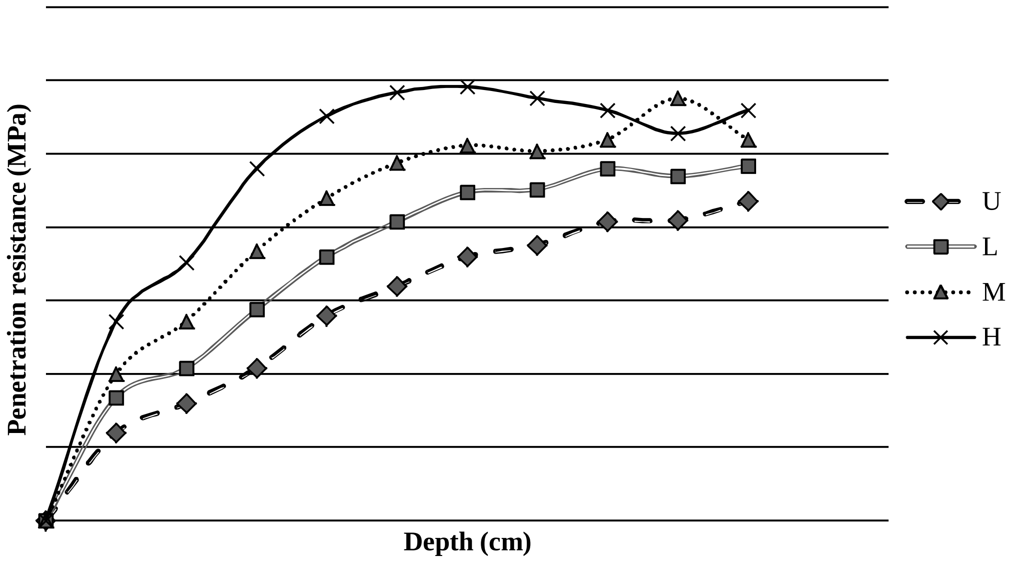

Figure 3: Penetration resistance trends from the ungrazed (U) woodland plots and after four years of grazing at light (L), moderate (M) and high (H) intensities.

The controlled rotational grazing of hilly coppice, though the forage offered could not satisfy the animal requirements, allowed a better utilization of the herbage pasture with additional favourable effects, such as: shelter for herd, reduced trampling and dung deposition on pasture. Coppice grazing with cattle rotation in different period and stocking rate adopted to local condition, did not greatly damage the flora, while proved to be a sound method for controlling bramble. If conducted accurately, avoiding the introduction of cattle when the soil is wet and more sensitive to trampling, and adapting the stocking rate to the conditions of the moment, the coppice grazing did not appear to have adversely affected the soil physical and chemical characteristics. The results should be assessed with the single farm view, as well as within the context of overall territory management.

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Physiological variability of soil microbial communities among different Atlantic pasture habitats

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Abstract

The traditional grazing activity carried out for centuries in mountainous areas of the Basque Country (Northern Atlantic Spain) facilitated the presence of different extensive pasture habitats, such as those included in the Gorbeia Natural Park (and surrounding valleys). Currently, these pastures are highly valued due to their high biodiversity, being the valley pastures most vulnerable because of the higher human pressure. In this context, one of the main objectives of the LIFE-SOILMONTANA project (ref LIFE 10 NAT/ES/579) is to demonstrate the suitability of alternative agronomic practices that promote the ecosystem services provided by these pastures through the conservation of their biodiversity, especially soil biodiversity. As soil microorganisms are mainly responsible for soil functions (*e.g.*, mineralization of organic matter and recycling of nutrients), our first aim was to know the original physiological activity and diversity of the soil microbial communities present in those pasture habitats considered for the project. In particular, we used the ECO-BIOLOG™ and FF-BIOLOG™ plates to analyse the AWCD (average well colour development), NUS (number of used substrates) and the Shannon diversity index (*H'*) of soil bacteria and fungi, respectively. Here presented data show the differences in these parameters among several habitats (bracken, mountain pastures and differently managed valley pastures) established on different parent materials (calcareous *versus* siliceous).

Keywords: Pasture, bacteria, fungi, functional diversity, community level physiological profiles

Introduction

Valley-mountain transhumance based grazing carried out traditionally around the Gorbeia massif has facilitated the presence of extensive mountain and valley pastures. Nowadays it is well recognized the need to protect the high biodiversity they harbour, as a guarantee for the ecosystem services they provide us. In this context, this study is part of the LIFE-SOILMONTANA project (ref 10 NAT/ES/579 LIFE) whose main objective is to promote agricultural practices that maintain the functionality of ecosystems through the biodiversity conservation. The soil on which each pasture is developed is of vital importance for the conservation of terrestrial life. Apart of being a growth media and habitat for plants and animals, soils host a variety of microorganisms that are responsible for 80-90% of its biological activity (Reichle, 1977). This biological activity drives important processes such as decomposition and recycling of nutrients, nitrogen fixation, structure maintenance, detoxification of pollutants, etc. Regarding pastures, microbial activity directly influences its productivity, as they are the base of the detritivorous chain, releasing nutrients for plants (Bardgett et al., 1997).

Soil microbial functional diversity can be addressed through the analysis of community level physiological profiles (CLPPs) which reflect the ability of the culturable portion of the microbial community to use a battery of carbon substrates (Bending et al., 2004).The Biolog EcoPlates™ were developed for CLPP of terrestrial communities (Insam, 1997) and contain 31 useful carbon sources for soil community analysis. The Biolog FF-Plates™ contains different 95 carbon substrates for culturable fungi.

The main objective of the study was to compare the physiological profiles of bacteria and fungi from different habitats included in the project (bracken, mountain pastures and differently managed valley pastures) both settled on siliceous or calcareous soils. For this purpose, we analysed their community level physiological profiles with specific Biolog™ plates.

Material and methods

The study site is settled in the Gorbeia Natural Park (21016 ha) and surrounding valleys in the Basque Country, Northern Spain. All soil samples were collected in the summer of 2012, within two months. Samples were taken in five habitat types: bracken (dominated by *Pteridium aquilinum* (L.) Kuhn), mountain pastures (assigned to codes 6230 and 6170 in the European Directive 92/43/CEE), and 3 types of valley pastures (grazed meadow, meadow for hay and mixed meadows), each established on both calcareous and siliceous soils, resulting in 10 habitat x soil combinations, in total. For each combination, four soil samples were taken in geographically differentiated areas, as replicates. Each soil sample was composed by ten subsamples (near located) extracted directly from soil with a probe (10 cm deep and 3 cm diameter). Once in the laboratory, samples were freshly sieved to <2 mm and stored at 4 ºC prior to analysis.
Physicochemical characterizations of soils were carried out according to standard methods (MAPA, 1994). For the determination of the community-level physiological profiles (CLPPs) of soil bacteria, were used the Biolog EcoPlates™ according to Epelde et al. (2008). Biolog EcoPlates™ are tailored to ecological applications and comprise three replicate sets of 31 environmentally applicable substrates, at least nine of which are considered as constituents of plant root exudates (Campbell et al., 1997). Similarly, the Biolog FF-Plates™ used for fungal analysis comprise just one replicate per plate with 95 different carbon substrates. Briefly, soil samples were extracted by agitating in an orbital shaker (125 rev min^{-1}) 1 g of equivalent of dry weight soil with 9 ml of autoclaved deionized water for 1 h. After shaking, samples were left to settle for 5 min and then a 1:100 dilution (1 ml soil suspension: 100 ml autoclaved Mili-Q ultra-pure water) was inoculated in Biolog EcoPlates™ (150 µL) and FF-Plates™ (100 µL). In this last case, 100 mg L^{-1} streptomycin and 50 mg L^{-1} gentamicin were added to the autoclaved water to inhibit bacterial growth in FF-Plates™. The plates were incubated at 30 ºC or 26 ºC (for EcoPlates™ and FF-Plates™, respectively) and colour development was read every day at 595 nm or 490 nm using a microplate reader (Anthos Zenyth 3100). The readings corresponding to an incubation time of 44 h (EcoPlates™) or 95 h (FF-Plates™) were chosen for further calculations (at approximately this incubation time, the highest rate of microbial growth was observed). For each reading time, raw absorbance data were corrected by subtracting the zero hour reading point and the absorbance value given by the control empty well. Average well colour development (AWCD) was determined by calculating the mean of every well's absorbance value at each reading time. The number of utilized substrates (NUS-the number of substrates with an absorbance value >0.1, which indicates the beginning of the exponential growing phase) was also counted as equivalent to species richness. Similarly, Shannon's diversity (*H'*) index was calculated ($H' = - \sum p_i \log_2 p_i$) (Magurran, 2004), considering absorbance values at each well as equivalent to species abundance. Redundancy analyses (RDA) were carried out with Canoco 5.0 according to Ter Braak and Šmilauer (2002). As Shannon's diversity (*H')* indexes were calculated from AWCD and NUS data they were not represented in redundancy analysis figures.

Results and discussion

The Figure 1 shows the redundancy analysis (RDA) of Biolog™ parameters in function of the habitat type (bracken, mountain pasture and valley pasture) as well as of the soil type (calcareous and siliceous).
Firstly, the catabolic potential of the bacterial communities (ECO AWCD) and in their functional diversity (ECO NUS) were more abundant in the valley pastures with respect to fungi (FF AWCD and FF NUS; $p<0.001$), which on the contrary were dominant in the mountain pastures, according their distribution along axis 1. The dominance of bacteria in the valley pastures could be related to a higher pH and nutrient availability (as P Olsen), as shown in Figure 1. Mountain pastures appeared to accumulate organic matter, indicating a lower biological activity probably due to a more difficult edaphoclimatic conditions (lower pH and labile nutrients, temperature and humidity variations, etc). This restrictive conditions favour the dominance of fungi. In fact, it's well known that fungi become more abundant with respect to bacteria concomitantly with lowering the pH values (Rousk et al., 2000).
Regarding the soil substrate types (siliceous/calcareous), the axis 2 appears to differentiate them (p=0.065), although it only explains 7% of the variance. Probably, the supposed effect of soil substrate type on pH is minimized in the study area by the high rainfall (1500 mm $year^{-1}$) that causes the leaching of basis leading to severe soil acidification.

Finally, it is worth noting that bracken presented significant values of microbial catabolic potential and functional diversity, despite their lack of interest for forage production.

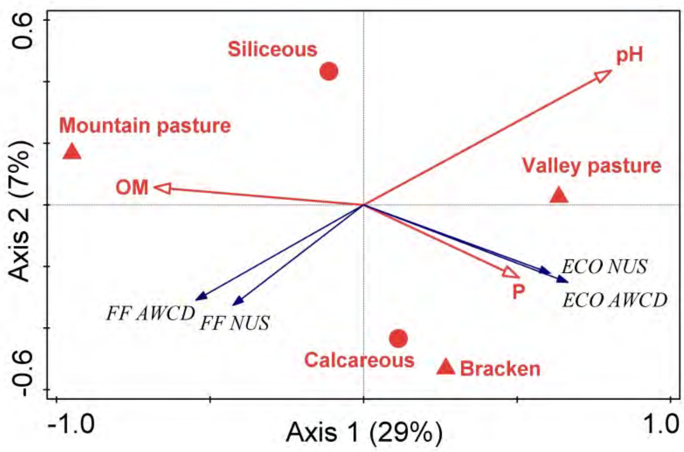

Figure 1: RDA of the AWCD and NUS obtained in Biolog EcoPlates™ and FF-Plates™ in function of the habitat (triangles) or the soil type (circles) analysed. OM, organic matter content (%); P, phosphorous content (%).

Within the valley pastures, the RDA analysis showed that bacteria predominated in grazed meadows while fungi were more abundant in meadows for hay, respectively linked to higher P values (bacteria) and low pH (fungi), once more (Figure 2). The extraction of grass for hay in absence of grazing reduces the return of organic matter and nutrients to the soil as plant litter or animal droppings, contributing to explain the lower pH and organic matter content found in non-grazed soils.

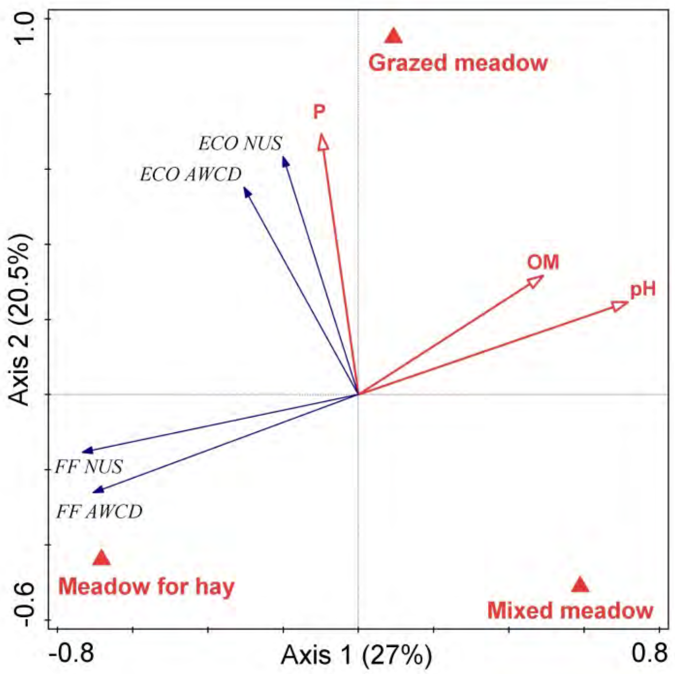

Figure 2: RDA of the AWCD and NUS obtained in Biolog EcoPlates™ and FF-Plates™ in function of the three managements analysed (meadow for hay, grazed meadow and mixed meadow) in the valley meadows. OM, organic matter content (%); P, phosphorous content (%).

Conclusions

Fungi predominated in mountain pastures where temperatures are more extreme and the soils more acidic. The higher pH values favour positively the diversity and the metabolic potential of bacteria, contributing to the predominance of bacteria in the valley pastures with respect to the mountain pastures.
Regarding pasture management, grazing appeared to increase soil pH, organic matter content and, concomitantly, bacterial communities, while fungi predominated in poorer meadows for hay.
Despite of their unpalatability, bracken may have real value in terms of microbial biodiversity conservation.

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Soil Health Evaluation Based on Microarthropod Communities in Pastures of Gorbeia Natural Park

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Abstract

The loss of biodiversity in the agroecosystems, apart from their *per se* value, entails a deterioration of the services that they provide. It is therefore necessary to enhance practices that allow to maintain these services and, at the same time, conserve soil biodiversity and functionality. Soil biota plays a key role being the main responsible for the biological activity of soils, fulfilling key functions such as the recycling of nutrients (mineralization, denitrification, nitrogen fixation), detoxification of pollutants and C sequestration among others, having a close relationship with plant communities. Due to its integrative nature and its rapid response, biological parameters are increasingly being used by researches as indicators of the health of ecosystems.

Whereas plant communities have been broadly studied, less attention has been paid to soil organisms. Soil invertebrates are excellent candidates for studying soil disturbances due to their sensitivity to the changes in soil conditions and land management practices. In this work we evaluated the soil health by studying the microarthropod groups present in soil samples from different grazing habitats of interest within the Gorbeia Natural Park (Biscay, Northern Spain) in the framework of the project LIFE-SOILMONTANA (LIFE10NAT/ES/579). The Soil Quality Index (BSQ) was calculated according to the different microarthropod groups, based on their adaptation to soil environment.

There were differences in the BSQ due to soil parent material (calcareous *vs.* siliceous). More interestingly, dependently of the substrate type, significant differences were observed among the analyzed habitats (bracken, mountain pastures and differently managed valley pastures), being significantly higher in the pastures, emphasizing the value of these habitats for the conservation of biodiversity and the ecosystem services that they provide.

Keywords: Pastures, Microarthropods, Soil Biodiversity, BSQ

Introduction

This study was carried-out in the framework of LIFE-SOILMONTANA project (ref. LIFE 10 NAT/ES/579), whose main aim was to improve the agricultural practices in pastures surrounding the Gorbeia mountain (Biscay, northern Spain) to maintain ecosystems functionality as well as to conserve their biodiversity, being his an important service. Soils provide a wide range of functions and services such as the recycling of nutrients (mineralization, denitrification, nitrogen fixation), detoxification of pollutans and C sequestration (Millenium Ecosystem Assessment, 2005). Soil ecosystem health is defined as the ability of a soil to carry out its functions in an appropriate way for the ecosystem operation. In this context, it is imperative to have a reliable set of indicators of soil health, among which soil biological properties stand out due to their integrative character, sensitivity, fast response and ecological relevance (Pankhurst *et al.*, 1997).

Several authors have proposed new methods for soil-quality assessment based on soil mesofauna communities. Some of these methods are based on a general evaluation of arthropods (Büchs *et al.*, 2003; Bardggett and Cook, 1998). The BSQ index "*Biological Quality of Soil*" has been proposed as an integrative approach (Aspettu *et al.*, 2010)

Our intention was to assess the differences in biodiversity according to the different microarthropod groups present in the soils analyzed in the project, as a result of their adaptation to different habitats: Bracken dominated pastures, mountain pastures and differently managed valley pastures, developed on both calcareous and siliceous substrates.

Material and methods

Study Site

The study site was settled in the surroundings of the Gorbeia Natural Park (21016 ha) in the Basque Country, Northern Spain.

The microarthropod index BSQ

BSQ was applied to soil microarthropods, separated according to the biological-form to evaluate the level of adaptation to soil environment. This Ecomorphological index attributes scores to each microarthopod group based on morphological features. The BSQ index was calculated by summing the ecomorphological scores of all groups present in the sample.

Sampling and extraction of microarthropods

Sampling was accomplished during 2012 in three types of habitats: bracken dominated pastures, mountain pastures and differently managed valley pastures, developed on both calcareous and siliceous substrates. Four composite soil samples (made by 10 subsamples, each) representative of the different habitats were taken with a cylindrical core of 10 cm diameter and 5 cm depth, and protected from thermal shock and evaporation until analysis.

For microarthropod extraction, a Berlese-Tullgren funnel method was carried out in the laboratory with a 2 mm mesh and lamps of 40W being placed 20cm from the sample to dry it and to drive out the microarthopods during 7 days. The extracts were preserved in 75% ethanol. The system was kept free from vibrations.

Extracted specimens were observed under a stereomicroscope at low magnification (usually 20-40x) in the same preservative liquid (Parisi *et al.*, 2005).

Statistical analysis

A two way ANOVA followed by a Fisher test was carried out to check interactions between soil and habitat types and to evaluate differences among treatments, using Statview software of Microsoft.

Results and discussion

The Two-Way ANOVA analysis showed a significative interaction ($p<0.05$) between the parental material of soils (calcareous/siliceous) and the habitat type (bracken/ valley pastures/mountain pastures.

In Figure 1 are represented the results in BQS for each type of habitat, for each the soil type.

Differences were observed in calcareous soils, where the BQS index was higher in valley pastures as compared with mountain and bracken ones ($p=0.015$). In siliceous soils, both mountain and valley pastures showed more diversity than bracken habitats ($p<0.05$).

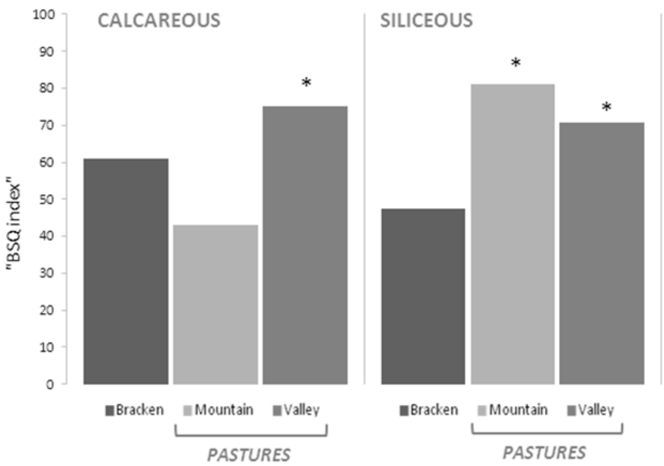

Figure 1: BQS based on Microarthropod communities in the different soil types. * mean significant differences among habitats.

The transition from pastures to bracken not only entails the loss of the pastural value, but also changes in the quality of vegetal litter inputs to the soil (higher C:N ratio and lignin content) generally related with a soil acidification and a decrease in easily metabolizable C and N compounds that can directly affect to the soil biota and, concomitantly, soil health (Potthass *et al.*, 2010).
Regarding the effect of the parental material of soil in the habitats analyzed (Figure 2), no differences were observed in brackens and valley pastures, while BSQ values of mountain pastures were significantly lower in calcareous than in siliceous soils ($p<0.05$).

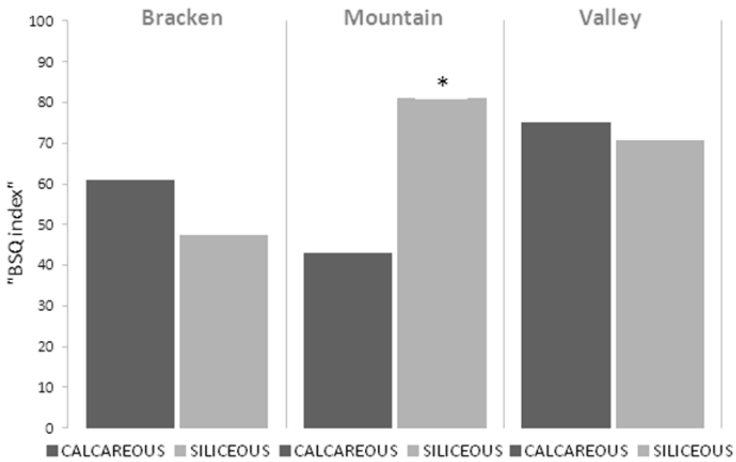

Figure 2: BQS based on Microarthropod communities in the different parental soil types. * mean significant differences among habitats.

Since calcareous pastures are considered one of the most diverse habitats in Europe, in terms of plant species richness (Kull and Zobel, 1991), we could expect to find there a higher belowground diversity. However, our BSQ results in mountain pastures disagreed with this hypothesis, although plant aboveground diversity was really lower in siliceous than in calcareous soils (data not shown).
Notwithstanding, some microarthropod families seem to be more abundant in less favorable abiotic conditions, which could be related with the enhancing of microbial colonization (Neher, *et al.*, 2009)
Moreover, the lower BSQ index founded in brackens (when compared with both mountain and valley pastures) do agree with their lower plant diversity (data not shown) and also with the lower rate of biodiversity reported by other works for brackens (Marss *et al*., 2007). This emphasizes the value of pastures in the conservation of biodiversity, further than their well-known service for grazing.

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Can minimal utilisation strategies contribute to maintaining ecosystem functions of mountain grasslands?

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Abstract

Grasslands are crucial to agricultural production, landscape aesthetics, biodiversity and hazard prevention in mountain regions. Ongoing changes in economic conditions are critical for the future management of many grassland sites in these ecologically sensitive regions. Marginal areas with highly diverse grassland communities are increasingly managed with as little labour as possible or are abandoned completely. In some regions in the Alps, up to two thirds of the traditionally utilized grassland area has been abandoned.

Even in areas with less structural changes such as the Northern Swiss Alps, it becomes evident that agriculture is likely unable to maintain the utilisation of the entire grassland area with traditional mowing or grazing. Alternative strategies of minimal utilisation, such as grazing with robust breeds and exotic species, mulching or burning, need to be considered in order to maintain ecosystem services of grasslands in mountain regions.

Based on a comprehensive review of the available literature, we compared traditional to alternative utilisation strategies based on six criteria (openness of the landscape, maintenance of landscape quality, conservation of biodiversity, protection against natural hazards and economic costs). The assessment showed that relatively little effort is needed to maintain the openness of the landscape using alternative management strategies. However, endangered species often rely on the continued traditional utilisation of a site, as does the protection against natural hazards. This means that the choice of the best suited land use strategy for a given site requires careful analysis and evaluation, bearing in mind criteria such as local, regional and national targets and the availability of financial resources.

Keywords: abandonment, natural succession, minimal utilization, literature review

Introduction

The cultural landscape in the Alps has largely been shaped by agriculture and mirrors the evolution of agricultural land use. The ongoing structural change in mountain agriculture resulted in less man power and fewer but larger farms. Land use has been rationalised and concentrated on fields where machinery could be employed (Flury *et al.*, 2012). Alongside, labour input to marginal sites, whose management required a high amount of human power, was successively reduced.

Figure 1: Mulching in field experiment of minimal utilization strategies for marginal grassland sites

The process of rationalisation and, in parallel, the process of abandonment, showed pronounced regional differences (Streifeneder *et al.*, 2007, Tasser *et al.*, 2011, Flury *et al.*, 2012, Pornaro *et al.*, 2013): In regions with a strong reduction of the number of farms, up to two thirds of the original grassland area has been abandoned. In contrast, only few sites were abandoned in regions with high grassland productivity because the improved mechanisation allowed using larger areas with similar amounts of labour. For example, the third Swiss National Forest Inventory (Brändli, 2010) indicates that reforestation in Switzerland was much stronger in the Southern and Central Alps (around +20% during the past 30 years) than in the rest of the country (between 0 and +5% in the past 30 years). However, in all cases, technical progress resulted in stronger inputs of capital rather than labour and a concentration of these inputs to sites without limitations to mechanisation and within easy reach.
The unabated trend of abandonment suggests that mountain agriculture is not able to maintain the current extent of land use based on the traditional management form of mowing and grazing. In order to meet the current political goals to preserve the open cultural landscape in the Alps and its productive potential, alternative strategies should be considered. These include grazing with robust breeds of cattle and sheep, grazing with goats or donkeys as well as mechanical interventions such as mulching (Figure 1).

Material and methods

In order to assess effects of alternative management strategies, a literature review was carried out and complemented by expert consultations (Bollmann *et al.*, 2013). Management changes were assessed for six criteria aligned with the central aims of Swiss agricultural policy: (1) openness of the landscape, (2) maintenance of landscape quality, (3) maintenance of faunal diversity, (4) maintenance of floral diversity, (5) minimisation of natural hazards and (6) costs of management. Changes were assessed along a qualitative scale from decline of the criteria over no change to improvement, separately for moist and dry sites. Dry sites were defined as those where plant growth is limited by available soil water every year. For each change in management towards minimal utilisation, qualitative assessment tables were elaborated (Figure 2)

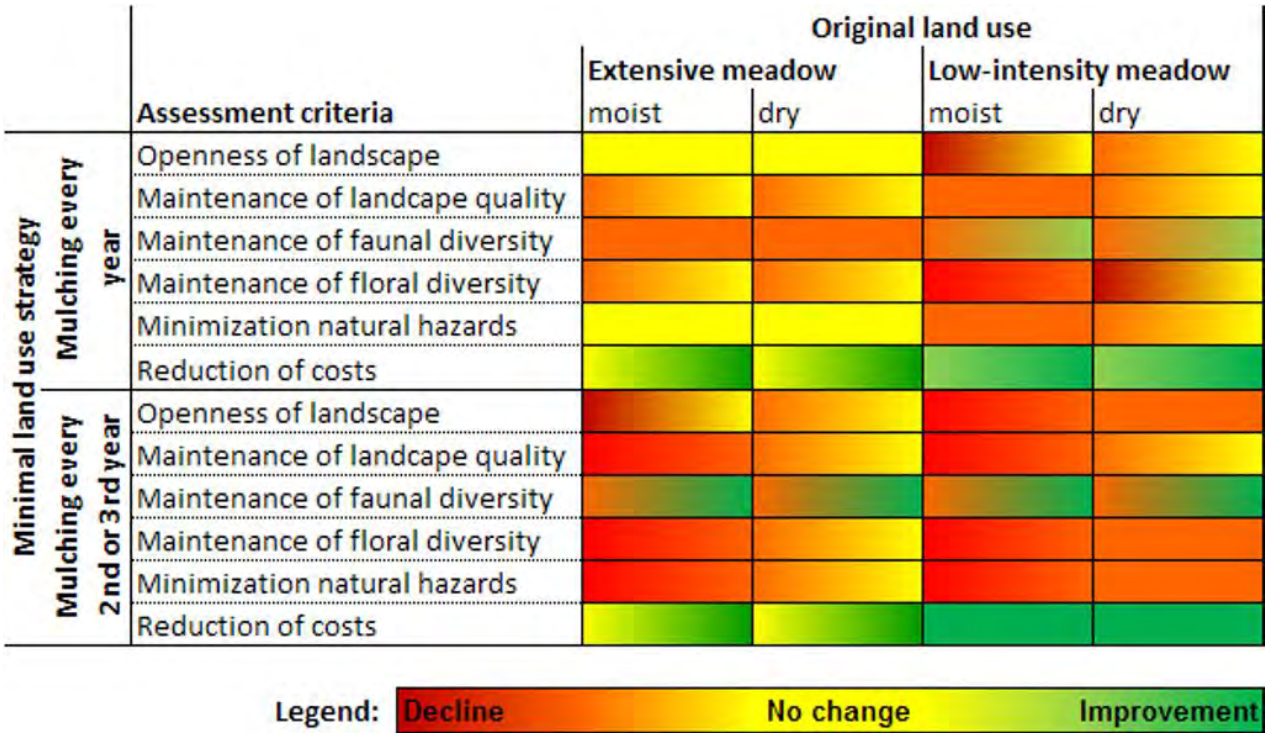

Figure 2: Example of a qualitative assessment table of management changes towards minimal utilisation. Changes from extensive and low-intensity mowing to mulching annually or every second or third year, respectively, are evaluated with regard to six criteria and for dry and moist sites. Colours are based on a qualitative scale ranging from a reduction of the criterion over no change to an improvement of the criterion.

Results and discussion

The evaluation of management changes towards minimal utilisation strategies has frequently shown contrasting consequences on the six evaluated criteria (Bollmann *et al.*, 2013):

1. Openness of landscape

Evidence to evaluate this criterion is relatively abundant and shows that the target of an open landscape can be met at relatively low effort for an area of considerable extent (e. g. Schreiber *et al.*, 2009). As an example, sites with low productivity can be kept open by mulching every year or, partially, also by mulching every second or third year (Figure 2). On more productive sites, mulching has to be carried out every year in order to inhibit reforestation. Goats as well as cleverly managed robust breeds of sheep and cattle are able to successfully control reforestation without additional mechanical interventions (e. g. Meisser *et al.*, 2011).

2. Maintenance of landscape quality

This is a complex criterion, difficult to define and to evaluate. However, the scarce evidence suggests that brown or sparse vegetation (such as a meadow after mowing or mulching) are least preferred by the general public. Three-dimensional elements, such as bushes or groups of trees increase the attractiveness of the landscape (Lindemann-Matthies *et al.*, 2010). This resulted in a positive assessment of management changes towards pasture with low levels of tree cover with regard to the criterion of landscape quality (Bollmann *et al.*, 2013).

3./4. Maintenance of faunal and floral diversity

In addition to the openness of the landscape, many grassland sites in mountain regions provide additional services such as the preservation of a unique biodiversity. This service is often coupled to the traditional management of mowing or grazing (Römermann *et al.*, 2009). Moreover, the degree to which the criterion is maintained under alternative management strategies (e.g. mulching) depends on the appropriate timing and intensity of the interventions. For example, the impact of mulching on biodiversity strongly depends on the speed by which the mulched biomass decomposes (Prochnow *et al.*, 2000) as well as on the species group. Insects are generally more susceptible to mulching than plants of soil organisms (Schreiber *et al*,. 2009). Bollmann *et al.* (2013) have therefore elaborated specific exclusion criteria for certain management strategies. For example mulching is not recommended in plant communities (1) with rare species of plants or animals, (2) traditionally mown after August, (3) with large biomass production, e.g. reed beds or tall herb communities, (4) with litter decomposition limited by humidity, drought or low temperatures and, finally, (5) where woody plants are an important characteristic element (e.g. heather moorland).

5. Protection against natural hazards

There is a substantial body of literature showing that both snow gliding as well as erosion and landslides increase by initial and intermediate stages of land abandonment. Only after a substantial amount of time, successive vegetation establishes which provides a similar degree of protection than the original management (e.g. Tasser *et al.*, 2003). There is little detailed information available in order to assess effects of minimal management strategies on this criterion (Bollmann *et al.*, 2013).

6. Reduction of costs

This criterion can be evaluated relatively easily but requires well-defined system properties for the investigated sites. Dux *et al.* (2009) calculated that on meadows, mulching is often cheaper than the original mowing regime. On pasture sites, the continuation of grazing is often the most economic management strategy because mechanical interventions require much more effort and, hence, higher costs.

Conclusions

While Bollmann *et al.* (2013) have assessed potential changes in management with regard to six criteria, utilisation strategies for marginal sites need to be evaluated with regard to all six criteria. The importance of these criteria is based on local and regional objectives which are derived from national and supra-national agricultural and environmental policy. On top, a utilisation strategy can only be selected based on an individual assessment of state and quality of the site. Certain properties, such as the composition of plant and animal communities may be assessed locally for each site, others, such as the requirements for openness of the landscape need to be evaluated in a regional context. Based on the proposed assessment of sites, a prioritised ranking is to be developed indicating which sites need to be preserved in the future and where abandonment and natural succession can take place. Using this approach, the final extent of utilisation of marginal sites is still depending on the amount of available funds to cover the costs of maintenance, but in optimal agreement with local and regional objectives.

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ISBN 978-88-908636-2-2

Department of
Agricultural, Forest
and Food Sciences