



Mountain pastures and livestock farming facing uncertainty: environmental, technical and socio-economic challenges

Edited by:
I. Casasús, G. Lombardi



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Foreword

Livestock farming is facing major challenges at a global level due to increasing uncertainty in markets, policies, socio-cultural trends, and the environment. One of the hot topics in research and policy design is to reconcile the sometimes conflicting objectives of delivering both animal products and environmental services. In Europe, as in other parts of the world, focus has been placed on the design of more sustainable farming systems, emphasizing the multifunctional role of livestock in the preservation of natural resources and the socio-economic development of rural areas.

On mountain pastures in particular, adequately conducted livestock can be a tool for the efficient management of large areas of high natural value. At the same time, it can sustain a viable economic activity and provide differentiated products that fulfill societal demands for quality and environmentally-friendly production. Optimizing these aspects requires a multidisciplinary approach, combining research and development on ecology, animal, plant, social and environmental issues. One of the objectives of the FAO-CIHEAM Subnetwork on Mountain Pastures, part of the FAO Network on Pastures and Fodder Crops, is to exchange information on these aspects. For this purpose, among other activities, it organizes biennial meetings in singular European mountain areas.

This publication compiles the contributions presented at the 19th Meeting of the FAO-CIHEAM Mountain Pastures Subnetwork, held in Zaragoza (Spain) in 2016: "Mountain pastures and livestock farming facing uncertainty: environmental, technical and socio-economic challenges". The meeting was co-organized by the Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA) and the Mediterranean Agronomic Institute of Zaragoza (IAMZ-CIHEAM), with collaboration from the University of Lleida and the Pyrenean Institute of Ecology (IPE-CSIC). The organization received financial support from the National Institute for Agricultural and Food Research and Technology (INIA) of the Spanish Ministry of Economy and Competitiveness.

Over 90 researchers and technicians involved in research and development activities on mountain pastures participated in the conference and presented 60 papers. The meeting, and consequently this Book of Proceedings, was organized around one invited conference and four scientific sessions:

- Pathways towards mountain farming system sustainability: assessment methods and case studies.
- Livestock on mountain pastures: animal performance and quality products.
- Animal-Pasture interactions in mountain areas: bottlenecks and opportunities in biodiversity management and forage production.
- Mountain pastures and society: biophysical, economic and socio-cultural valuation of ecosystem services.

The organizers would like to thank all the persons and institutions that have been involved in the meeting: direct participants (authors, reviewers and chairs), technical staff at the IAMZ, funding and hosting institutions, and those collaborating in the technical visit to pastures and farms in the Pyrenees. We hope that the fruitful exchange of information at the meeting can provide the basis for joint research projects, and eventually contribute to the development of technically and environmentally sound livestock production systems on mountain pastures.

Isabel Casasús and Giampiero Lombardi

On behalf of the Scientific and Organizing Committees

19th Meeting of the FAO-CIHEAM Mountain Pastures sub-network

Mountain pastures and livestock farming facing uncertainty: environmental, technical and socio-economic challenges

(14-16 June 2016. Zaragoza, Spain)

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Welcome Lecture

Profitability of permanent grasslands: How to manage them in a way that combines profitability, carbon sequestration and biodiversity?

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Abstract. The Focus Group “Profitability of Permanent Grassland” of the EIP-AGRI addressed the challenge of evaluating the current situation and defining paths for increasing profitability in a sustainable way. The multiple aspects of enhancing profitability and sustainability were grouped into seven key issues:

- Definition of a grassland typology in relation to their biodiversity and productivity.
- Achieving grassland production and quality that matches animal needs.
- Benchmarking grassland production.
- Increased grassland functionality through diversification of sward composition.
- Increased resource efficiency to improve profitability and sustainability.
- Differentiation of grass-based products for higher market value.
- Evaluation of the environmental impacts of grassland-based and livestock systems using Life Cycle Thinking.

The main conclusions include practical recommendations, the identification of relevant fail factors and ideas to overcome them, and potential innovative and research actions, such as:

- Provide farmers with appropriate technology to optimise grass production, including tools to better manage grazing systems.
- Integrate data sets at local level and implement ICT tools for interconnecting advisory services and other stakeholders.
- Develop benchmark systems.
- Develop management tools of animal-sward interactions to maximise productivity and biodiversity (including animals adapted to grassland management systems).
- Develop tools to describe ecosystem services and link grassland management to local demands.
- Define technical and political solutions to capture value of high quality products and ecosystem services.
- Evaluate grassland-based and livestock systems through Life Cycle Assessment.
- Develop knowledge production through a participatory process notably with Operational Groups.
- Identify different farmers’ incentives for innovation and for using the innovative solutions.

Keywords. Management tools – Ecosystem services– Product quality – Participatory approaches.

Rentabilité des prairies permanentes : Comment les gérer de façon à combiner rentabilité, stockage du carbone et biodiversité ?

Résumé. Le Groupe Cible « Rentabilité des prairies permanentes » de l’EIP-AGRI a relevé le défi d’évaluer la situation actuelle et de définir des voies pour atteindre une plus grande productivité de manière durable. Les multiples aspects relatifs à l’augmentation de la productivité et de la durabilité ont été groupés en sept questions clés :

- Définition d’une typologie des prairies par rapport à leur biodiversité et productivité.
- Production de qualité qui répond aux besoins des animaux.
- Analyse comparative de la production des prairies.
- Fonctionnalité accrue des prairies par la diversification de la composition de leurs couverts.
- Augmentation de l’efficacité de l’utilisation des ressources pour améliorer la rentabilité et la durabilité.
- Différenciation des produits basés sur herbe pour une valeur marchande plus élevée.
- Évaluation des impacts sur l’environnement des systèmes basés sur les prairies et l’élevage en utilisant le Raisonnement du Cycle de Vie.

Les conclusions principales comprennent des recommandations pratiques, l'identification des facteurs d'échec, des idées pour les surmonter, et des actions potentielles innovantes et de recherche, comme :

- Fournir aux agriculteurs la technologie appropriée pour optimiser la production d'herbe, y compris au pâturage.
- Intégrer des ensembles de données au niveau local et mettre en œuvre les outils ICT pour mettre en réseau diverses parties prenantes.
- Développer des systèmes d'analyse comparative.
- Développer des outils de gestion des interactions entre animaux et couverts prairiaux pour maximiser la productivité et la biodiversité.
- Développer des outils pour décrire des services écosystémiques et faire correspondre la gestion des prairies aux demandes locales.
- Dégager des solutions techniques et politiques pour prendre en compte la valeur des produits de haute qualité et celle des services écosystémiques.
- Comparer les systèmes basés sur les prairies et l'élevage par l'Évaluation du Cycle de Vie.
- Développer la production de connaissances par un processus participatif notamment dans des Groupes Opérationnels.
- Identifier différents incitants pour les agriculteurs pour qu'ils innovent et utilisent ces innovations.

Mots-clés. Outils de gestion – Services écosystémiques – Qualité des produits – Approches participatives.

I – Introduction

In 2012, permanent grasslands (PG) covered more than 60 million hectares across the EU-28 according to Eurostat. They accounted for 34.6% of the total Utilised Agricultural Area (UAA), although there were large differences between countries. The highest percentages were found in Ireland (80% UAA), the United Kingdom (65%) and Slovenia (65%) (Huyghe *et al.*, 2014).

Permanent grasslands are by far the first crop in Europe although their area has declined due either to abandonment and afforestation, to urbanization or to conversion to arable crops including green maize. These changes affect many livestock production systems which play a role in maintaining natural resources such as local breeds and their associated products. They also influence PG biodiversity and ecosystem services they provide, e.g. C sequestration, cultural heritage, including the contribution to beautiful and living landscapes.

Within the context of the European Innovation Partnerships for Agricultural Productivity and Sustainability (EIP-AGRI), several Focus Groups (FG) were created for "helping the agricultural and forestry sectors to become more productive, sustainable and capable of tackling current challenges such as fiercer competition, more volatile market prices, climate change and stricter environmental rules" (<http://ec.europa.eu/eip/agriculture/>).

All the aspects mentioned above on permanent grasslands motivated the creation of a Focus Group "Profitability of Permanent Grassland". In 2014 and 2015, this FG regularly met and addressed the challenge of evaluating the current situation, the status, the constraints and the perspectives for these habitats and their related rural communities. The group included farmers, farmers' advisers, representatives of Farmers Unions and other NGOs, and scientists.

PGs were defined as "any land/vegetation that can be grazed/mown and that has not been included in the crop rotation of the holding for a minimum of five years, independently of the type of vegetation, the type of animal or the type of farming system". Other definitions are though available in Europe such as the one of the EC Regulation N° 1307/2013 published on 17 December 2013 and that of a group of recognised grassland scientists (Peeters *et al.*, 2014).

The full report of the Focus Group is available on the web site: <https://ec.europa.eu/eip/agriculture/en/content/profitability-permanent-grassland>.

II – Permanent grassland issues or functions

The Focus Group clustered the multiple aspects of enhancing permanent grassland productivity and sustainability into seven key issues:

1. Definition of a grassland typology in relation to their biodiversity and productivity.
2. Achieving grassland production and quality that match animal needs.
3. Benchmarking grassland production and its utilisation at regional and national levels.
4. Increased grassland functionality through diversification of sward composition.
5. Increased resource efficiency to improve profitability and sustainability.
6. Differentiation of grass-based products for higher market value.
7. Evaluation of the environmental impacts of grassland-based and livestock systems by using Life Cycle Thinking (LCT).

The seven topics identified by the Focus Group are interrelated (Fig. 1).

European farmers deal with very different environmental and socio-economic conditions. For this reason, permanent grasslands are not uniform and neither are the associated production systems. Therefore a proper typology of PG is needed (Issue 1) to evaluate their potential from economic and environmental perspectives (Peeters, 2015). By understanding the diversity of management scenarios linked to the diversity of PG, their quality and quantity can be increased as well as the efficient use of available resources. In particular, the FG discussed which tools and strategies farmers can apply to match animal needs (Issue 2).

Proper data and benchmarks are needed at site and region levels to increase profitability (Issue 3). By benchmarking grass production and establishing the reasons for differences in grass output, botanical composition, grazing season length, ratio of grazing to harvesting, etc., a better understanding of PG potential and management could be obtained. The FG discussed tools that could be used at farm level by farmers to increase their knowledge with reference to the benchmarks of their farm.

The sustainable management of PG requires a compromise between different factors (Issue 4). The challenge when balancing sward composition is to optimise productivity, climate adaptation, environmental impact or nutrient efficiency by improving functional group diversity of sward species. Sward components vary in their morphological characteristics, feeding quality, nutrient uptake, water needs, etc. Therefore, their relative presence significantly affects animal performance, health and welfare, as well as product quality and environmental impact. Functional benefits of increasing sward diversity should be appreciated when considering simultaneously productivity and ecosystem processes and services.

Proper resource use efficiency (land, vegetation and animal) should be optimised. This involves considering trade-offs between profitable use and delivery of ecosystem services by using a minimum level of complementary external inputs to ensure profitability (Issue 5). It also requires that the livestock type is adapted at different levels (Ferreira *et al.*, 2013) to local resources and to a forage self-sufficient system (Osoro *et al.*, 2015).

There is a great potential to add value to products from PG. The FG explored how premium grassland-based products can achieve a high market value (Issue 6).

Maximising positive ecological impacts (Rosa *et al.*, 2013) could be highlighted to improve competitiveness of grassland-based farming through market mechanisms or by public incentives linked to enhanced services provided to society. Life Cycle Thinking approaches and evaluation methods should help to accordingly identify, quantify and showcase ecosystem services provided by PG-based farms (Issue 7). This is particularly important for PG located on marginal lands or within protected and High Nature Value (HNV) areas.

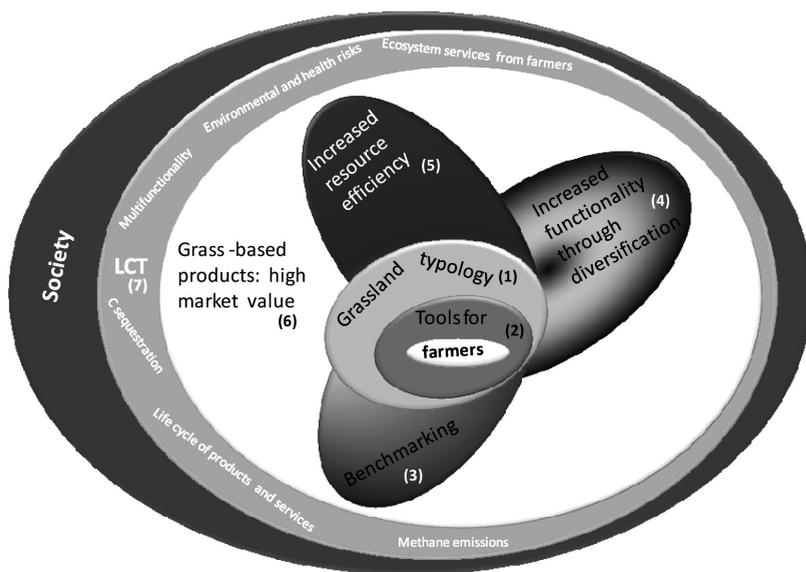


Fig. 1. Relationship and interactions between issues (issue number in brackets).

III – Innovative actions and research needs: a summary of the Focus Group findings

1. Definition of grassland typology in relation to their biodiversity and productivity

Innovative actions

- Create a typology of permanent grasslands according to their multi-functionality, particularly to their productivity and biodiversity values.
- Document easy-to-use indicators for PG identification based on their production potential, management and main ecological conditions.
- Document ecological relationships among PG types that can be used in management: how to maintain PG types or how to move from one type to another.
- Map PG types and adapt existing vegetation maps to PG typology and Land Parcel Information System maps.

Research needs

- Design new methods and tools to evaluate the role of functional biodiversity in the field, including legumes and woody vegetation.
- Develop comparable botanical methods easily implemented at plot and farm level for a variety of vegetation types.
- Develop remote sensing based technologies and statistical classification techniques for easy and broad scale classification.
- Develop models to better understand interactions among biodiversity components for different soil and climate conditions.

2. Achieving grassland production that matches animal needs

Innovative actions

- Develop methods to quickly measure grass yield.
- Promote “brain storming” and learning processes in mixed groups, where farmers could learn from farmers and other stakeholders, and could identify possible solutions.
- Develop internet/smartphone applications for grassland management (e.g. grazing planning, grazing measurements, assessing forage quality, etc.).
- Put into practice tools that can help farmers to identify the critical animal body condition at periods affecting productivity, such as before mating, calving/lambing, and finishing before slaughter.

Research needs

- Develop models to predict grass growth for assisting farmers in managing a fluctuating grass supply. Develop practical tools (robust, simple to use and appealing) taking advantage of the large amount of information already available in farm-related databases and territorial information systems.
- Increase yield through a combination of an extension the grass growing season in areas where the weather allows this, more focussed plant breeding, use of forage mixtures (including legumes and woody vegetation), smart fertilisation, dynamic and flexible stocking systems.
- Develop novel grazing systems (large-scale, high/medium/low productive, highly automated) that are technically and socially feasible, economically viable and environmentally sound.
- Design new strategies to convert grassland management into an attractive activity for young generations.
- Develop the concept and methods for precision grazing which include all components of agroecosystems, particularly plant-animal-product interactions.

3. Benchmarking European grassland production and utilisation at national and regional levels

Innovative actions

- Select measuring tools (visual assessment, plate meter, stick, palatable species height, etc.) to estimate dry matter production adapted to different grassland types.
- Develop national and Europe-wide grassland databases. These databases would be populated with data from commercial farms within Member States.
- Increase measurements of dry matter production, quality and biodiversity across Member States. Integrate these data in a grassland measurement network.

Research needs

- Further investigate the potential of plant species to provide bioactive compounds, biomass production, etc.
- Improve grass growth prediction at regional, national and international levels.
- Integrate the following knowledge into a database for subsequent analyses, development of models and practical tools:
 - Potential dry matter production levels and seasonal distribution that can be achieved in different kinds of PG in Europe.

- Estimation of production cost of grass as a feed and definition of a common methodology for all EU Member States.
- Yield variation between EU Member States, accounting for soil type, climate, grazing animal type, management etc.

4. Increased grassland functionality through diversification of sward composition

Innovative actions

- Develop new methods for introducing legumes and herbs into pasture to enhance productivity, digestibility and herbage intake by grazing animals.
- Select multi-species mixtures with different growth patterns for PG establishment and renovation under different soil and climate conditions and linked to different animal species and breeds.
- Develop and optimise types, density and distribution of trees and shrubs using agroforestry practices (hedges, wooded pasture, multi-purpose woody vegetation).
- Use legumes, forbs and shrubs rich in tannins to maximise protein utilisation, prevent bloat, suppress internal parasites and produce healthier food.
- Optimise and/or develop new forage conservation techniques to avoid nutrient losses, mitigate the risk of forage contamination (e.g. mycotoxins) and minimise the use of maize silage and concentrates.

Research needs

- Optimise the combination of the extension the growing season, plant breeding, use of mixed dynamic stocking systems.
- Breed new forage species better adapted to extreme weather conditions.
- Identify seed mixtures for each soil/climate condition and production system (dairy, meat, cattle, sheep, goats, horses, etc.) by using different functional groups.
- Improve legume management by grazing for better persistence and intake.
- Monitor grassland production by remote sensing.

5. Increased resource efficiency

Innovative actions

- Inform farmers on pasture growth in specific locality: use of the 'big data' concept to enable matching grass growth with input utilisation and outputs.
- Improve fertilisation strategies to increase grassland production with less input.
- Develop and promote new systems of mixed grazing (for cleaner grazing with fewer parasite eggs, better use and higher animal and grassland growth rates).
- Improve grazing practices and strategies to reduce the parasite burden, especially on meadows. Look for plants containing condensed tannins or other beneficial animal nutrients associated with legumes, other herbaceous dicotyledons and shrubs.
- Optimise silvo-pastoral practices to promote efficient production of milk, meat, bio-energy, bio-diversity etc.
- Reduce labour by using new technology to supervise animals on large areas.

Research needs

- Improve understanding of the association of microorganisms with plants, to promote plant uptake of soil nutrients.
- Find adequate productive and persistent legume and woody species, cultivars and their respective Rhizobia adapted to variable soil and climate conditions.
- Develop knowledge on soil microorganisms, inoculants and processes which, in association with plants, may be able to solubilise P (e.g. *Pseudomonas*) and/or extend the plant rhizosphere (e.g. arbuscular mycorrhiza) and their potential use for improving legume growth and woody vegetation.
- Establish methods or practices to avoid negative interference between extensive production systems and predators to avoid conflicts between farmers-shepherds and other groups (e.g. nature conservationists).
- Identify the main factors preventing farmers from using PG and affecting farm management: current policies, authorities, markets, lack of cooperatives, limited access to credit, extension and technical information, access to slaughter houses, vets, etc. (especially on small farms and marginal areas).

6. Differentiation of grass-based products for higher market value: linking quality traits and management practices

Innovative actions

- Define marketing arguments ensuring valorisation of permanent grassland-based products to consumers (e.g. by promoting local breeds and cultures).
- Develop mobile applications making easy product marketing and delivery from remote PG areas.
- Adapt legislation to control food safety of homemade products, so that they can be implemented in rural conditions.
- Improve communication to increase citizens' awareness about the characteristics and functionalities of this type of products.

Research needs

- Identify a set of markers to allow product identification in relation with management practices and/or origin. Optimise authentication and traceability protocols minimising the bureaucratic effort for farmers. Exploit the potential of ICT-based tools.
- Develop affordable and rapid analytical methods for routine authentication and traceability, including a validation at local level under controlled conditions or on-farm on a large scale.
- Establish ways to help farmers to identify society preferences for their products.
- Refine understanding of the effect of botanically diverse composition of PG on the product biochemical composition, quality and functionality.
- Appraise the relevance of ecosystem services for product improvement. Study and model the trade-offs between product quality traits and other ecosystem services.

7. Life cycle assessment: evaluation of the environmental impacts of grassland-based and livestock systems using Life Cycle Thinking (LCT)

Innovative actions

- Develop user-friendly, inter-operable indicators and tools at farm scale for LCT assessment of PG-based and livestock farms.
- Integrate data sets at local and regional levels by a participatory approach integrating different stakeholder types to provide an accurate dynamic picture to the market.
- Design new strategies and tools to communicate to final consumers LCT assessments of PG systems (i.e. territorial committees of stakeholders where farmers and consumers directly participate, using social media to improve connections between rural and urban life, to form a network of educational grassland-based farms).

Research needs

- Assess the role of PG on soil erosion control, wildfire prevention, carbon sequestration, enhanced biodiversity and products with functional components from LCT perspective.
- Further develop and apply LCT to support scientifically sound methodological choices enabling a harmonised assessment of improvement options for social acceptability of agricultural systems.

IV – Fail factors and solutions

A summary of the identified fail factors of PG systems is presented in Figure 2. It shows the complex interactions among different components of the systems. This complexity is also reflected by the multi-dimensional and multi-level fail factors: *i.e.* PG are not directly marketed but are the main resource for different types of livestock productions and, at the same time, they deliver many important ecosystem services, which are often not properly assessed and rewarded. The more complex the value chain, the more potential failures at different steps.

The first step for designing new solutions is to recognise the need to involve all actors, that their actions have multiple consequences, and that the responsibility for system maintenance and development should be assumed by all. This includes farmers, scientists, advisers, official institutions, enterprises, and consumers.

The Focus Group sought to identify innovative ideas or actions, which would address the different problems within each section of fail factors (Fig. 3). These can be grouped under six generic headings:

1. improved knowledge/information/expertise;
2. enhanced investment in research/education;
3. enhanced resources (actors/tools);
4. reduced bureaucratic and regulatory restrictions;
5. improved marketing infrastructure;
6. enhanced stakeholder communication.

The proposed improvements at different levels in agricultural knowledge and innovation systems should result in numerous innovative actions to improve PG management. However, some other failures directly affecting productivity and sustainability may be difficult to address. For example,

how to stop land abandonment in marginal areas where there are still big problems with social services. There are also more subtle problems linked to socio-economic matters, even cultural issues. For example, young farmers have to follow protocols accepted in their family/community, or fight against values linked to many PG regions. Breaking from these will not be easy. Such fail factors linked to young farmers, should be given priority as they will be responsible for the future. Other actions may need a change of philosophy within community groups. Farmers assuming risks and getting involved as stakeholders, will have to take a more business-like approach to farm management, and should be encouraged to sell their products directly to local markets, thereby helping to maintain a vibrant rural economy and a cohesive rural society. Getting citizens to accept their direct or indirect responsibility for the continued existence of PG is also difficult, given the physical, social and economic differences that often exist between rural and urban communities. However, this issue must be tackled. Likewise it is important that public institutions recognise their role in searching for solutions which take into account all stakeholders, the peculiarities of each situation, and most importantly, which are independent of political scenarios.

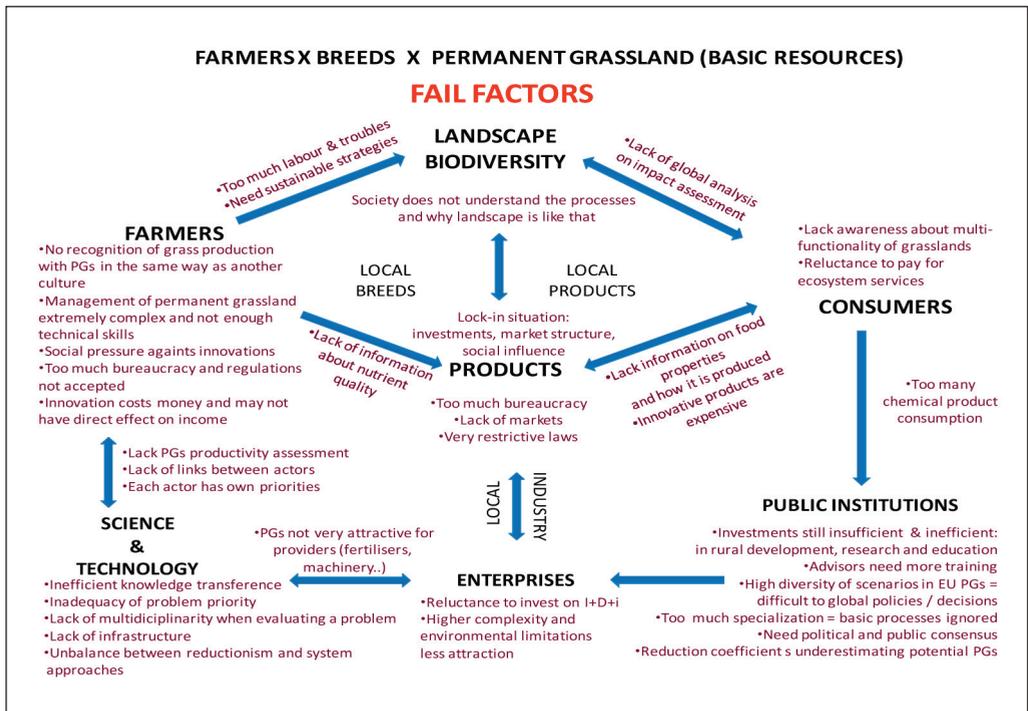


Fig. 2. Summary of fail factors linked to the sustainable development of permanent grasslands.

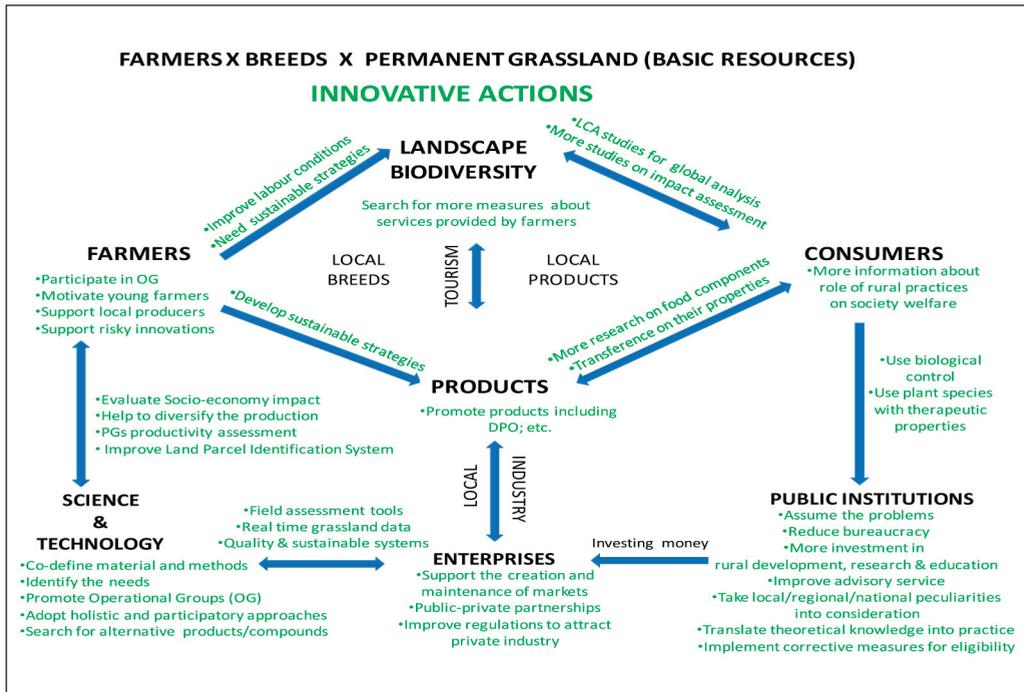


Fig. 3. Summary of innovative actions linked to the sustainable development of permanent grasslands.

V – Conclusions

The Focus Group paid special attention to the farmers' point of view. Out of all the issues identified by all experts, a few were further identified as particularly important from their perspective by farmers present in the group (marked with '(F)').

Innovation Needs

- Integrate data sets at local level and implement ICT tools to connect advisory services and other stakeholders (Decision Support Systems, DSS).
- Provide technology to farmers to optimise grass production (F) and to identify the best grazing systems using new technologies such as DSS, ICT tools, Big Data (F).
- Re-think technical and political solutions to improve farmers' livelihoods by producing quality products (F).

Research needs

- Develop a benchmark system for future dairy and meat farms (large scale, high production) integrating productivity, environmental, biodiversity, carbon sequestration and adaptation to climate change (F).
- Assess Life Cycle of PG systems including ecosystem services at regional level.
- Develop tools describing ecosystem services of PG to respond to local demand (F).
- Research & analyse what motivates different groups of farmers in their strategies for PG management (F).

Development needs

- Share knowledge between farmers, scientists and other stakeholders about the management of PG in a participatory approach (F).
- Use demonstration/pilot farms.
- Manage animal/sward performance to maximise productivity, biodiversity, carbon sequestration and climate change adaptation (F).
- Identify animal/grassland systems adapted to available resources and markets.
- Increase biodiversity in agri-environmental measures (adding product value-labelling).

More efforts in participatory and holistic approaches with farmers are required, with a special focus on the correct use of the different management strategies adapted to local conditions. Ecosystem services which currently have no market value may become valuable also in monetary terms in the future and farmers may also, therefore, seek to maximise ecosystem service values. After two or three decades of research, the contribution of farmers to their provision is still not quantified in practical terms. LCA approaches should be developed to assess PG systems and to fill in this gap.

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Session 1

Pathways towards mountain farming systems sustainability: assessment methods and case studies

Beef cattle farms in less-favoured areas: drivers of sustainability over the last 24 years. Implications for the future

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Abstract. Over the past 24 years (1990-2013), the Common Agricultural Policy reforms succeeded one another with subsidies provided to compensate the erosion of farm meat and grain prices. Support was given to grasslands or extensive farming systems. One response to the CAP, but also to market signals, was that French beef cattle farms in less-favoured areas have expanded in size and increased labour productivity by over 70%, chiefly, though not exclusively, through capital intensification (labour–capital substitution) and simplifying herd feeding practices (more concentrates used). The technical efficiency of beef sector production systems, as measured by the ratio of the volume of farm output to volume of intermediate consumption, has fallen by nearly 20%. The environmental performances did not improve, while income per worker has held stable thanks to subsidies and the labour productivity gains made. Among the various beef cattle production systems, grass-based and low inputs systems displayed encouraging performances compared to lowland mixed crop-livestock farming systems. These grass-based suckler cattle production systems in less-favoured areas seem to be better prepared to face the future beef production scheme and societal demand. Public policy also has its role to play by supporting positive externalities of low inputs and grass-based beef cattle farming systems.

Keywords. Suckler beef farms – Less favoured areas – Economics – Environment – Efficiency.

Systèmes d'élevages bovins allaitants en zones défavorisées : déterminants de leur durabilité sur les 24 dernières années. Questions et perspectives.

Résumé. Au cours des 24 dernières années, en réponse à l'évolution des soutiens aux élevages bovins allaitants en zones défavorisées herbagères, et à leur environnement socio-économiques, ces exploitations d'élevage ont accru leur taille et productivité du travail de 70%. Cette évolution s'est opérée par une intensification de l'utilisation du capital (substitution travail/capital) et par une simplification des pratiques d'alimentation (notamment par une plus forte utilisation de concentrés). L'efficacité technique de ces systèmes de production, mesurée par le ratio volume de production agricole sur volume de consommations intermédiaires et capital utilisé, a chuté de près de 20%. Les performances environnementales ne se sont pas améliorées, et le revenu par unité de main d'œuvre s'est juste maintenu grâce aux aides et aux gains de productivité du travail. Parmi la diversité des systèmes de production de viande bovine, les systèmes herbagers et/ou à faibles intrants montrent d'encourageantes, voire meilleures, performances comparativement aux systèmes polyculture-élevage de plaine. Ces systèmes herbagers des zones défavorisées semblent mieux armés face à la potentielle future demande sociétale et à celle des filières concernant la production de viande bovine. Les politiques publiques ont également leur rôle à jouer, principalement en supportant les externalités positives des systèmes herbagers à faibles intrants.

Mots-clés. Elevages bovins allaitants – Zones défavorisées – Economie – Environnement – Efficience.

I – Introduction

European (UE) beef farming systems are relatively diverse, the main system being the cow-calf production system that concerns half of the European commercial beef farms (Sarzeaud *et al.*, 2008). The bovine activity of cow-calf farms is based on calf production from a suckler cow herd. The cow-calf farms produce either weaners (cow-calf producers) sold to fatteners, or fatten the majority of the progeny on their farms (cow-calf-fatteners). The UE pure cow-calf producers (60% of the suckler cattle owners) are mainly located in 3 areas: 27% in the grasslands of Britain, Ireland, France and North Europe, 20% in the Mediterranean areas of Spain, Italy, Greece or Portugal, and 16% in the mountain areas of France, Spain and Eastern Europe. This distribution of the beef farming systems on the European territory causes that 71% of the 12.1 million suckler cows of the European Union in 2014, are located in only 4 countries (Eurostat, 2016): France 4.1 million (34%), Spain 1.9 million (16%), United Kingdom 1.5 million (13%) and Ireland 1.0 million (9%).

Suckler cattle farming systems play a key role in agricultural production and rural development of European mountains and grassland areas (McDonald *et al.*, 2000; Casaus *et al.*, 2007). Grass-based livestock farming systems are highly relevant in both environmental and social terms (Gibson, 2005). Over the last decades, as a response to the evolution of the public aids and subsidies (successive reforms of the Common Agricultural Policy (CAP)) and to their socio-economic environment, these suckler cattle farming systems have considerably changed. The objective of this paper is to analyse past trends in order to check if beef cattle systems are evolving toward more sustainable systems. The sustainability will be assessed in terms of revenue, production efficiency, greenhouse gas (GHG) emissions and fossil energy consumption, based on beef cattle farms data from 1990 to 2013, in French mountain and/or less-favoured areas, from different farm networks. Since mixed crop-livestock farming enjoys broad consensus as an economically and environmentally sustainable farming system (Ryschawy *et al.*, 2012), it will be tested if the presence of crops improve beef cattle farms sustainability.

II – Context, data bases and methods

Suckler cattle farming is a major feature of French agriculture. French beef farmers are cow-calf producers and cow-calf-fatteners. 60% of the males are exported as store cattle to the Italian fattening enterprises. The national beef herd, 4.1 million suckler cows, is mainly composed of various pure breeds. With its 1.5 million cows, Charolais is the main breed. The Charolais area, located in the North Massif Central (a grassland and less-favoured area within Central France), counts 41% of the French Charolais-breed cows, that is to say 20% of the total French suckler cows.

1. Beef cattle farm networks

Two networks were used to analyse recent evolution of beef cattle farms.

The Farm Accountancy Data Network (FADN) is an EU-wide harmonized network that sources and publishes representative statistics on farming business accounts, revenues and economics. Farms in the FADN-scope field of survey are classed by region under a typology scheme based on their type of farming (TF). Specialized beef cattle farms are classified as TF46. Ninety-eight percent of the French beef cattle farms represented in 2013 have suckler cows (cow-calf producers and cow-calf-fatteners). We distinguished the 3 regions where mountains and less-favoured areas are a major part of their territory: Auvergne, Limousin and Midi-Pyrénées (the other French mountains regions, Alpes and Jura, are dairy production oriented). In these 3 less-favoured regions, we found 39% of the total French cattle farms in 1990, and 44% in 2013.

In order to understand the drivers and determinants of evolutions in suckler cattle system farms, an Economics team from INRA set up a **Charolais-region suckler beef farms farm network** for

long-term observational statistics that has been running since the 1970s. Each farm in the network is surveyed every year. Data is collected on labour, structure, land allocation scheme, herd, aggregated intermediate consumption, sales, aids and subsidies, investments and borrowing. To study the main evolutions (structure, productive, economic and environmental performances) over a long period, we were able to form a constant subsample population of 43 farms, from 1990 to 2013 (Veysset *et al.*, 2014a).

As we want to study the performances of grass-based and mixed crop-livestock farming systems, we subdivided a constant group sample of 59 farms from the Inra network tracked over 2 years (2010 and 2011) into three groups: (i) "GF", this group includes 7 farms where the entire utilized agricultural area (UAA) is grassland, (ii) "B/c": 31 specialized farms that only market animal products but that grow cereal crops on-farm for animal feed, and (iii) "B+C": 21 farms that sell both beef and cereal crops to market. MFA covers only 68% of UAA.

2. Expression and analysis of results

We underlined the major evolutions on the structure, farm sizes, and economic results observed on the FADN TF46 mountain (FADN TF46-Mo) and Charolais INRA-network (INRA-Charol). As we had, for the INRA-Charol, values of all structural, technical and economic variables year by year, it was possible to detail the evolutions of the productive performances, feeding and inputs use strategies. The presented results were the respective annual average values of all farms constituting each network.

To question the rationality of the management system and the technical efficiency of the production system, we calculated the volume of the total farm product, the volume of the intermediate consumptions and the volume of fixed capital used each year, for both networks. For that, we have separated the variation of annual economic values of each output/input into volume variation and price variation. The annual values of each product have been weighted with their own index of producer prices of agricultural products (PPAPI). In the same way, the annual mean values of each cost were weighted with their own respective index of purchase prices of the means of agricultural production (PPMAPI). Once weighted to correct for pure price effects, annual evolutions represent evolutions of volumes produced and consumed. The technical efficiency of the production systems was represented by the ratio: volume of farm product over volume of intermediate consumptions plus fixed capital consumed (Veysset *et al.*, 2015). In addition to this evolution of the technical efficiency, we presented, for INRA-Charol, the evolution of the emissions of greenhouse gas (GHG) and non-renewable energy (NRE) consumption per kg of live weight produced (kglw). The methodology to assess the GHG emission and NRE consumption per kglw for each farm was detailed by Veysset *et al.* (2014b).

To assess if there was some significant performances differences between the three identified suckler cattle farming systems (GF, B/c, B+C), we ran a systemic analysis of the three groups (Veysset *et al.*, 2014c).

III – Results and discussion

1. Main structural trends

The main structural trends marking beef cattle farms over the 1990-2013 period (Table 1) were:

- large increase in hectarage, herd size, and labour productivity (hectarage and number of livestock units per worker unit, respectively +55% to +78%),
- continued reliance on grassland systems, with extensification,
- considerable capital investment (capital per worker +41% to +52% in constant-euro values).

The networks did not show a land intensification trend, and in INRA-Charolais we observed a de-intensification of the forage area, in 2013 stocking rates were on a par between networks. Charolais farms, in less favoured Charolais area, were less beef-specialised than farms in mountainous areas.

Despite this strong increase in labour productivity, income per worker has remained relatively stable in the two networks, with strong interannual variability (Fig. 1). The trends ran parallel between both networks, the revenue differential between the FADN sample and the INRA-Charolais sample was due to difference in structures, breeds and regions.

Table 1. Main structural characteristics of the Farm Accountancy Data Network, French mountains, type of farming beef cattle farms (FADN TF46-Mo), and the constant INRA-Charolais-network sample of 43 beef cattle farms: 1990 vs 2013. Average values of each variable for each sample

		1990	2013	Trend, %
Annual work units, AWU	FADN TF46-Mo	1.54	1.36	-12
	INRA-Charolais	2.09	2.00	-4
Utilized Agricultural Area, UAA, ha (UAA/AWU)	FADN TF46-Mo	65 (42)	102 (75)	+56 (+78)
	INRA-Charolais	122 (58)	191 (95)	+57 (+64)
Livestock Units, LU (LU/AWU)	FADN TF46-Mo	70 (45)	108 (80)	+54 (+75)
	INRA-Charolais	123 (59)	183 (91)	+48 (+55)
Main Fodder Area, MFA, % UAA	FADN TF46-Mo	87	88	+1
	INRA-Charolais	82	83	+1
Stocking rate, LU/ha MFA/year	FADN TF46-Mo	1.23	1.23	≈
	INRA-Charolais	1.29	1.22	-6
Specialization [†]	FADN TF46-Mo	88	89	≈
	INRA-Charolais	83	86	+3
Non-land assets, k€/AWU ^{††}	FADN TF46-Mo	167	235	+41
	INRA-Charolais	190	289	+52

[†] Specialization = gross product on cattle (excl. aids) / gross farm product (excl. aids).

^{††} Non-land assets: constant-euro values for 2013 (deflator: national consumer price index).

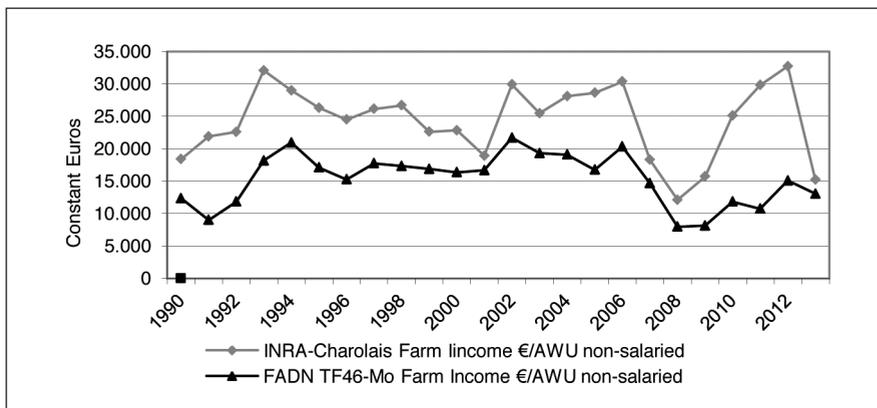


Fig. 1. 1990-2013 evolution of the farm income (FI) per non-salaried worker (AWU non-salaried).

Income in constant-euro values for 2013 (deflator: national consumer price index). FADN TF46-Mo: Farm Accountancy Data Network, type of farming beef cattle farms, in mountain. INRA-Charolais: constant sample of 43 Charolais beef cattle farms.

All the French suckler cattle farms were more and more dependant to the aids and subsidies, especially since the Mc Sharry CAP reform in 1992 (Veysset *et al.*, 2005a). Aids and subsidies represented 60% to 90% of the farm income in the early 90's. Since 1995, aids and subsidies were higher than the farm income in the two networks, without aids the farm income will be negative. Since the mid 2000's, aids and subsidies represented more than 200% of the farm income. Suckler cattle farms in mountainous areas were not more (or less) dependant to the subsidies than the average of the French suckler cattle farms.

2. Evolution of technical performances

The analysis of the INRA-Charolais network show that numerical productivity (number of calves weaned per 100 cows serviced) decreased by 1.4 percentage units in 24 years (86.9% in 2013 vs 88.3% in 1990). This numerical productivity decrease was related to lower pregnancy rate (from 94% to 91%) and a slight increase in calf mortality: 7.5% to 9.5%, trends observed in large herds (Veysset *et al.*, 2004). Given the strong and constant demand from Italian fatteners for young and heavy weanlings, the share of animals finished on-farm for slaughter has dropped: in 2013, only 24% of males sold to market were finished on-farm, against 42% back in 1990. However, the drop in numerical productivity and finishing was offset by the genetics gains and feeding practices leading an increase in body size (carcass weight of cull cows has gained 50 kg, i.e. +13%), and beef live-weight output per livestock unit (kgLW/LU: weight productivity) increased from 295 kg in 1990 to 313 kg in 2013, i.e. a 6% gain.

The increase in extensification premiums with Agenda 2000 (the 2000 Common Agricultural Policy reform package) was a strong incentive. Mean stocking rate dropped below 1.25 LU/ha MFA/year in 2002 and has stayed there ever since. The decrease in stocking rate corresponded with a drop in mineral fertilizers use per ha UAA: from 50 kg N/ha to 43 kg N/ha (-14%). This decrease in stocking rate practically cancelled out the increases in average weight productivity, with beef live-weight output per ha of forage area increasing by a modest 2 kg in 24 years (+0.6%) when beef live-weight output per LU gained 18 kg.

The de-intensification of forage area has not slowed efforts to improve the quantity and quality of forage harvested: the proportion of grassland mowed every year increased from 38% in 1990 to 47% in 2013, and the proportion of this mowed grasslands bale-wrapped climbed from 7% to 21% to the detriment of hay. Despite less on-farm fattening and more conserved forages available, the amount of concentrate distributed per kg of live-weight have increased substantially: +33% in 24 years (1.63 kg concentrate/kgLW in 1990 vs 2.18 in 2013). Note that to produce one kg of beef live-weight, concentrate produced on-farm (self-supplied) and concentrate bought off-farm have co-increased in use in the same proportions. The net result over 22 years was a 6 percentage unit drop in forage feed unit (FU) feed self-sufficiency (share of the herd's annual FU needs covered by FU from forages produced on the farm: 88% in 1990 vs 82% in 2013) and a 2 percentage point drop in total FU feed self-sufficiency (share of the herd's annual FU needs covered by FU from all feed produced on the farm: 94% in 1990 vs 92% in 2013). Over the period, cereal crop yield remained stable at around 4.7 tons/ha.

3. Global technical farm system efficiency

Volume of French beef cattle farm output (meat and crops) per ha UAA stayed flat over the last 24 years, nevertheless with a slight rise trend for the farms in mountain areas (Fig. 2). This flat-lined land productivity was associated with less intensive consumption (in volume terms) of fertilizer (-24% and -43% respectively for INRA-Charolais and FADN). However, these costs were the only expenditures to have decreased in volume terms over the period studied. Amounts used per ha UAA increased across the board for all other intermediate consumption expenditures, includ-

ing: cattle feed (+29% and +38% respectively), veterinary supplies (+31% and +8%), fuel (+55% and +47%), equipment maintenance and repair (+32% and +34%). In global trend terms, aggregate volume of intermediate consumption per ha UAA increased 0.64% and 0.55% per year respectively for FADN and INRA-Charolais. Despite the increase in farm size, annual fixed capital consumption (FCC) per ha UAA also increased, growing at a rate of 0.02% and 0.26% per year respectively for FADN and INRA-Charolais. Equipment expenditure was the main cause of this increase, accounting for more than 60% of annual fixed capital consumption per ha UAA.

The strong increase in physical labour productivity drove a 76% and 61% increase in output per worker (AWU) between 1990 and 2013 respectively for FADN and INRA-Charolais. However, over the same period, beef cattle farms registered strong increases in volume of intermediate consumption and fixed capital consumption per AWU (from +66% to +105% depending to the networks), with the result that value added per AWU fell by more than 35%. Net gains in labour productivity did not lead to net increase in value added per worker.

Stable volume of farm output per ha even at heavier intermediate and fixed-capital consumption per ha meant that technical farm system efficiency has declined over the last 24 years, in parallel across the two subsample populations surveyed (Fig. 3). Annual decline in technical efficiency was -0.5%/year for FADN-sample beef cattle farms and -0.7%/year for INRA-Charolais-sample beef cattle farms.

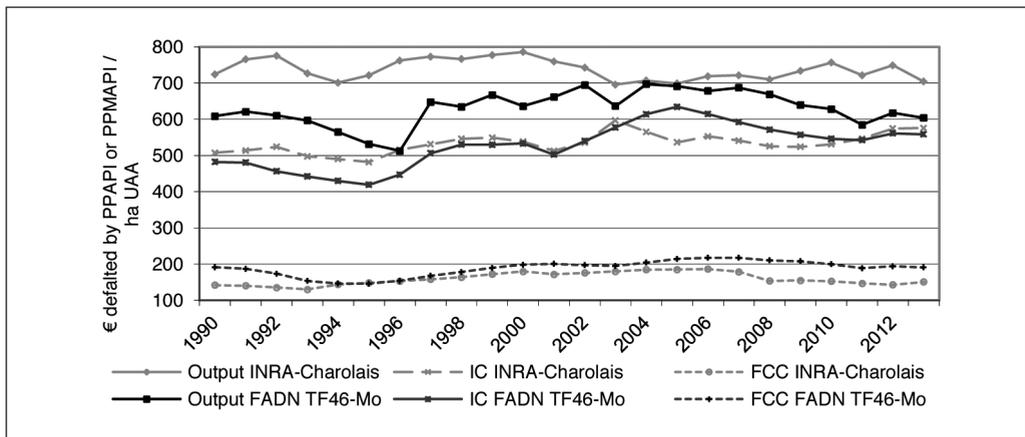


Fig. 2. Year-on-year trends in output volumes, intermediate consumption (IC) and fixed capital consumption (FCC) per ha agricultural area (UAA).

Figures in € deflated by index of producer prices of agricultural products (PPAPI) and index of purchase prices of the means of agricultural production (PPMAPI). FADN TF46-Mo: Farm Accountancy Data Network, type of farming beef cattle farms, in mountain. INRA-Charolais: constant sample of 43 Charolais beef cattle farms.

This technical farm system efficiency was strongly positively correlated to the feed self-sufficiency, itself negatively correlated with the farm size. Feed self-sufficiency was directly linked with the amount of purchased concentrates used per livestock unit. Despite a relative low variability in the total feed self-sufficiency, the largest herds (more than 250 LU) posted systematically lower results. We also observed that the farms with the lowest feed self-sufficiency (less than 82%) posted systematically low farm income per worker. Anyway, the technical efficiency is a positive determinant of income per worker.

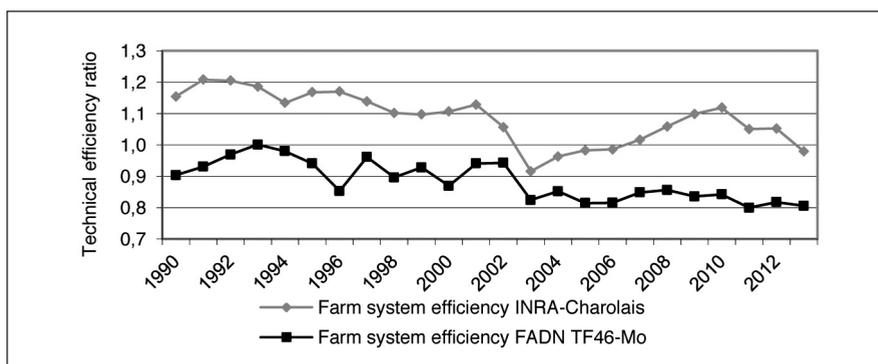


Fig. 3. Evolution of technical farm systems efficiency: farm product excluding aids in euros deflated by index of producer prices of agricultural products (PPAPI) / intermediate consumptions plus fixed capital consumed in euros deflated by index of purchase prices of the means of agricultural production (PPMAPI).

FADN TF46-Mo: Farm Accountancy Data Network, Mountain type of farming beef cattle farms.
 INRA-Charolais: constant sample of 43 Charolais beef cattle farms.

4. GHG emissions and fossil energy consumption

In the INRA-Charolais network, emissions of GHG per kg of live-weight produced tended to slightly decrease, while NRE consumption tended to increase (Fig. 4). The decrease in GHG emission was due to the slight increase in the animal productivity (kg/w produced per livestock unit), so to the dilution of emitted methane (CH₄). The method used to assess the GHG emissions at the farm level (GES'TIM, Gac *et al.*, 2010), allocated a fixed CH₄ emission per bovine animal, so this CH₄ emission per animal was the same in 1990 and in 2013, although animals were heavier in 2013.

A consequence of the decrease in technical farm system efficiency (more inputs and capital for the same volume produced), was the 15% increase in fossil energy consumed per kg/w.

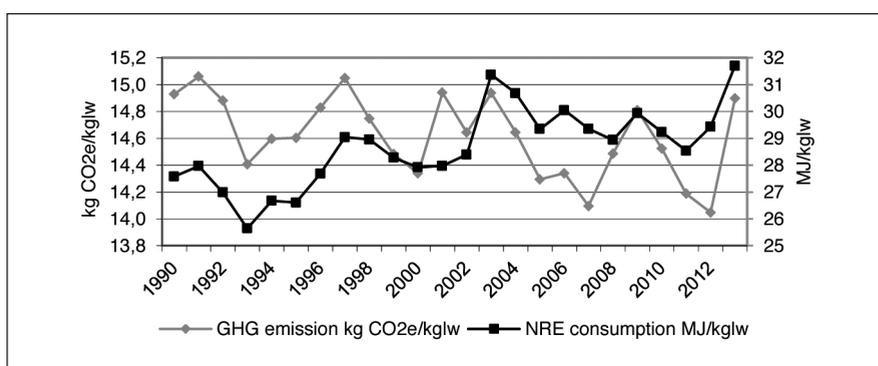


Fig. 4. Evolution of greenhouse gas (GHG) emissions in kg CO₂e and non-renewable energy (NRE) consumption in MJ, per kg of live weight produced (kg/w) for the INRA-Charolais network, constant sample of 43 Charolais beef cattle farms.

5. Grass-based and mixed crop-livestock farming systems

Main performances of the three groups: grassland farms (GF), beef farms that grow cereal crops on-farm for animal feed (B/c), mixed crop-livestock farms (B+C), over two years (2010 to 2011), were reported in Table 2. The size of the farms were not significantly different between the 3 groups, the stocking rate was lower in the grassland farms.

Table 2. Main characteristics and performances of the three groups: grassland farms (GF), beef farms that grow cereal crops on-farm for animal feed (B/c), mixed crop-livestock farms (B+C), over two years (2010 to 2011)

	GF	B/c	B+C
Structural characteristics			
Annual Work Units (AWU)	1.62 ^a	1.99 ^a	1.84 ^a
Usable Agricultural Area (UAA), ha	159.7 ^a	161.7 ^a	179.9 ^a
Main Fodder Area (MFA) % UAA	100 ^c	89 ^b	68 ^a
Total Cattle Area [†] (haCatt) % UAA	99 ^a	96 ^a	77 ^b
Livestock units (LU)	176.3 ^{ab}	179.6 ^b	158.8 ^a
LU stocking rate / ha MFA / year	1.15 ^a	1.24 ^b	1.27 ^b
LU stocking rate / haCatt / year	1.15 ^a	1.16 ^a	1.16 ^a
Technical performances			
Numerical productivity ^{††} , %	84.6 ^a	85.3 ^a	83.8 ^a
Kg live-weight produced (kg/w) / LU	320 ^a	317 ^a	320 ^a
% fattened cattle sold	31 ^a	45 ^b	30 ^a
Kg live weight (kg/w) produced / ha MFA	370 ^a	395 ^a	408 ^a
Kglw produced / haCatt	373 ^a	368 ^a	372 ^a
Total concentrates, kg / LU	638 ^a	740 ^a	834 ^a
On-farm concentrates, % total concentrates	0 ^a	56 ^c	58 ^b
Total concentrates, kg / kg/w produced	1.98 ^a	2.29 ^b	2.60 ^b
Feed self-sufficiency, Forage Units %	83 ^a	90 ^b	90 ^b
Mineral nitrogen, kg N / ha MFA	9 ^{ab}	20 ^{bc}	33 ^c
Cereal yields, t / ha Cereal crop	–	4.95 ^b	5.59 ^b
Mineral nitrogen, kg N / ha Cropland	–	92 ^b	116 ^b
Economic and environmental performances			
Operational herd costs, % gross product on cattle	34 ^{ab}	32 ^a	38 ^b
Gross margin on cattle, € / LU	560 ^b	508 ^b	448 ^a
Farm income, € / AWU	24,708 ^a	25,112 ^a	24,140 ^a
Aggregate aids, € / AWU	45,756 ^b	36,714 ^a	38,048 ^{ab}
N balance, kg N / ha UAA	+31 ^a	+32 ^a	+41 ^b
Gross GHG kg CO ₂ e / kg/w	12.35 ^a	12.56 ^a	13.27 ^{ab}
Carbon offset % Gross GHG	27.7 ^b	20.0 ^a	20.9 ^a
Net GHG kg CO ₂ e / kg/w	8.95 ^a	10.02 ^{ab}	10.48 ^b
Non-renewable energy (NRE) MJ / kg/w	27.0 ^a	29.7 ^{ab}	32.5 ^b

Notes: a, b, c – same-row values with different-letter superscripts indicate groups from statistically-different populations at $P < 0.05$.

[†] Total Cattle Area (haCatt): area dedicated to the cattle herd = MFA + area of annual on-farm crops sidelined for cattle feed.

^{††} Numerical productivity: % calves weaned per cow serviced.

Livestock productivity (kgLW/LU) was not significantly different between the 3 groups. B/c farms tended to fatten more animals. Live-weight of weanlings sold to market and carcass weight of fattened cull cows were virtually identical across the 3 groups. The two groups that produced concentrate on-farm (B/c and B+C) were the two heaviest consumers of concentrate per LU and per kg of beef produced. The GF group was logically the group that bought in the most concentrates, on B/c and B+C farms, concentrate self-sufficiency (on-farm concentrate-to-total concentrate ratio) was 57%.

Due to a lower rate of operational costs on gross bovine product, the gross margin on cattle was higher on GF and B/c. On average, over the two years studied, we did not observe differences on farm income per worker between the 3 groups. Total amount of aids and subsidies per worker was highest for 100%-grassland farms (GF) and lowest for B/c farms. Aid entitlements under the CAP second pillar (green grassland premium, compensatory allowances for natural handicaps scheme) were then picked up on top of the aid entitlements under the CAP first pillar for grassland-based farms.

With higher mineral fertilization per ha UAA than the other farms without concomitant more intensive beef production, the B+C farms had the highest surplus of farm-scale apparent N balance, excluding symbiotic N fixation by legumes. Gross GHG emissions per kg beef live weight were highest B+C farms due to heavier use of inputs. With their higher grassland-to-UAA ratio, GF were able to offset 28% of gross GHG emissions due to carbon storage in grassland soil (a carbon sink). Consequently, the net GHG emissions per kg beef live weight produced were lower on GF farms. The 100%-grassland farms (GF) also registered the lowest NRE consumption per kg beef live weight produced (they purchased all their concentrates, but they used less fuel and fertilizer).

6. Discussion, perspectives

Over the 24-year period studied, the main changes observed were the large increase in farm sizes, and consequently herd sizes, at constant labour level. This entailed an increase in labour productivity, possible due to a more intensive use of intermediate consumptions and due to a substitution labour/capital. These changes, and direct aids to farmer, had just allowed maintaining the farm income per worker. We observed these same trends in the Spanish Central Pyrenees (Garcia-Martinez *et al.*, 2009).

Productivity gains have been “redistributed” (Boussemart *et al.*, 2012) further downstream (drop in farmed commodity prices) and further upstream (farming supplies and machinery). The size increase has not therefore produced economies of scale. Size has long been a major driver in protecting livestock farmer income levels, initially through the increase in output volumes and then, from the mid-1990s, through the aid support granted to farms without size limits (Veysset *et al.*, 2005a). Diversifying into mixed crop-livestock farming did not necessarily bring about economies of scope (Perrot *et al.*, 2013).

Feed self-sufficiency was a key factor in the technical and economic efficiency (Ripoll-Bosh *et al.*, 2014) of suckler beef production systems. However, all these variables were significantly negatively correlated to farm size. One of the objectives of the 1992 Common Agricultural Policy reforms was to use incentivization mechanisms to promote the incorporation of EU-farmed cereals into animal feed as a substitute for imported cereal-crop by-products. This incentivization policy manifested as a sharp drop in cereal crop prices (–50% in constant-euro values between 1992 and 2005). Livestock farmers were consequently able to increase herd size and simplify the feed work burden by distributing more concentrates (easy to store and distribute, and with known and reliably stable nutritional value) with only small increases in expenditure on feed. This feeding strategy was also pulling by the downstream sector demanding for more homogeneous ‘standard’ cattle weight and conformation. Farms, also growing cereals on-farm, logically achieved a higher feed sufficiency for their herds than the 100%-grassland farms that had to buy in all the needed concentrates. However, these 100%-grassland farms used more efficiently the concentrates; as MC-L farms enjoyed

a feed resource (cereal crop) that grassland farms did not, they tended to distribute more of it to their livestock, without getting significantly higher beef live-weight at the farm gate.

Due this more efficient use of concentrates, a lower use of fertilizers, seeds and pesticides, grassland farms in less favoured areas showed better environmental performances.

Perspectives

Public policies are strong drivers of livestock farming systems evolutions (Veyssset *et al.*, 2005b, Matthews *et al.*, 2006, Garcia-Martinez *et al.*, 2011). The new CAP 2014-2020 (European Commission, 2013), for the French part, aims to “rebalance aids for livestock and employment, without unbalancing the sectors, for a CAP fairer, greener, more regulatory and targeting young people”. Concerning the beef cattle sector, the suckler cow premium remains coupled, but with a digressive amount above 40 cows. To limit the continuous expansion and to support employment, a redistributive payment is set up to promote small and medium structures with an extra-premium to the first 52 ha. For a greener CAP, 30% of the payment from the first pillar (pillar for the agricultural production) would be a “green payment”. This payment implies maintaining permanent grassland, a problem for farms in less-favoured areas, where more than 90% of the UAA is allocated to permanent grassland; these farms seeking to improve their feed and straw self-sufficiency with forage cereals. This search for self-sufficiency can help secure the production system and to spread the risk in relation to climate hazards on some alternative crops (fodder or not) for a small portion of the surface. The diversification of the forage system is part of the production system security strategies; this self-insurance will be a key point in the decision of farmers to purchase or not, and in what amount an insurance against climate risks (Mosnier, 2015). Less-favoured areas will benefit from the 15% revaluation of the compensatory allowance for natural handicaps.

Overall, all things being equal, the CAP guidelines 2014-2020 should result in a substantial improvement of the income of beef suckler farms in mountainous areas. The income of lowland farms should be impacted in contrasting ways, depending on the size and specialization of the farm: income increase for cow-calf systems, slightly increase for cow-calf-fatteners and mixed crop-livestock systems. The major novelty of this CAP reform is the split of the proportionality between the amount of aids received and the size of the farm. For the first time since 1992, the encouragement of the size expansion is restricted.

In a longer term perspective, the possible scenarios of a decrease in beef consumption, and greater consideration for the environment and animal welfare, could be favourable to systems in mountainous areas: low-input systems based on grazing, carbon sequestration in grasslands, biodiversity maintenance, meat “quality” from long production cycles (Bernués *et al.*, 2011). The possible pursuit of a liberal scenario based on volumes and prices should also help to maintain cow-calf systems in mountains, capable of producing calves cheaply over large areas. In all cases, there is not much alternative agricultural production, and farming systems, for farms in mountainous areas, which could have advantages to meet the demand for beef, taking into account societal and economic developments.

IV – Conclusions

Over the decades, suckler cattle production systems have re-adapted to regular CAP reforms and changing market trends by constantly increasing farm size and physical labour productivity. These adaptations entailed a heavier use of off-farm resources (inputs and capital) to the detriment of better use of on-farm resources (genetic potential of livestock and plant resources). The animal productivity gains were counterbalanced by evolutions in practices, the result is that we observed a decrease in the wealth created by the beef cattle farming activity, and no gain on farm income and environmental performances.

Despite this gloomy picture, among the various beef cattle production systems, grass-based and low inputs systems displayed encouraging performances compared to lowland mixed crop-livestock systems. These suckler cattle production systems seem to be better prepared to face the future beef production scheme and societal demand.

The main concerns of beef production systems in mountainous areas will be to reinforce the wealth created and to maintain the ecosystem services they provide. The future challenge is to develop the fattening activities on farm without purchasing human-edible proteins. These systems have to value their unique feed resource: grass, by adopting adapted breeds and practices. Public policy also has its role to play by supporting positive externalities of low inputs and grass-based beef cattle farming systems.

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Field validation of an automatic coefficient of pasture eligibility in mountain areas

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Abstract. In most Spanish regions the quantification of permanent pastures eligible for Common Agricultural Policy payments is based on a recent remote sensing method (*CPEauto*) that combines terrain slope and greenness, and vegetation height. In complex landscapes with herbaceous-shrub-tree mosaics, such as in many mountain areas, this method aims to distinguish used from abandoned pasture land. During 2015 we performed in Cantabria (north of Spain) a field validation of the *CPEauto* based on information collected in 343 transects covering the most common extensive grazing habitat types of the region, each homogenous in vegetation and *CPEauto* values. Measured plant composition, vegetation structure and grazing signs were integrated in a single index of land grazability (*GI*), which was confronted against *CPEauto* values using regression models. *GI* was robustly and unbiasedly related to *CPEauto* when the latter was corrected by the slope ($R^2 = 0.83$). Analysing separately shrub-dominated, tree-dominated and grassland transects, the relationship *GI-CPEauto* was only kept in shrublands, while woods and grasslands showed frequent cases of under- and overestimation respectively.

Keywords. Shrubs – Woods – Plant grazing adaptation – Transitability – Grazability index.

Validation sur le terrain d'une méthode automatique de calcul du coefficient d'éligibilité des pâturages des zones de montagne

En la plupart de l'Espagne la quantification des pâturages permanents éligibles pour les paiements de la PAC a été basée sur une méthode de télédétection (CPEauto). Dans des paysages complexes composés de mosaïques herbacées-arbustives-boisés, comme ceux de la plupart des areas de montagne, on voudrait utiliser cette méthode pour différencier entre pâturages qui sont actuellement en cours d'utilisation et ceux qui ont été abandonnés. Pour cela, pendant l'année 2015, en Cantabria (nord de l'Espagne) une validation sur le terrain de la méthode CPEauto a été effectuée. L'information obtenue à partir de 343 transects qui prennent en considération les habitats associés au pâturage extensive et considérés comme homogènes selon la végétation a été utilisée. Un index d'aptitude au pâturage (GI) a été aussi élaboré en intégrant l'information sur la composition botanique, la structure de la végétation et la présence ou non des signes de pâturage. Les valeurs de cet index ont été mises en relation aux valeurs du CPEauto à partir des modèles statistiques de régression. L'index GI a montré une relation robuste et non biaisée avec les valeurs du CPEauto corrigées selon la pente ($R^2 = 0,83$). Par ailleurs, en considérant individuellement les transects dominés par la végétation arbustive, boisée ou herbacée, la relation entre l'index GI et les valeurs du CPEauto est robuste seulement pour les transects arbustives, tandis que pour les transects boisés ou herbacés les valeurs GI obtenues sont souvent sous-estimées ou surestimées, respectivement, par rapport à ceux du CPEauto.

Mots-clés. Arbustes – Bois – Adaptation des plants au pâturage – Accessibilité – Index d'aptitude au pâturage.

I – Introduction

Permanent pastures devoted to extensive livestock grazing systems have been the focus of recent debates regarding their eligibility for payments within the new Common Agricultural Policy (CAP) reform (Beaufoy, 2015). In mountain areas these pastures are frequently mixtures of herbaceous, shrub and tree species at fine spatial resolutions. In these agroecosystems most shrubs and trees

have proven benefits for whole pasture productivity and biodiversity (Plieninger *et al.*, 2015), and can also be strategic forage resources for grazing animals (Celaya *et al.*, 2010). However, their abundance may in other cases denote grazing abandonment, usually driving to shrub encroachment and high risks such as uncontrolled fires. In the last years the European Commission (EC) has pressed Member States having this type of agroecosystems to better distinguish them from non-used dominant shrub/wood vegetation, as only the former are entitled to CAP payments related to livestock farming. This is clearly reflected in the new official redefinition of “permanent pasture” (EU Regulation 1307/2013 Article 4.1h and EU Delegated Reg. 639/2014 Articles 6 and 7), and the proposed approaches to calculating the eligible area for CAP payments in the case of pastures (EU Delegated Reg. 640/2014 Article 10.1). In 2015 the Spanish government proposed, as the main asset of an action plan requested by the EC, a new coefficient of pasture eligibility (*CPEauto*) based on integrating remote sensing terrain and vegetation measures of all the Spanish territory at a very high spatial resolution. Regional administrations were requested to validate this *CPEauto* in their territories. The validation of the *CPEauto* in Cantabria (north of Spain) was based on a novel field methodology for quantifying what is pasture. This methodology and the relationship of its results with the *CPEauto* are presented in the next sections of this paper.

II – Materials and methods

1. The coefficient of pasture eligibility

The *CPEauto* was calculated at 5x5 m cells of all the Spanish territory multiplying three factors scaled to 0-1: *slope* (four values, with extremes <60%:1 and >100%:0), *greenness* as measured by the *NDVI* (Normalized Difference Vegetation Index) obtained from *RapidEye* satellite images (two values: 0,1), and *height* of the vegetation obtained by *LiDAR* technology (a height threshold of 40 cm was used to assign values of 0 –above, or 1 –below). Values obtained were further modified to correct for small isolated tree or shrub patches or hedges. In Cantabria the factor *slope* was not applied, as the regional government argued the existence of a significant amount of well managed grasslands on very steep terrains.

2. Field sampling

We used a recent environmental stratified-random sample of the vegetation of Cantabria (Busqué *et al.*, 2015) to choose the location of 343 linear transects (transect mean length 92m ± s.d. 25.8 and width of 10 m) of homogeneous terrain and type of vegetation. Vegetation types were broadly classified as grasslands (47), shrubs (222) and woods (74 transects). Each transect was located on land with all their 5x5m pixels with *greenness* values of 1 and *height* values of either 0 or 1. In each transect, information was collected at two levels. At the whole transect level we registered the slope, aspect, evidence of livestock tracks (*LT*; 3 levels: inexistent, weak or evident), ease of walking out of tracks (*WE*; 4 levels: easy, medium, hard or impossible), signs of burning or vegetation cutting, and presence of livestock dung. Along each transect and equidistantly we collected more precise information in ten 1x1m quadrats: cover (5-15; 15-25; 25-50; 50-75; >75%), phenology and signs of defoliation of existing plant species or defined functional plant groups at different height strata (0-0.1; 0.1-0.4; 0.4-0.6; 0.6-1; 1-2; 2-3 m); tree species above 3m; presence of dung of livestock and other ungulate species. Special care was taken to avoid bias when locating these quadrats.

3. Integration of field measurements into a grazability index

The synthetic index “*grazability*” (*GI*) was obtained multiplying two range variables derived from the field measurements: aggregated *plant grazing adaptation* (*PGA*) and *transitability*. *PGA* is defined as the probability of a plant species or functional group to maintain stable populations when grazed at a forage utilisation level similar to what is sustainable in the most productive neighbouring grass-

land. A fixed *PGA* value (0 –null–, 0.33, 0.67 or 1 –high–) was assigned to each of the 216 plant species/functional groups recorded. *PGA* was further aggregated at transect level, weighing each species value by its volumetric cover (*i.e.* considering plant cover at each height strata) at each 1x1 quadrats. *Transitability* is defined combining *LT* and *WE* categorical values: 0 when *WE* is impossible or when *LT* are inexistent and *WE* is hard; 0.25 when *LT* are weak and *WE* is difficult; 0.5 when *LT* are inexistent and *WE* is medium, or when *LT* are evident and *WE* is hard; 0.75 when *LT* are weak and *WE* is medium; and 1 when *LT* are evident and *WE* is medium or whenever *WE* is easy.

4. Statistical analysis

All the transects were grouped according to their *GI* values into 10 segments of 0.1 ranges (0-0.1, 0.1-0.2, 0.2-0.3, ...). *GI* and *CPEauto height* transect values were averaged for each of these segments and the relationship between both segment mean values (10 pairs of values) was quantified through linear regression. Values of the coefficients of the linear regression, their standard errors, the coefficient of determination (R^2) and the residual standard error (*RSE*) were calculated bootstrapping the sample of transects 10,000 times in order to avoid overfitting.

III – Results and discussion

For all transects, the linear relationship between *GI* and *CPEauto* values averaged by segments was strong [$CPEauto = 0.16 (\pm 0.042) + 0.85 (\pm 0.081) \times GI$; mean $R^2 = 0.81$; mean $RSE = 0.12$], but showed an overestimation of pasture eligibility of the *CPEauto*, especially at low *GI* values (Fig. 1a). An analysis of the relationship between *GI* and the slope of the terrain for transects with *CPEauto* equal to 1 revealed the existence of a significant negative linear relationship ($R^2 = 0.20$). The correction of *CPEauto* by this factor ($CPEauto \times (1 - 0.003 \times \text{slope})$) improved slightly its relationship with *GI* (mean $R^2 = 0.83$; mean $RSE = 0.11$) and resulted in a new equation [$CPEauto_{corr} = 0.13 (\pm 0.038) + 0.81 (\pm 0.074) \times GI$] closer to the 1:1 ratio (Fig. 1b).

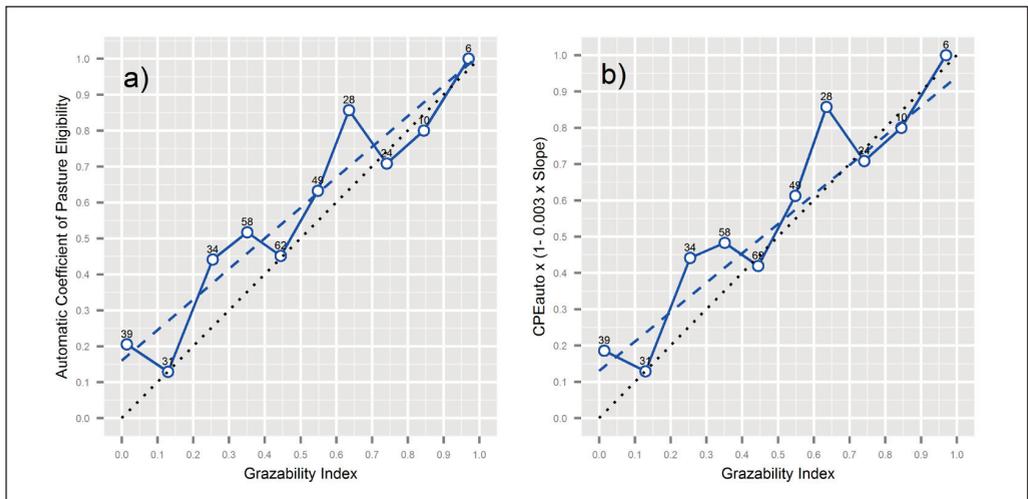


Fig. 1. Linear relationship between the Grazability Index (*GI*) and the automatic coefficient of pasture eligibility (*CPEauto*) (a), or the *CPEauto* corrected by a terrain slope factor (b). The numbers above the points are the n° of transects in each *GI* 0.1 segment. The dashed blue line is the regression line obtained bootstrapping the initial sample of transects 10,000 times. The dotted black line is the 1:1 ratio.

If the relationship $GI-CPE_{auto}$ was analysed differentiating transects by broad types of pasture/vegetation (herbaceous, shrubs and woods; Fig. 2), it was clear that the most abundant shrubland transects were the only ones that kept the robust relation previously found (Fig. 2a). Woods were in many cases underscored as pasture with the CPE_{auto} method (Fig. 2b), as this method penalises heavily large patches of tall vegetation. This is especially the case of intensively grazed hawthorn (*Crataegus monogyna*) – holly (*Ilex aquifolium*) – grassland formations, and of many deciduous *Quercus* forests (Beaufoy, 2015), that are only viable in the long-term under moderate grazing by large ungulates (Vera *et al.*, 2006). At the other extreme (Fig. 2c), the CPE_{auto} overvalued some types of rough grasslands (i.e. those dominated by the grasses *Molinia caerulea*, *Brachypodium pinnatum* or *Pseudarrhenatherum longifolium*) that thrive under very low or even abandonment of livestock grazing (Grant *et al.*, 1996) and under fire regimes of high frequency (Brys *et al.*, 2005).

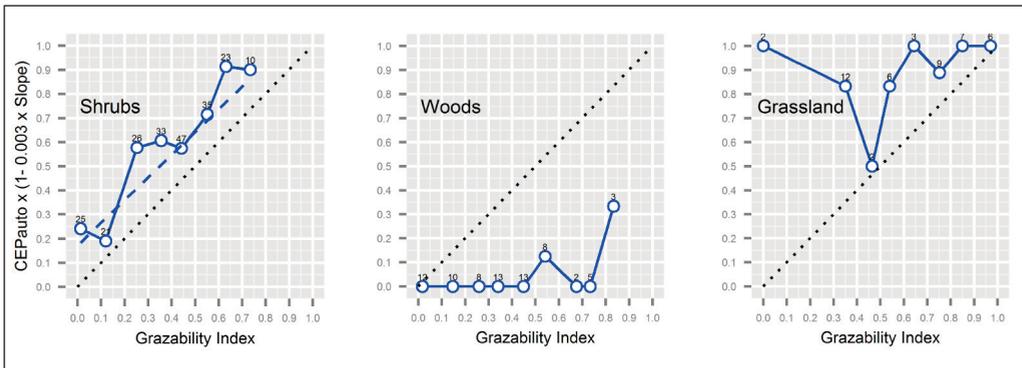


Fig. 2. Linear relationship between the Grazability Index (GI) and the automatic coefficient of pasture eligibility (CPE_{auto}) corrected by slope for transects dominated by shrubs, woods and grasslands. The numbers above the points are the n° of transects in each GI 0.1 segment. The dashed blue line is the regression line (only significant for shrubs) and the dotted black line is the 1:1 ratio.

IV – Conclusions

Even in complex vegetation communities, as in those of mountain areas, we have demonstrated that it is possible to quantitatively evaluate in the field what is grazable pasture using fast sampling procedures. This might be very useful when auditing pasture eligibility, but is unfeasible as a direct method for assigning eligibility in big territories. The development of automatic methods based on remote sensing, such as the described Spanish CPE_{auto} , is a promising way forward. However, the detected failures of CPE_{auto} in grasslands and woods would need addressing in the future through the incorporation of predictors of vegetation types and transitivity below tree canopies in order to better estimate real grazability.

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Adopting a resilience lens to analyse adaptation to climate change on summer mountain pastures

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Abstract. Summer mountain pastures represent a key forage resource for many agropastoral farming systems, whose herds graze on these areas during summer. The extensive pastoral management of these areas enables to preserve both the forage value and the biodiversity of the vegetation. However, climate change threatens the fragile equilibrium of these complex socio-ecosystems, and existing analytical frameworks appear inadequate in this new context. In this paper we mobilise the concept of social ecological resilience in order to bring new keys to accompany adaptation to climate change on summer mountain pastures. Through this concept, we analyse the way diversity of vegetation is mobilized for adaptation at different management levels.

Keywords. Social-ecological resilience – Summer mountain pasture – Alpines pasture – Adaptation to climate change.

Adopter une grille de lecture « résilience » pour analyser l'adaptation des alpages au changement climatique

Résumé. Les alpages sont une ressource estivale clé pour de nombreux systèmes agropastoraux. Leur gestion pastorale extensive permet de maintenir à la fois la qualité de la ressource et la biodiversité associée. Mais le changement climatique menace le fragile équilibre de ces socio-écosystèmes, et les cadres d'analyse existants ne permettent pas d'accompagner l'adaptation au changement climatique. Dans cet article nous mobilisons le concept de résilience pour apporter une nouvelle clé de lecture du fonctionnement des alpages. A travers ce concept, nous analysons la façon dont la diversité des végétations est mobilisée pour l'adaptation à différents niveaux de gestion.

Mots-clés. Résilience socio-écologique – Alpage – Estive – Adaptation au changement climatique.

I – Introduction

Summer mountain pastures (SMP) can be defined as permanent grasslands used specifically for grazing in summer. They are used by many livestock farmers in the mountain regions and surrounding plains and cover a wide variety of spaces: different sizes and configurations, elevations and altitudinal zones. SMP are often used in a collective manner by several farmers. SMP are also multipurpose areas (tourism, hunting, logging, etc.) with a very rich biodiversity resulting from several thousand years of pastoral use. SMP are thus a good example of complex social-ecological systems (SES) with closely-linked human and ecological dimensions.

Climate change creates strong disturbances to SMP, which are highly exposed, and challenges the ability of these SESs to adapt (IPCC, 2014). Climate change causes two difficulties in two different timeframes. (1) In the short term of annual management, climate change results in an increase in inter-annual climate variability and extreme events, particularly summer droughts. (2) In the long term, climate change is expected to lead to a change in the type of vegetation, with major uncertainties as to future developments.

In response to climate change, adjustments have to be made at different management scales. The diversity of vegetation is said to be an important source of flexibility, but the current analytical framework and management-support tools (Savini *et al.*, 1995) are not adequate to analyse adaptation to climate change. It is difficult to use them to understand the adjustments made on SMP or at SMP-farm interactions, in particular the way farmers and shepherds mobilise the diversity of vegetation, neither at an annual management scale nor at a multiannual scale. In this article we propose a new analytical framework based on the concept of social-ecological resilience, which is “the capacity of a social-ecological system to absorb disturbances and reorganize while undergoing change so as to continue to retain essentially the same function, structure, feedbacks and, therefore identity” (Folke *et al.*, 2010). It is an increasingly widespread concept whose success depends on the promise of an operational character for management of SES. We propose to test the capacity of this framework to analyse the way diversity of vegetation is mobilised for adaptation to climate change.

II – Methods

We applied the method proposed by Walker and Salt (2012) to the case of SMP. We built a conceptual model of the functioning of SMP based on expert knowledge, through participatory modelling. We crossed this model with Walker and Salt’s generic criteria conferring resilience to SES (diversity, openness, reserves, tightness of feedback (or detection and reaction capacity, reactivity), modularity, social capital) in order to build an analysis grid of criteria conferring resilience to SMP (Table 1). We illustrate the use of this grid through a focus on the way two contrasted study cases mobilise the diversity of vegetation.

III – Results

1. Summer mountain pasture management model and analysis grid

The model comprises a management sub-model and a biophysical sub-model. In this paper we only present shortly the management sub-model. This model comprises 5 interlinked spatial and time scales and makes it possible to define the functions expected from the vegetation in the SMP at different management scales. The first three of these five scales (day and “grazing route”, pastoral season and “allotment”, SMP season) correspond to the scales previously proposed by Savini *et al.* (1995). There are also two higher scales: the first encompasses the entire year to consider the interactions between the SMP and the associated farms; the second is the long-term scale that is essential to consider the lasting dynamics of the system with respect to the different spatial scales (changes in climate, vegetation, system managers, characteristics of the associated farms and their objectives for the SMP, etc.).

From this five management scales, we built an analysis grid of generic criteria conferring resilience to SMP, according to the “Men-Herd-Resources” triptych of the livestock farming systems approach (Gibon *et al.*, 1999) (Table 1).

2. Analysis of two study cases

We present here how our model enables us to understand the way the diversity of vegetation is mobilized on two different study cases (DAR and CRO: Table 2), and conclusions on resilience on these two SMP. For DAR study case, due to multiple constraints, the usage of vegetation diversity at different management scales is vital for system resilience. That’s why shepherds take care to maintain this diversity on long-term. Nevertheless uncertain property rights threaten the maintenance of vegetation diversity at the annual scale, which is the main adjustment level (less constraints). For

CRO resilience is permitted by altitudinal zonation and a reserve of very flexible vegetation in the undergrowth. Forestry management maintains balance in the habitat. The main risk stems from the arrival of wolves on the SMP, which would prohibit access to the undergrowth (today the main adjustment resource).

Table 1. List of generic criteria conferring resilience to SMP. Generic criteria identified by Walker and Salt (2012) are indicated in square brackets

Spatial and temporal management scale	People	Herd	Resource
Day and grazing route	Herders, with their know-how and knowledge [tightness of feedback], technics of shepherding [diversity].	Behaviour of livestock regarding its capacity to use the vegetation [diversity, tightness of feedback]	Functional diversity of the vegetation, diversity of sector configuration [diversity]. Configuration of the allotment: position of equipment, ease of herd movement [diversity, modularity]
Allotment and pastoral season	Herder (as above) [tightness of feedback]. Livestock farmers, depending on their involvement with the SMP (as above) [tightness of feedback], and on their collective motivation [social capital (leadership)]. Herder-farmer relations [tightness of feedback, social capital (trust)]. Availability of farmers (labour) [reserves, modularity].	Buffering capacity (genetic, health status and zootechnical objectives) [reserves]. Level of livestock needs (w.r.t. production cycle) [diversity].	Vegetation response diversity: supports availability of grass regardless of climatic hazards [diversity, modularity]. Preservation of supplementary resource in management [reserves]
SMP and SMP season	Herder-farmer relations [tightness of feedback, social capital (trust)]. Availability of farmers (labour) [reserves, modularity].		Diversity of soil and climate conditions (aspect, elevation, slope, soil types) to not suffer from the same events everywhere [diversity, modularity]. Existence of a supplementary resource to be used at any time in the season [reserves].
Year and SMP-farms system	Relationships between farmers, functioning rules [diversity, social capital, tightness of feedback]. Relationships with extension officers, sources of information [openness, tightness of feedback, social capital (social network)]. Hiring of herders, requiring the support of professional networks [openness, social capital].	Selection criteria for dates, summer pasturing livestock numbers and needs [tightness of feedback] Health status [reserves]. Genetic and behavioural differences between herds (breeds, selection criteria, previous learning) [diversity]. Ability to buy/sell livestock to adjust to resources [openness].	Bridging resource between farms and SMP to be able to adapt carrying capacity [reserves] or off farms: purchased fodder, pasturing outside farm land [openness]. Resources that can be grazed at different times on the farms [diversity]. Use of other summering areas [modularity, diversity]. Diversity of farming systems (location, functioning, weather experienced and weather sensitivity) [diversity]. Number of farms [modularity].
Long term	Change in pastoral association members, in farm selection criteria [diversity, modularity]. Learning [tightness of feedback].	Livestock selection criteria [reserves]. Diversity of selection criteria between farms [diversity]. Changes in the size of the herd [reserves]. Herd learning ability [diversity]. Changes in the herds and in selection criteria across farms [diversity].	Changes to spatial organisation and equipment: change in available land, in access to parcels, [reserves], in vegetation diversity at different scales [diversity]. SMP practices (grazing, maintenance): change in the quality of vegetation types (cf. state and transition model in appendix 1) [reserves] and in the diversity of vegetation [diversity]. Shift in the forage systems and choice of farms during their replacement [diversity, modularity].

Table 2. Comparison of the way in which vegetation diversity is used at different management levels on two individual SMP used for sheep grazing

SMP:	DAR	CRO
Configuration and types of dominant vegetation	Dry plateau (1300 m a.s.l.): intermediate subalpine grassland (high intra-type diversity); grazing woodland Crest (1900 m a.s.l.): Intermediate subalpine grassland of mediocre quality; no water	North side slope (1500-2500 m a.s.l.): Grazing woodland; productive facies; intermediate alpine meadows
Day and grazing	Usage of the functional diversity route of vegetation to balance the daily rations (between rich and fibrous vegetation) and to adjust for weather conditions (between open spaces for nice days and woody spaces for rain and heatwaves).	
Pastoral season	Usage of the diversity of vegetation responses to droughts, the main hazard impacting grazing on this SMP with superficial soil (increased usage of undergrowth that is less drought-sensitive).	Usage of response diversity to early seasons (increased usage of early productive facies, during late springs and conversely).
Season and SMP	Due to the shortage of water in the Crest area, the capacity to use altitudinal layering is limited. Functional vegetation diversity is used to compensate: shepherds will use the different capacities to be standing stock to ensure sufficiently rich resources throughout the SMP season.	Essentially usage of the diversity of conditions allowed by altitudinal zonation to dispose of sufficiently rich resources throughout the SMP season.
Year and SMP – farm interaction	Wide variety of vegetation on the farm used in a different way each year to adjust to hazards; high capacity to shift SMP climb/descend dates (to compensate for the absence of early vegetation and variations in productivity).	Many constraints on the farm limiting the capacity to adjust SMP climb/descend dates. Hence, adjustments will be made on the SMP.
Long-term	Drop in quantity and diversity of resources available on the SMP: appearance of predators (wolf) that reduces the possibilities of grazing in the undergrowth. Progressive reduction in time spent on the SMP thanks to the usage of new areas at an intermediate elevation between the farm and the SMP but with a low level of control over the property. Improvement to the equipment (water reserves) to better use the existing resources on the SMP. Management of grazing pressure to preserve the functional diversity of the vegetation.	Grazing pressure adapted to the exact renewal of the resources on the open spaces and insufficient on the closed-off spaces, where it is the forestry activities that ensure that the habitat does not become overrun with brush.

III – Discussion – Conclusion

Social-ecological resilience theories are meaningful for SMP management. Among the concepts linked to social-ecological resilience is the concept of Panarchy (Gunderson and Holling, 2002) that we can summarize in two principles. (1) SES constantly evolve over time and according to the disturbances that cause them to adapt or transform. Sometimes they become more resilient and develop

their adaptive capacities, sometimes they become less resilient. There will always come a time when a very strong disturbance occurs and adaptability will be insufficient to cope. The system then exceeds a threshold and will transform itself to change functions, structures, feedbacks, and identity. This transformation may be forced, but it may also be desired to obtain a situation with improved resilience. (2) SES are made up of sub-systems at lower organisational levels and they are included in systems at a higher scale. These different levels of system organisation are not independent and a change in resilience at one level will have repercussions on resilience at the other levels. Developing adaptability at one level could necessitate a transformation at another level. The model that we built is in line with this understanding of the functioning of social-ecological systems. Different management scales have corresponding semi-autonomous systems: sectors, allotments, SMP, SMP-farm systems (Nettier *et al.*, 2015). The challenge is to preserve or develop the adaptability of the SMP system and avoid reaching a threshold that would lead to the transformation of the SMP (abandonment for example). The different organisational levels interact and it is possible to make transformations at higher or lower levels to preserve the functions of the SMP (such as an allotment being abandoned or a disruption in farm functioning).

The Walker and Salt method that we implemented proved to be promising in terms of analysing the resilience of pastoral systems with a view to improving their management. The team of experts mobilised for modelling were already very close to resilience thinking. The construction of this model enabled us to put forward a vision of SMP as dynamic systems in a dynamic environment.

Acknowledgments

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Increased Arctic beef production

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Abstract. The aim of this project was to develop scientific based recommendations to functional and simple management systems for beef production in northern Norway. The specific focus is on cheap housing, pasture utilization and animal welfare in the Arctic region. Twelve “top league” beef farms (located 66-70°N) within the three northern counties of Norway were visited. Two of 12 farmers were dual purpose combined dairy- and beef producers, one had bulls for fattening and nine kept suckler cows. Animal based parameters as well as environmental factors were recorded and semi-structural interviews with the farmers were performed. In addition, an internet based questionnaire was distributed to all beef producers in the region. In this presentation, we focus on pasture utilization: 9 out of 12 farmers started beef production to utilize the farm’s resources (land and buildings) and to keep the farm in good condition. Six of the farmers provided outdoor running yards or areas during winter, although the climate can be harsh and involves ample amounts of snow. All animals, except the fattening bulls, had access to summer pasture and seven of nine suckler cow farms used rangeland/forest/mountain pastures for grazing. In Norway, steer production is uncommon because the profit depends on access to huge grazing areas and cheap housing during winter. However, specialized steer production might in future be a way of increasing the Norwegian beef production based on natural resources.

Keywords. Cattle – Rangeland pasture – Questionnaire – Animal welfare.

Augmenter la production bovine arctique

Résumé. Le but de ce projet était d’élaborer des recommandations, établies sur une base scientifique, pour des systèmes fonctionnels et simples de production de viande bovine dans le nord de la Norvège. Un accent particulier a été porté aux stabulations bon marché, à l’utilisation des pâturages et au bien-être des animaux dans la région arctique. Douze fermes bovines de pointe, situées entre 66 et 70° N dans trois comtés du nord de la Norvège, ont été visitées. Deux des 12 agriculteurs ont un double objectif de production de lait et de viande, un seul avait des taureaux d’engraissement et neuf des vaches allaitantes. Les facteurs zootechniques et environnementaux ont été enregistrés et des entretiens semi-structurés avec les agriculteurs ont été réalisés. En outre, un questionnaire sur Internet a été distribué à tous les producteurs de viande bovine de la région. Dans cette présentation, nous nous concentrons sur l’utilisation des pâturages. Neuf éleveurs sur 12 ont commencé la production de bœuf afin d’utiliser les ressources locales (terre et bâtiments) et de garder l’exploitation en bon état. Six des agriculteurs ont prévu des aires de détente en plein air pendant l’hiver, bien que le climat puisse être rude et impliquer de grandes quantités de neige. Tous les animaux, à l’exception des taureaux d’engraissement, ont eu accès à des pâturages en été. Sept des neuf exploitations de bovins allaitants ont utilisé des pâturages boisés de montagne. En Norvège, l’élevage des bœufs est rare, car elle dépend de l’accès à de vastes zones de pâturage et de conditions de logement bon marché pendant l’hiver. Cependant, à l’avenir, une spécialisation dans cette voie pourrait être un moyen d’augmenter la production de viande bovine norvégienne basée sur les ressources naturelles.

Mots-clés. Bovins – Pâturages marginaux – Enquête – Bien-être animal.

I – Introduction

Beef production in Europe is to a large degree based on pasture and cattle utilize a range of pasture types and plant species to produce tender and healthy meat (Varela *et al.*, 2004). There is a shortage of 10,000 tons of beef meat in Norway (Animalia, 2015). A superior political goal for the Norwegian agriculture is to increase the food production based on national grassland resources

to improve the food self-sufficiency as well as to maintain and manage the cultural landscape (Stortingsmelding 9, 2011-2012). Currently, approximately 3.2% of the Norwegian land area is in use for intensive food production, while approximately 50% of the land area has a potential as culture- and rangeland pastures (Rekdal, 2013). In order to increase the Norwegian beef production, the number of suckler cows must increase from 40,000 to 80,000 heads (Ekspergruppen, 2013; Hageberg *et al.*, 2014). Due to the harsh Arctic climate and high costs of labour, a large amount of total costs in beef operations are linked to farm buildings and mechanization. The profitability of the production in this region is therefore marginal.

The aim of this study was to develop science-based recommendations for functional and simple management systems for beef production in the Arctic region. The project focused on animal welfare and the potential for cheap but functional housing as well as pasture utilization.

II – Materials and methods

1. Selection of “top league” farms

The Norwegian Cattle Health Service (Animalia), practicing veterinarians, The Norwegian Food Safety Authority (Mattilsynet) and the Norwegian Beef Cattle Control (Nortura -Storfekjøttkontrollen) provided contact information to top league producers from the three counties Nordland, Troms and Finnmark. Top league farms were defined as farms that had produced beef of high class during the last year and, at the same time, showed profitability. Out of these, we selected twelve example farms that were willing to welcome us for an on-farm visit and interviews. Two to three researchers visited six farms in Nordland, four farms in Troms and two farms in Finnmark County during April and May 2015. From these, one farm was specialized in finishing of calves acquired elsewhere, two farms were oriented on dairy production and finished calves from their own production as well as acquired calves, three farms had suckler cows with finishing of own and acquired calves while six farms had suckler cows and either sold or fattened their calves for finishing (Table 1).

Table 1. The importance of pasture and grazing practices among the four different production systems visited

Production system/ Interview result	Finishing acquired calves (1)	Combination with dairy production (2)	Suckler cows and finishing calves (3)	Suckler cows, calves are sold (6)
Access to outdoor exercise pen during winter	No	1 only for heifers, 1 no	2 yes, 1 no	2 yes, 4 no
Access to summer grazing	No access. Mainly bulls	No access for fattening bulls. Heifers may be grazed	2 rangeland, 1 improved	6 yes, improved and rangeland pastures according to season
Importance of pasture	No comment	Not so important	3 high, essential for production	6 high, essential for profitability and animal welfare

2. Farm visits and interviews

Before each visit, the farmers received the interview questions and a written agreement, allowing NIBIO to use anonymized data from their farm in presentations and economic analysis. Interview lasted between 2 and 2.5 hours and was followed by a guided tour on the farm. We recorded an-

imal welfare, facilities and any smart solution the farmer brought to our attention by taking pictures. Registrations of space per animal, animal cleanliness, health, temperature, drafts (by using smoke ampoules) were performed. Tips and factors that might be regarded as bottlenecks for the present production were discussed with the farmers. Results from the semi-structured interviews were saved as electronic records for further analysis according to acknowledged qualitative methods.

3. Questionnaire

An electronic link to a Quest Back questionnaire was distributed by e-mail to all registered members of the Norwegian Beef Cattle Control with help from their advisors. The questionnaire consisted of 90 questions including buildings, management, feeding routines, use of pastures, production economy and animal health. Only questions dealing with pasture utilization and related farmer attitudes are presented in this paper. Data are presented descriptively and calculated as percentage of total number of answers for each question and production form.

III – Results and discussion

Farm visits. Nine of the twelve farmers started the beef production in a way to utilize the farm's resources (land and buildings) and to keep the farm in good condition. Farms specialized in finishing of acquired calves had little focus on outdoor access and utilization of pastures in their production (Table 1). This is mainly because bulls are difficult and dangerous to keep in fences and the Norwegian "male animal act" §3 states that it is prohibited to release intact bulls on joint rangeland pastures where other cattle are present (LMD, 2003). The strict regulation that should ensure free exercise and grazing for Norwegian cattle is thus not in force for bulls (LMD, 2004). None of the farms we visited practiced steer production, although the questionnaire revealed that there are some farmers interested in it.

Farming systems with beef production in combination with dairy cattle also seemed to put little emphasis on grazing and in one of the two farms visited, only heifers had access to pasture (Table 1). This may be explained by the fact that the adult dairy cows are given priority if pastures close to the farm are limited.

Operations with suckler cows were highly oriented on pasture resources and utilized both improved and rangeland pastures according to season (Table 1). All farmers with suckler cows used natural mating with a bull, of which one used about 50% artificial insemination. Some farms used two different bulls. For better control, the herds were divided and typically kept on improved pastures until mating was over. Rangeland pastures were utilized during mid-summer and additional roughage was provided on improved pastures during autumn to extend the grazing season and thus save winter feed. Some farmers mentioned the costs of fence maintenance and conflicts with neighbours, tourists and the community in general as limiting factors for further utilization of rangeland pastures.

Questionnaires. The e-mail based questionnaire gathered information from a total of 144 farms, including 83 suckler cow farms, 19 farms with suckler cows in combination with additional finishing calves, 21 farms with beef production in combination with dairy and 20 farms only with finishing calves acquired elsewhere (Fig. 1).

When asked how important access to pasture is for their production, the farmers answered according to the type of system they had (Fig. 1). The majority of the farms with suckler cows argued that access to good quality pasture was of utmost importance for their production (78%), whereas operations specializing in fattening of calves tended to argue that pasture access was important but difficult (10%) or even impossible to handle (20%) as a large percentage of their herd consisted of bulls. Only one farm had steers as main production (Fig. 1), while three farmers mentioned that castrating of bulls was performed, but their main production was listed as one of the four farming systems given in Fig. 1.

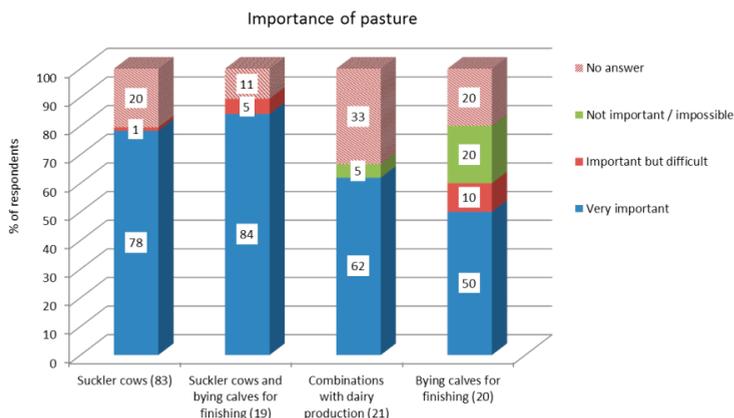


Fig. 1. The importance of pasture in four different types of beef production systems. Numbers are given in % of total number of respondents.

Almost half of the respondents (48.3%) offered outdoor enclosures for their beef cattle during winter. As also found during farm visits, all respondents with suckler cows in the survey used pasture during summer and argued that access to good quality pasture was an important prerequisite for profitability. Only 3.5% of the farms included steers and used pasture for their entire herd during summer.

IV – Conclusions

There is a large potential for increased beef production in the northern parts of Norway based on rangeland pastures, and steer production might prove to be an important operation practice for future utilization of this valuable resource. Upgrading of proper fences may however involve large costs for each producer. Moreover, conflicts with tourists and neighbouring property owners have been emphasized as the two major limiting factors to a wider implementation.

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Assessing the sustainability of a combined extensive/intensive beef production system: the case of French suckler cow-calf farms integrated with Italian beef fattening herds

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Abstract. This study aimed to analyse the sustainability of the beef system based on the integration between pasture-based suckler cow-calf farms in France (Massif Central) and cereal-based fattening farms of northern Italy. Two indicators were considered: carbon footprint (kg CO₂-eq/kg body weight, BW, sold), and the human-edible feed conversion ratio computed as the ratio between the energy content in human-edible feed-stuffs and the energy content of human-edible animal products (HeFCR). The reference unit was the batch (i.e. a group of stock calves homogenous for origin, finishing period and fattening farm). We considered 73 Charolais young bulls batches (4882 heads), born in France (Massif Central), sold to northern Italy beef herds at 405 ± 13 kg BW after a 1.16 ± 0.13 kg/d weight gain and slaughtered at 729 ± 23 kg BW, after a 1.52 ± 0.09 kg/d weight gain during fattening. Mean carbon footprint of overall beef production system averaged 13.0 ± 0.6 CO₂-eq/ kg BW, and the French suckler cow-calf phase accounted for 65% of global emissions. Conversely, the French suckler cow-calf phase was more efficient than the Italian beef finishing phase in terms of food supply for the human consumption, as the HeFCR averaged 2.9 ± 0.4 and 4.6 ± 0.8 MJ/MJ in the French and Italian phases, respectively. Therefore, our results suggest that the evaluation of global sustainability of mountain livestock systems would require the use of different indicators and approaches.

Keywords. Beef – Sustainability indicators – Mountain pastures – Intensive fattening.

Evaluer la durabilité des systèmes naisseurs engraisseurs en bovin viande. Analyse de la filière brouillard française et de l'engraissement en Italie

Résumé. Une évaluation de la durabilité du système bovin viande Charolais combinant la phase de naissance sur prairies françaises du Massif Central et la phase d'engraissement sur maïs ensilage de la plaine d'Italie du nord, a été réalisée en considérant 73 lots de jeunes mâles engraisés en 2014. Ces lots observés étaient homogènes pour la race, le sexe, le type de finition et les lieux d'engraissement. Deux indicateurs ont été calculés sur l'ensemble des deux phases naissance et engraissement: (i) l'empreinte carbone brute (CO₂/kg PVif vendu) calculée par méthode ACV, et (ii) l'efficacité de production de la viande, produit consommable par l'homme (ratio = énergie consommable par l'homme dans les aliments utilisés / énergie de la viande produite = HeFCR). Les observations regroupent 4882 têtes arrivées en Italie au poids vif moyen de 405 ± 13 kg (GMQ naissance-vente 1,16 ± 0,13 kg/j). Ils ont été abattus au poids de 729 ± 23 kg BW soit un GMQ d'engraissement de 1,52 ± 0,09 kg/j. L'empreinte carbone moyenne du système est de 13,0 ± 0,6 CO₂-eq/ kg PV. La phase de naissance correspond à 65% des émissions globales. Mais par l'importance de l'herbe ingérée, cette phase a l'indice HeFCR moyen le plus bas 2,9 ± 0,4 contre 4,6 ± 0,8 MJ/MJ pour la suivante. Ces résultats suggèrent l'importance d'évaluer la durabilité de ces systèmes en combinant toujours plusieurs approches.

Mots-clés. Bovins viande – Indicateurs de durabilité – Paturages de montagne – Engraissement intensif.

I – Introduction

The beef production system causes a relevant environmental impact, in particular because of greenhouse gases (GHG) emission (Gerber *et al.*, 2013). On the other hand, it contributes to food security converting not-edible feedstuffs into edible products with a favourable contribution to output/input ratio of human-edible feedstuffs (Wilkinson, 2011). The integrated France-Italy beef production system represents a particular situation, characterized by a geographical separation of the suckler cow-calf herds, located mainly in a mountain area of Central France (Massif Central) and based on extensive pasture (Brouard *et al.*, 2014), and the fattening farms in North-East Italy, which rear the imported stock calves using total mixed rations based on maize silage and concentrates (Gallo *et al.*, 2014). This study aimed to analyse the sustainability of the integrated France-Italy beef production system through carbon footprint indicator (kg CO₂-eq/kg body weight, BW, sold, computed according to Life Cycle Assessment method) and the human-edible feed conversion ratio computed as the ratio between the metabolisable energy (ME) content in human-edible feedstuffs and the energy content of human-edible animal products (HeFCR).

II – Materials and methods

This study involved 73 Charolais breed fattening batches (i.e. animals homogenous for origin, finishing herd and Italian fattening period) with a total of 4882 heads reared during 2014. The cradle-to-farm gate system boundaries included three steps: the suckler cow-calf herd, the transport of stock calves to Italy and the Italian fattening period until slaughter. The suckler cow-calf period combined the inputs and emissions due to the reproduction step (suckler cows during one lactating and one not-lactating period, reproduction heifers during the same period, pre-weaned calves from birth to weaning) and due to the pre-fattening of male calves destined to Italy (from weaning to the sale to Italy). A mass method was used to allocate the emissions due to the reproduction step to the pre-fattening male calves destined to Italy. The reference unit was the batch and the functional unit 1 kg BW sold at the end of the fattening period.

Data about the French suckler cow-calf phase were derived from INRA Charolais Network (Lienard *et al.*, 1998), which provides long term information about herd management, agricultural surfaces and their management (type and amount of fertilizers), use of off-farm inputs (concentrates, fuel, plastic). In order to connect the fattening batches with the suckler cow-calf herds, a cluster analysis of the fattening batches was performed. The variables were the birth date, age and BW at sale to Italy. Three clusters were obtained. Mean \pm SD range, calculated for the BW and age of pre-fattened young bulls per cluster, was used to identify those France farms which sold animals with the most similar characteristics to those found for each Italian cluster. A mean suckler cow-calf farm was obtained by using the mean information derived from the farms selected for each cluster.

Diet composition and dry matter intake (DMI) per animal category (suckler cows, reproduction heifers, breeding bulls and calves) were computed using rations derived from Brouard *et al.* (2014); a resolution model (Office Excel software) was used to constrain the DMI per head within the range of 1.8 and 2.0% BW. Data for the Italian fattening period were collected from 14 North-East Italy fattening farms. For each batch, data about number of animals, date of arrival and sale to slaughterhouse, BW at the sale to Italy (BWS), at arrival to Italy (BWI) and at the end of the fattening period (BWF) were collected. Feed intake per head and per day, diet composition and diet samples at the manger for the chemical composition were monthly collected for each batch. Dry matter intake (kg DM/head/day) was calculated as the mean of monthly feed intake, weighted by the time period between two following diet samples. Average daily gain (ADG, kg BW/d) was calculated as the difference between BWF and BWI, divided for the total animal presence (heads x days). Nitrogen and phosphorus input-output flows were calculated using the Environmental Resource Management (ERM, 2002) procedure. Agricultural inputs for on-farm feedstuffs and materials (plastic, fuel, lubricant, bedding materials) for herd management were derived from official and farmers' documents.

Transport of stock calves to Italy was based on a mean distance from Clermont-Ferrand (Central France) to Padua (North-East Italy) and 32-ton trucks, while soybean was supposed to arrive from Brazil and fattening off-farm maize and sugar beet by-products from Ukraine.

Greenhouse gases emissions were estimated using the equations proposed by Sauvant *et al.* (2011) for enteric methane (CH₄) and by IPCC (2006) for CH₄ and nitrous oxide (N₂O) due to manure management (Tier 2) and for N₂O due to the spread of fertilizers and manure (Tier 1, IPCC 2006). The emission factors for the off-farm feeds, the production of agricultural, industrial and bedding materials and for the stock calves transport were derived from Ecoinvent (Ecoinvent, 2014) and Agri footprint (Blonk, 2014) databases. The procedure proposed by Wilkinson (2011) was used to compute HeFCR, on the basis of the mean energy value of 1 kg BW derived from Pelletier *et al.* (2010) and of ME content of diets, calculated using procedure suggested by INRA (2007). The edible fraction of different feedstuffs was derived from Wilkinson (2011).

III – Results and discussion

The batch size was 67 ± 33 heads on average, showing a large variability in the availability of stock calves during the year. Mean BWS was 405 ± 13 kg, with a range from 350 to 426 kg. The mean BW loss due to transport from France to Italy amounted to $4.8 \pm 0.4\%$ on average. The BW at the end of the fattening period was 729 ± 23 kg on average, with an ADG of 1.52 ± 0.09 kg BW/d during the 226 ± 11 days of fattening, and an overall ADG of 1.27 ± 0.09 during the 542 ± 36 days of the whole production cycle. DMI was 6.8 ± 0.4 kg DM/head/day for the overall cycle, and 10.6 ± 0.5 kg DM/head/day during the fattening period on average. Table 1 shows the results of the carbon footprint and HeFCR. For the overall beef production cycle, mean GHG emission was 13.0 ± 0.6 kg CO₂-eq/kg BW sold on average, with a mean share due to suckler cow-calf phase of $65 \pm 3\%$. Mean HeFCR was 3.8 ± 0.5 MJ diet edible/ MJ edible in animal products, showing a larger variability than the carbon footprint. The carbon footprint of the overall France-Italy beef production system was comparable to those of other studies, even if the methods for enteric CH₄ computation differed (Beauchemin *et al.*, 2010, Nguyen *et al.*, 2012). The HeFCR for the entire production chain was comparable to values for beef systems found in Wilkinson (2011).

Table 1. Carbon footprint (CF) and efficiency to produce human edible products (HeFCR, MJ diet edible/ MJ edible in animal products) for the integrated France-Italy beef sector (cradle-to-end of the fattening period gate) at Italian fattening batch level (N = 73)

Variable	Unit	Mean	SD	Min	Max
CF, suckler cow-calf phase	kg CO ₂ -eq/ kg BW sold	15.1	0.7	14.3	15.9
CF, fattening phase	kg CO ₂ -eq/ kg BW gained	9.6	1.0	7.7	12.1
CF, France-Italy beef sector	kg CO ₂ -eq/ kg BW sold	13.0	0.6	11.8	14.4
HeFCR, suckler cow-calf phase	MJ/MJ	2.9	0.4	2.6	3.7
HeFCR, fattening phase	MJ/MJ	4.6	0.8	3.0	6.9
HeFCR, France-Italy beef sector	MJ/MJ	3.8	0.5	2.9	5.3

Carbon footprint and HeFCR were negatively correlated ($r = -0.41$, $P < 0.001$), with suckler cow-calf showing a greater carbon footprint and a lower HeFCR than the fattening phase. This implies a trade-off situation, for which the reduction of HeFCR, to optimize the conversion ratio of human-edible feedstuffs, could lead to an increase of GHG emission intensity. We have also to consider that the pasture-based livestock systems offer several positive externalities in terms of ecosystem services (Rodríguez-Ortega *et al.*, 2014) and carbon storage, with related influence on the net GHG

emission. Consequently, the exclusive use of indicators of environmental impact, such as the carbon footprint, to assess the sustainability of beef systems could be distortive, especially for grassland-based farms in mountainous areas.

V – Conclusions

The integration between pasture-based suckler cow-calf farms in France (Massif Central) and cereal-based fattening farms of northern Italy allows optimizing the use of the resources offered by different agro-ecosystems for beef production. The pasture based livestock systems in mountainous areas showed a convenient human-edible feed conversion ratio but high GHG emissions per unit of product, while the opposite was found for the intensive, cereal based fattening systems. The trade-off observed between carbon footprint and human-edible feed conversion ratio highlighted how the use of different indicators permits to address a more holistic evaluation of livestock systems sustainability. The approach used in this study can be extended to other indicators and other production systems (i.e. dairy sector) for the evaluation of sustainability of mountainous livestock systems.

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The current status of transhumance systems in the province of León (Spain), towards a multi-dimensional evaluation

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Abstract. A multi-dimensional approach is proposed to evaluate the changes in transhumance systems associated to natural resources management in León (Cantabrian mountain, Spain), in order to know their sustainability status. This evaluative model focuses on the production system, owing to the fact that agroecosystem sustainability depends on the ecological integrity (the maintenance of ecosystem functionality) and specifically on the ecological coherence (the appropriate connection between the production system and the ecosystem). Two different methodological proposals are used to assess production system qualities: one based on farmers' opinion evaluation and the other on experts criteria assessment. The results show that the ecological rationale of transhumance is still rooted and adapted to resources management in León's territory: firstly, the new transhumance model of short movements has demonstrated flexibility and adequacy to the current conditions, being, indeed, an opportunity to develop a transition towards more sustainable systems. And secondly, beef cattle expansion in the mountain pasturelands with speculative aims is degrading natural pastures and increasing the land abandonment process.

Keywords. Transhumance - Multidimensional evaluation – Sustainability–Mountain pastures.

État des lieux des systèmes de transhumance dans la province de León (Espagne), en vue d'une évaluation multidimensionnelle

Résumé. Une approche multidimensionnelle est proposée pour évaluer les changements des systèmes de transhumance en lien avec la gestion des ressources naturelles dans la province de León (Monts Cantabriques, Espagne), afin de connaître leur situation sous l'angle de la durabilité. Ce modèle d'évaluation est axé sur le système de production, dû au fait que la durabilité des agroécosystèmes dépend de l'intégrité écologique (maintien de la fonctionnalité de l'écosystème) et spécifiquement de la cohérence écologique (connexion appropriée entre le système de production et l'écosystème). Deux propositions méthodologiques différentes sont utilisées pour évaluer les qualités des systèmes de production : l'une basée sur l'évaluation de l'opinion des éleveurs et l'autre sur l'évaluation de critères par des experts. Les résultats montrent que la logique écologique de la transhumance est encore enracinée et adaptée à la gestion des ressources sur le territoire de León : d'abord, le nouveau modèle de transhumance de courts mouvements a fait preuve de flexibilité et d'adéquation aux conditions actuelles, et constitue indéniablement une opportunité pour développer une transition vers des systèmes plus durables. Et ensuite, l'expansion des bovins dans les pâturages de montagne à des fins spéculatives est en train de dégrader les pâturages naturels et d'augmenter le processus d'abandon des terres.

Mots-clés. Transhumance – Évaluation multidimensionnelle – Durabilité – Pâturages de montagne.

I – Introduction

The geographical diversity of the Iberian Peninsula results in different areas which are complementary on pasture productivity along time, within the Mediterranean climate region. Transhumance is an extensive traditional livestock breeding system based on recurrent movements for aimed to take advantage of this ecological circumstance.

Some areas on the Northern Mountains, very productive on summer, complement the pastureland on the South-West (Extremadura), productive during the winter and spring (Gómez Sal and Lorente, 2004). Transhumance has enabled humans to link this disposition of primary productivity, along history.

In León province, placed on the south aspect of Cantabrian Mountains, Transhumance has been a constant activity since Middle Ages. However, this activity has suffered a recession since the XVIII century, when an agriculture based productive model was favoured. In the last century, most of the traditional large sheep flocks were abandoned, divided or sold. The overall number of transhumance livestock has been reduced significantly and the long displacements with Merino sheep between León and Extremadura have been partially replaced for a model of shorts movements inside the province, to the new irrigated lands (Gómez Sal y Rodríguez Pascual, 1992). In parallel, on the mountain pasturelands sheep has been replaced by cattle, due to the better price on the markets and an easier management (free ranging, without shepherding in the summer pastureland). The production system has nowadays a meat orientation (instead the wool), more intensive, with a lack of interest at improving or maintaining the productivity and composition of mountain pastures.

In León there are more than 300 units of a specific mountain pastures, known as “puertos de merinas”, historically devoted to transhumance uses, integrated on public and common lands. Recent studies show that the recession of Transhumance has an effect on these ecosystems. A half of their surface is now occupied by shrubs (Tecnosylva, 2005). In addition, there is a lack of control and a loss of ancestral knowledge of pastoralism in the “puertos”.

Besides, the agriculture sector and rural society in León has been deeply restructured in the last decades due to the adhesion of Spain to the EU and the application of the Common Agrarian Policy (CAP) with important changes on the land use and the industrialization of the activity (Modino, 2012). At the same time, a rural depopulation, really intense in mountain areas, has taken place.

The present study aims to understand and evaluate the current status of Transhumance in León, the changes that have occurred and present problematics, taking in consideration the whole context and the different dimensions which interact in this activity.

II – Materials and methods

The methodology used in this study has included two different phases. In the first one, heuristics, proceeded to search and collect information including: official and private documents, applied research, consulting experts on transhumance and pastures ecology, conducting 9 deep interviews with transhumance farmers and contacting the regional services of livestock and environment from the regional administration.

The second, hermeneutics, has analysed and evaluated all the information collected, to understand the context, the status and problematics that Transhumance has nowadays.

Social research techniques were chosen, given the fact that the different participants in transhumance, still present in León, could intervene and have an active role. Semi-structured interviews were applied, allowing collecting descriptive information of technological, social and cultural dimensions. At the same time, it allows to understand the context of this activity.

The heuristics phase has intended to perform an assessment of the management systems presented in León province through a multi-criteria approach. The evaluation model used is based on the methodology proposed by Gómez Sal (2001, 2013). Two different approaches were applied;

a) A sustainability assessment of the different transhumance systems based on the farmers' opinion, which is used to quantify the importance of the different problematics. That allows obtaining a comprehensive view of the status of each system evaluated.

b) The second is a theoretical model based on expert's criteria. It evaluates the different indicators (derived from above mentioned problematics) and compares three different livestock systems in the mountain pastures: (1) long transhumance movement, around 500 km length displacements from Extremadura, (2) short ones, known as "transterminancia", altitudinal movements within the province 100 km approx. and (3) cattle transhumance, about 100 km from pastures place on the North side of the "cordillera", near the coast, in the Atlantic zone. These actual transhumance systems were collated with 3 references scenarios; traditional self-sufficiency agriculture, conventional intensive agriculture and sound sustainable land use system (Gómez Sal and González García, 2007).

The evaluative dimensions selected were 5:

- Ecological dimension: Ecosystem assessment, it aims to determine the supporting capacity of ecosystems and their conservation value.
- Productive dimension: Evaluation of the production system. An evaluation of its efficacy (yield).
- Economic dimension: Profitability assessment.
- Cultural dimension: Documentation and valuation of heritage.
- Social dimension: Social functions. Indicators for human development.

The evaluative model focuses on the technological or production system, due to the fact that agroecosystem sustainability depends on a degree of the ecological integrity (the maintenance of ecosystem functionality) and on the ecological coherence (the appropriate connection between the production system and the ecosystem). The productive dimension is considered as a link between ecological and economic systems and it is where lies the essential ability to make the system sustainable. The social and cultural dimensions emerge from the interaction of the previous ones (Gómez Sal, 2013).

The main problems detected in the heuristics phase have been selected and summarised for evaluating the dimensions. They have been taken as indicators for the components of each dimension.

III – Results and discussion

Both sheep transhumance systems (long/latitudinal and short/altitudinal) have shown a high sustainability value in both ecological and productive dimensions (Fig. 1). The knowledge about the pasture ecosystems of these shepherds allows utilising and maintains the mountain pastures productivity and composition. However, these shepherds discern that the productive dimension is threatened, for example by the actual scarcity of expert shepherd and the intensification of some process. Additionally, "transterminant" farmers have to interact with other agriculture systems, utilising stubble of cereal land and agriculture gardens, being affected by agroecosystem degradation.

The long movements have increased their cost significantly because of the abandonment of walking displacements and the use of tracks. Also because of the raise of the land rent, both in mountain pastures and Southern Pasturelands, owing to beef outcompete and its better price on markets.

Furthermore, sheep transhumant systems contribute to made use and preserve a wide and important heritage, as the "cañadas" (transhumance drover roads). It is necessary to develop the economical profitability in both sheep systems, gaining independence from subventions

The social dimension obtains lower values in long displacements (Fig. 1), mainly due to the problems it has to satisfy present lifestyle conditions and expectations. The short movements offer a more sustainable way, compared with long transhumance displacements. The first ones are more adapted to current lifestyle, near home and family; the second unfortunately is nowadays a very de-structured profession that needs social support and recognition.

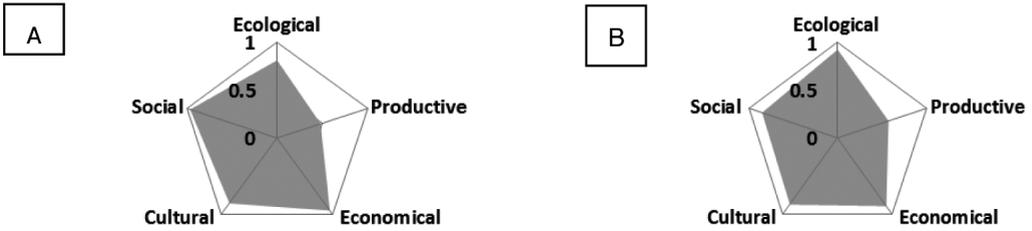


Fig. 1. Comparative schemes of sheep transhumance systems Multidimensional Evaluation of detected problematics based on Shepherds' opinion. A: Long Transhumance Movements, B: Short "Transterminant" Movements.

However, short movements just as much as long displacements are close to sound sustainable land uses system.

The beef cattle obtain lower values comparing to the sheep raising. These unsustainable results of cattle (Fig. 2) are explained because of its economical speculative aims, not linked with the natural resources of the area. This activity is not based on traditional knowledge, and does not care about the livestock management and the use of the natural resources of the mountain pastures or the development of new techniques. This system does not try to consolidate marketing lines or have a diversified production. It depends completely on the subsidies, which ensure the return of investment, and does not interact with the rural society of the mountain area. In many cases, the effect is the degradation of pastures in the "Puertos", as its productivity and composition.

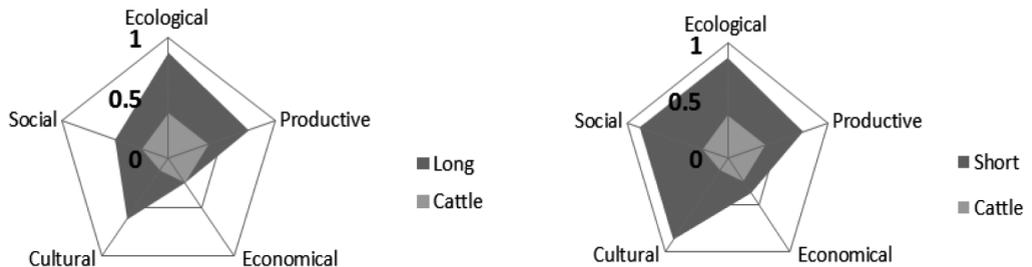


Fig. 2. Comparative schemes of Multidimensional Assessment of three transhumance systems sheep transhumance, "transterminance and cattle transhumance. Expert criteria assessment.

IV – Conclusions

Transhumance is an original production system, highly adapted to the characteristics of the territory and available resources in the province of León. The suffered recession has not affect Transhumance to adequate to new contexts. The shorts movements are an example, more flexible and adapted to current socio-cultural concerns and to the use of natural and new agricultural resources available in the region. This fact has shown a potential to promote a transition to more sustainable scenarios.

A new agent, whose effects were not sufficient evaluated in former studies, has appeared: the beef cattle short transhumant raising spreading with an unsustainable speculative model, which is degrading natural pastures. This system has also a negative impact and displaces the traditional sheep based Transhumance systems.

The mountain pastures have suffered an abandonment process, with serious changes in their ecological integrity and coherence. The Administration has had a role in this process promoting agrarian intensification policies, and not supporting sheep Transhumance in the region. The mountain society increases the lack of opportunities and the depopulation trend.

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Comparing transhumance in Xinjiang, China and California, USA

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Abstract. Comparing transhumance in China and the United States is challenging because of vast social and economic differences, but here we make a first attempt. Globally, rangeland livestock producers share many challenges, practices and even social relations because of the ecological dynamics of rangeland grazing. In Xinjiang, China and California, USA, pastoralists move their herds to mountain pastures in summer. However, there are major differences in animal husbandry affecting the costs of transhumance. Costs are lower in the US because ranchers raise only cattle and sell most of the calves produced each year. Most montane rangeland is owned by the government. In Xinjiang, herders keep mixed herds of diverse ages, which increases the need for skilled labor in the mountains, and means they must keep most of the herd through the winter. Rangeland grazing areas are fragmented by division and privatization of grazing rights. In California, ranchers participate directly in the market, selling directly to buyers. Most have outside income to buffer variability in markets and forage, and a spectrum of investment opportunities for cash. Xinjiang herders do not have the same opportunities for outside employment, or lucrative investment opportunities as yet, and usually sell to middlemen because they are isolated from and unfamiliar with markets. Historical, land tenure, market, and cultural differences are reviewed to help explain the constraints and current decline of the different systems. This may offer insights for Xinjiang policy development during the transition from traditional subsistence pastoralism to commercial animal husbandry.

Keywords. Pastoralism – Costs – Animal husbandry – Rangelands – Mobility.

Comparaison de la transhumance au Xinjiang, Chine, et en Californie, USA

Résumé. C'est un grand défi de comparer la transhumance en Chine et aux États-Unis en raison de vastes différences sociales et économiques, mais il s'agit ici d'un premier essai. Globalement, les producteurs sur parcours ont en commun de nombreux défis, pratiques, et même relations sociales en raison de la dynamique écologique de la paissance sur parcours. Au Xinjiang, Chine, et en Californie, USA, les pastoralistes emmènent leurs troupeaux aux pâturages de montagne en été. Toutefois, il y a des différences majeures en élevage concernant les coûts de transhumance. Les coûts sont plus faibles aux États-Unis car les éleveurs produisent uniquement des bovins et vendent la plupart des veaux produits chaque année. La plupart des parcours de montagne sont la propriété du gouvernement. Au Xinjiang, les bergers ont des troupeaux mixtes d'âge divers, ce qui augmente les besoins en main-d'œuvre qualifiée dans les montagnes, et signifie qu'ils doivent garder la plupart du troupeau pendant l'hiver. Les zones de pâturages de parcours sont fragmentées par la division et la privatisation des droits de paissance. En Californie, les éleveurs participent directement au marché, vendant directement aux acheteurs. La plupart ont un revenu supplémentaire pour atténuer la variabilité des marchés et du fourrage, et une gamme d'opportunités d'investissement pour l'argent liquide. Les bergers du Xinjiang n'ont pas encore les mêmes opportunités d'emploi externe, ou d'investissement lucratif, et vendent généralement aux intermédiaires car ils sont isolés des marchés, avec lesquels ils ne sont d'ailleurs pas familiarisés. Les différences historiques, de propriété foncière, de marché, et de culture sont examinées pour contribuer à expliquer les contraintes et le déclin actuel des différents systèmes. Ceci constitue un aperçu sur le développement de politiques au Xinjiang durant la transition du pastoralisme traditionnel de subsistance à l'élevage commercial.

Mots-clés. Pastoralisme – Coûts – Élevage – Parcours – Mobilité.

I – Introduction

Comparing range livestock production patterns using transhumance in China and the United States is challenging because of the vast social and economic differences between the two countries. However, globally, pastoral people, those who raise livestock on rangelands, share many of the same challenges, practices and even social relations because of the ecological dynamics of livestock grazing and rangelands (Huntsinger *et al.*, 2010a). Transhumance is a common pattern of rangeland use. Pastoralism generally occurs at the political, economic, and ecological margins (Sayre *et al.*, 2013). Regardless of their location, pastoral peoples and rangelands face growing political, economic, and climatic stresses that challenge their coupled resilience and ability to adapt (Reid *et al.*, 2014). In this paper we make a first attempt at comparing transhumance for summer pastures in Xinjiang, China, and California, USA. Our goal is to lay the groundwork for a more detailed comparison that will offer insights for pastoral development in Xinjiang. While there is no reason that Xinjiang animal husbandry should develop in exactly the same way as US pastoralism, it is likely that elements of the two pastoral system can be identified as potentially transferable.

II – Study area and methods

Our results are based on interviews with herders, outreach professionals, and officials in both places, conducted at various times over many years. In Xinjiang, the case study area is in the Ili Valley of the northwestern part of the province. The area borders on Kazakhstan, and the Mongol and Kazakh herders studied are part of small pastoral communities that have relied on transhumance for centuries and more. Fall through Spring pastures are in the valley, at elevations of around 1000 meters, average precipitation between 200 and 500 mm, and average temperatures of around 9 c. Summer pastures are in the Tian Shan Mountains, ranging up to 4000 meters, with warm summers and snowy winters and average precipitation as high as 800 mm. The area is in a temperate semi-arid continental climate zone. In California, the case study area is the westside central Sierra Nevada foothills. Transhumance began in the mid-nineteenth century. Fall through spring pastures are in the foothills at elevations ranging from 20 to 1,000 meters with an average precipitation of around 900 mm and average temperatures of around 16°C. Winter pastures are at higher elevations, ranging to 3,000 meters, with warm summers and snowy conditions in the winter. The area is in the Mediterranean climate zone.

III – Findings

Although in both countries livestock producers face the challenge of moving animals up to the mountains, and of taking care of the herds, differences in production practices affect costs.

1. Xinjiang

In Xinjiang, sheep, cattle and horses of diverse ages may be kept by one household. Livestock are born in early spring, mostly from February to April, when the herders are at winter camps. Winter settlements usually have infrastructure such as covered pens, veterinary services, and so forth. Around the mid-May, the herds move to spring camps for about a month, then leave for summer camps around the middle of June where they spend around 3 months to the end of September. They then move to fall camps for one month, and come back to their winter camps at the end of October. Herders only sell some of their one year old male livestock in the autumn, and keep all the female livestock for reproduction. For this reason they wind up keeping most of the livestock all year round. Because herders tend to have mixed herds, including dairy animals for the household, labor must be skilled in the husbandry of diverse animals.

In Xinjiang, because of the complex labor needs and the culture of summer pasture life, under traditional community organization families followed the herds as they moved among different pastures, using shared labor and land to move and husband the herds. But in the last 30 years with the government encouraging pastoralist settlement and particularly with the division of pastures to households, along with collective actions being replaced by individual household production, labor shortages and high production costs have changed transhumance. Summer is the busiest time because herders must herd sheep in higher summer pastures as well as cut grass in lower winter/spring pastures for winter. Household labor is in short supply, so families cannot move with herds like in the old days – many have to hire someone to take care of the herds in summer, increasing costs. Herds are beginning to be simplified. Division of land to households has also increased costs. Transhumance distances are as long as 100 km, so households need to rent vehicles to transport animals because they have to cross large areas of once shared rangeland that is now controlled by individual households. Given these cost increases, the number of livestock moving to summer pastures is decreasing and the time herds stay in fall-spring pasture is increasing, leading to the visible degradation of fall-spring pastures.

2. California

Most ranchers raise only cattle. Calves are generally born in late fall in California, earlier than in the rest of the western U.S. because the annual time of peak forage availability is spring. Before the herd goes to the mountains, the calves are weaned and sold, and only cows go up. In most of the rest of the arid west, calves are born in spring, go up to summer pasture with the cows, and are weaned and sold in fall, aside from a few replacement females. Weaned calves are sold to enterprises that use high quality lowland pastures or feed to encourage rapid growth. Eventually calves are slaughtered at 14-18 months of age, often after passing through a third enterprise, the feedlot. In a feedlot, cattle are fed high quality feeds for a month or so preparatory to slaughter, and they are often located in regions where grain is grown. Much of pastoral mobility is in transferring animals to enterprises in different regions with different feed sources and husbandry practices. This is the typical U.S. commercial pattern, but there are many variations.

At each strata labor needs are focused on a narrow part of the production stream. «Cow-calf» ranchers, with a fairly uniform herd, can limit labor needs by, for example, attending to the standard veterinary needs of the entire herd at the same time. Summer husbandry needs are to keep the animals safe and in the right grazing area, and to watch out for illness, accidents, and predation. In many cases one member of the family or a hired herder can take care of the entire herd, and the rest of the family farms or works at home. Herds can be left untended for short periods of time. During the fall, when rangeland forage is most constrained in California, the herd is at its smallest size and animal demand is low because calves have been sold. Animal demand peaks in spring, when the most forage is available in this climate zone. While ranchers have traditionally often moved up to summer pastures and enjoy it, since most households now have obligations in town it is rare to stay for long periods if at all. Fragmentation due to land development and conversion have also increased transportation and management costs. The majority of transhumant ranchers in one survey said that their operations had been impacted by land fragmentation, vegetation change, and changes in government priorities for the land, such that transhumance is declining (Huntsinger *et al.*, 2010a).

IV – Discussion: Historical and cultural context

The history, land tenure, market relations, and cultures differ in each place, and explain some differences in practices. While ranchers often are from multigenerational ranching families, U.S. ranching has from the start has been oriented to producing livestock for the market. Herders in the Ili Valley are not generally part of the majority culture, including the market culture of the majority popu-

lation of China. Their cultures have developed in the context of thousands of years of subsistence herding, and husbandry practices have deep cultural meaning.

In California, most summer pastures are owned by the government and leased to ranchers, while the base ranch and much of the winter range is privately owned. Leases for government land, or permits as they are known, were allocated early in the twentieth century, mostly to ranches adjacent to federal lands. They tend to remain with a ranch, but can be adjusted or even canceled by the government. Permits specify a number of livestock equivalents that can be grazed over a specified period of time. The number of equivalents allowed has declined regularly since allocation, because of policy change and fire suppression, as there is growing public demand for recreation land and protected preserves, and without the traditional burning of ranchers and native peoples many California ranges convert to trees and shrubs.

In Xinjiang land tenure has gone through three comparatively recent phases: tribal ownership, collective ownership and long term government contracting of grazing areas to individual households. From 1978 to 2000s, herders gradually went through different stages of privatization: livestock privatization, pasture use right privatization, and then fencing to clarify boundaries between pastures. Today, a household may have rights to several widely scattered parcels of land, representing the different seasonal ranges. They are small by U.S. standards. Land has also been lost to development, tree planting, and grazing bans.

The markets that each group must rely on are structurally different. U.S. livestock producers negotiate directly with the owners of the next part of the production chain. Auctions, video marketing, and online selling facilitate communication between those needing calves and those selling them. In Xinjiang, herders are more isolated and have less access to technology, and less knowledge of the process of competitive marketing. They usually rely on middlemen who come out to distant villages and pastures to negotiate for buying stock. The middlemen then sell to the slaughterhouse or other buyers. Investment opportunities are also limited in Xinjiang, and most herders believe they get a higher return from keeping their capital in animals.

In both places, livestock are more than commodities to the producer and have social meaning. (Eillis 2013), and there is a network of social relationships that facilitates livestock herding on rangelands (Li and Huntsinger 2011; Ellickson 1986; Bennett 1968). While «being a rancher» confers an identity and status to ranchers in the United States, livestock have deeper and more complex meaning to the ancient Mongol and Kazakh cultures. Livestock are considered as family insurance, a symbol of family status, and are the media of gift economy. The number and kinds of animals kept by a family is key, as they must be gifted at certain times to maintain critical cultural practices and rituals, and the family's stature in the community.

Finally, despite the advanced commercialism of U.S. rangeland production, the majority of ranching households in the U.S. rely on outside income to support their ranch, with less than 14% of California foothill ranchers earning most of their income from livestock production (Huntsinger *et al.*, 2010b). On a per hectare basis, rangeland production is low, and the benefit is producing food from land that is otherwise not useful for production. Interviews in Xinjiang indicate that most households also seek outside income but there are limited opportunities.

IV – Conclusions

Transhumance costs in California are likely lower than in Xinjiang, because of the different patterns of animal husbandry. However, the cultural meaning of various aspects of animal husbandry, and current conditions for employment, marketing and investment, make it difficult for Xinjiang herders to transition to a more efficient system of producing livestock.

Costs to U.S. producers are increasing due to land fragmentation, just as they have done in Xinjiang. Trailing to the mountains has become more difficult. Shifts in policy land, and land tenure and use are also an impact. Herders in Northern Xinjiang are transitioning from subsistence to commercial production, but it is difficult for them to give up traditional husbandry, for cultural and financial reasons. This includes raising livestock for their entire life cycle, keeping most animals all year, and carrying out other practices with social and cultural meaning. The collective management that once helped reduce labor needs for each household has largely been lost (Li and Huntsinger, 2011). We suspect that in both places transhumance will further decline, with unknown impacts on rangeland vegetation, and reducing the available rangeland for Xinjiang herder households and California ranches. Given the positive impacts grazing has been shown to have on some rangelands, and the cultural values of transhumant grazing, can, and should, this trend be reversed?

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Extended lactations to overcome reproduction problems in mountain low-input dairy systems

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Abstract. With the end of milk quotas, dairy mountain farmers cannot compete with low-land farmers because of higher costs and lower productivity. So they have to maximize the use of local forages, reduce their inputs and make quality products like PDO cheeses. To study this new context, we designed since 2011 two low-input innovative farming systems at an INRA experimental farm (1100 m asl): 12 Holstein and 12 Montbéliarde cows in each; a short calving season (~77 days) before turning-out to pasture to superimpose lactation curve on grass growth; no concentrate or 4 kg/d during 200 days. Unfortunately, those systems led to poor reproductive performances, with only 35% of adult cows calving during the following season, without difference between systems or breeds. To overcome the low number of pregnant cows, we decided to extend of ~10 months the lactation of some non-pregnant cows (7 to 23 each year), in order to have always 24 lactating cows by system during summer. The 53 cows involved in extended lactations (~568 d) produced 70% more milk by lactation (8026 vs. 4715 kg) than cows with 'standard' lactations of 289 days, without significant difference between systems or breeds. In addition, these cows had better reproductive performances, with 79% of pregnant cows and 72% of calving the following spring. Even if these results must be completed by an economic study, extended lactations seem to be an interesting practice to reinforce the sustainability of seasonal low-input dairy mountain systems.

Keywords. Dairy cow – Low-input system – Reproductive performances – Extended lactation.

Des lactations prolongées pour remédier aux problèmes de reproduction dans les systèmes laitiers bas-intrants de montagne

Résumé. Avec la fin des quotas laitiers, les éleveurs de montagne ne peuvent plus rivaliser avec ceux de plaine sans maximiser l'utilisation de leurs fourrages, réduire leurs intrants et fabriquer des produits de qualité comme les fromages AOP. Pour étudier ce nouveau contexte, nous avons conçu depuis 2011 deux systèmes d'élevage bas-intrants innovants, dans une ferme expérimentale INRA (1100 m d'altitude) : 12 Holstein et 12 Montbéliarde chacun ; saison de vêlage réduite (~77 jours) avant la mise à l'herbe pour superposer courbe de lactation et croissance de l'herbe ; zéro concentré ou 4 kg/j pendant 200 jours. Malheureusement, ces systèmes ont entraîné de mauvaises performances de reproduction avec seulement 35 % des vaches adultes vêlant la saison suivante, sans différence entre systèmes ni entre races. Pour pallier ce faible nombre de vaches gestantes, nous avons décidé de prolonger de ~10 mois la lactation de certaines vaches « vides » (7 à 23 par an), afin d'avoir toujours 24 vaches traites par système l'été. Ces 53 vaches en lactation prolongée (~568 jours) ont produit 70% de lait en plus par lactation (8026 vs. 4715 kg) que les vaches en lactation « standard » (~289 jours), sans différence significative entre systèmes ou entre races. De plus, ces vaches ont eu de meilleures performances de reproduction, avec 79% de gestation et 72% de vêlage l'année suivante. Même si ces résultats doivent être complétés par une étude économique, les lactations prolongées semblent être une pratique intéressante pour assurer la durabilité des systèmes bas-intrants, saisonnés, de montagne.

Mots-clés. Vache laitière – Système bas-intrants – Performances de reproduction – Lactation prolongée.

I – Introduction

With the end of milk quotas in 2015, mountain areas cannot compete with low-land because of the higher cost of inputs (cereals, fertilizers...) and their lower productivity. So, as evoked by Horn *et al.* (2013), these farmers have to implement seasonal pasture-based milk production systems to reduce their inputs, reinforce their link to terroir and meet consumers' expectations with quality products like PDO cheeses. To study this new context, we designed and implemented since 2011 two low-input innovative farming systems (called Bota and Pepi) for a long term 'system experiment' at the INRA experimental farm of Marcenat (French Massif-Central, 1100 m asl). These two farming systems, as self-sufficient as possible (12 Holstein [**Ho**] and 12 Montbéliarde [**Mo**] cows each; a short mating season of ~77 days; a calving season before turning-out to pasture to superimpose lactation curve on grass growth; no concentrate [**Bota**] or 4 kg/d at pasture [**Pepi**]; >180 days at pasture on permanent grassland) were described in detail by Pomiès *et al.* (2013). Unfortunately, these low-input systems led to poor reproductive performances, with only 35% of adult cows calving during the following season, without difference between systems or breeds. To overcome this low number of pregnant cows and in order to have always 24 lactating cows by system during summer, we decided to extend of ~10 months the lactation of some non-pregnant cows (7 to 23 each year) to put them to reproduction a second time the next spring. This study aims to compare the lactation and reproductive performances of these cows over the 4th first years of the experiment.

II – Materials and methods

1. Data collection and calculations

Every year, for every cow, the milk production was measured twice a day, the milk composition (fat and protein contents) 4 times a week on 2 consecutive days, and all the reproduction events were registered: oestrus (when detected), insemination (artificial or by the bull), pregnancy (confirmed by echography at ~60 days), and calving. Over the 192 possible 'lactation data' (24 cows × 2 systems × 4 years), 186 were used for this study and 6 were removed (dead or culled in early lactation). For milk production and composition, we compared the data of 80 cows that had a 'standard' lactation (**ST**) of about one year with 53 cows that had an 'extended' lactation (**EX**) of about two years (80 ST + 53 × 2 EX = 186). For reproductive performances we compared the data of all the cows put at reproduction just after calving (80 ST + 53 EX) with the data of the 53 EX cows put at reproduction a second time, after one year of lactation.

2. Statistical analysis

The measured data (milk production, composition, intervals between reproduction events) were analysed using the mixed procedure of SAS software (SAS Institute Inc., 2013). The model took into account the effects of the type of lactation (ST or EX), the system (Bota or Pepi), the breed (Ho or Mo), the rank of lactation (1, 2 or ≥ 3) and the interactions type × system, type × breed and system × breed. The counting data (number of cows inseminated, pregnant...) were analysed by chi-square tests according to the type of lactation, the system, the breed, and the rank.

III – Results and discussion

1. Milk production and composition

With 568 days on average (= 18.7 months), the duration of one EX lactation was only 10 days less than two ST lactations, with no significant difference between breed and rank (Table 1). The EX cows produced 70% more milk by lactation, with an expected effect of the system (+699 kg for Pepi), of

the breed (+574 kg for Holstein) and of the rank (-625 kg for primiparous), but with no interactions between these parameters and the type of lactation. Consequently, the average daily milk yield during lactation was 2.2 kg/d lower for EX cows. The shapes of the lactations curves were very similar during the 9 first months (Fig. 1A). The lactation peak of EX cows was lower (-1.2 kg/d from week 4 to 7) but during their last weeks of lactation ST cows produced less milk (-1.6 kg/d from week 36 to 44), partly due to pregnancy. After 44 weeks, the two groups of cows had produced exactly the same amount of milk; at this point, with the second turn-out to pasture, the milk production of the EX cows grew-up again. In the same way, the milk composition of the two types of lactation was very similar until week 36 (Figure 1B). From this point to the end of lactation, by concentration effect, fat and protein contents of ST milk were slightly higher (+1.7 and +0.9 g/kg, respectively). During the second half of EX cows' lactation, fat and protein contents increased continuously (+9.4 and +8.7 g/kg, respectively). Over the total lactation, it led to higher averaged fat (+1.3 g/kg) and protein (+2.2 g/kg) contents of EX milk compared to ST milk. The high protein and fat contents of EX cows during their 2nd summer also allowed to partly correct the low contents of new-calved cows in milk tank.

Table 1. Comparison of milk production, milk composition and reproductive performances between cows, according to type of lactation (standard or extended); adjusted values by system (Bota or Pepi), breed (Holstein or Montbéliarde) and rank of lactation (1, 2 or 3)

(Means ± standard error)	Type of lactation		Effect			
	Standard	Extended	Type	System	Breed	Rank
Duration of the lactation (d)	289 ± 5.1	568 ± 6.2	***	+	ns	ns
Lactation milk yield (kg)	4715 ± 103	8026 ± 124	***	***	***	***
Average daily milk yield (kg/d)	16.5 ± 0.21	14.3 ± 0.25	***	***	***	***
Average fat content (g/kg)	40.2 ± 0.41	41.5 ± 0.49	+	***	*	ns
Average protein content (g/kg)	31.6 ± 0.20	33.8 ± 0.24	***	*	***	ns
Length of previous dry-off (d)	104 ± 3.3	101 ± 5.7	ns	ns	ns	ns
Duration of the gestation (d)	285 ± 1.0	283 ± 1.2	ns	ns	*	ns
From calving to conception (d)	93 ± 4.6	422 ± 5.2	***	ns	ns	ns
Average date of conception	27 July ± 3.4 d	26 June ± 3.7 d	***	ns	ns	ns
Calving interval (d)	378 ± 4.8	705 ± 5.3	***	ns	ns	ns
Average daily milk yield during calving interval (kg/d)	12.6 ± 0.22	11.7 ± 0.25	**	***	**	***

Mean values ± standard errors ns (non-significant) $P \geq 0.10$; + $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

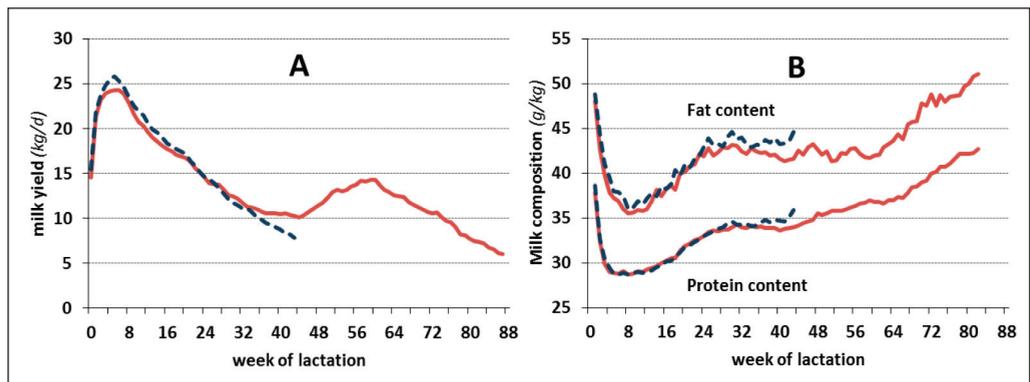


Fig. 1. Milk yield (A) and milk composition (B) of cows in standard (- -) or extended (—) lactation.

2. Reproductive performances

The type of lactation, the system, the breed, and the rank of lactation were not correlated to the length of the previous dry-off (Table 1). The breed was the only parameter that affected the duration of gestation, which was 3.5 days longer for Mo cows, slightly less than expected (Guerrier *et al.*, 2007). The average calving-conception interval of 93 days for ST cows led to a calving interval 378 days, greater than one year, that penalise cows for the following reproduction period. On the opposite, EX cows had more opportunities to reproduce from the start of the ~77 days period, and in fact they did it on average 31 days earlier. This led to a calving interval 25 days shorter than two years, whatever the system, the breed or the rank. Thus, if we calculate the average daily milk yield during the calving interval, the difference between ST and EX cows was down to 0.9 kg/d ($P < 0.01$), even less for Mo (0.3 kg/d).

In addition, only 74% of the 133 ST cows were inseminated after calving (artificially on oestrus detection or by the bull), whereas 100% of the 53 EX cows were. On these inseminated cows, the conception rate (**CR** = number of pregnant cows divided by number of cows inseminated) was higher ($P < 0.01$) for EX cows than for ST cows (79 vs. 55%). This good CR was statistically independent of the system (77% for Bota vs. 81% for Pepi), of the breed (72% for Ho vs. 86% for Mo) and of the rank of lactation (81%, 77% and 79% for ranks 1, 2 and ≥ 3 , respectively). Similarly, the poor CR of ST cows was independent of the system, the breed or the rank of lactation. The percentage of calving after a positive echography was identical for ST and EX cows (87 vs. 90%). It resulted that on 133 cows in condition to be inseminated after calving only 47 calved one year after (35%) whereas on 53 cows at reproduction after one year of lactation, 38 calved the next year (72%).

IV – Conclusions

All those technical results suggest that the extension of the lactation of some selected non-pregnant cows could be a solution to overcome the problem of poor CR in seasonal low-input dairy systems. This solution must be confirmed by an economic study of the results, that takes into account specificities of the context: necessity to have the maximum of cows in lactation at pasture because of the best quality-price ratio of this feeding to produce milk; difficulty to buy new cows to replace the non-pregnant ones (obligation to find cows born in the PDO area, sanitary aspects...); interest of higher protein and fat contents from extended lactation cows for PDO cheese-making; veterinary costs (mainly linked to calving and dry-off periods); etc. If the economic performance is not favourable, the only way to maintain that type of pasture-based systems will be to switch to other breeds that reproduce easily even with low inputs, such as Jersey or Holstein-Friesian from Ireland or New-Zealand (Piccand *et al.*, 2013).

Acknowledgments

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Towards sustainable dairy sheep farms based on self-sufficiency: patterns and environmental issues

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Abstract. Agroecology can provide a framework to ensure the sustainability of farming systems in regard to environmental issues of agriculture. In the case of livestock productions, the improvement of feeding systems is one way to limit their environmental impacts. In southern France, development of dairy sheep production under the Roquefort label has led to most of farms to using a high level of input. But over the past few years, groups of farmers have shared perspectives and ideas to test innovative sustainable practices to improve their farms adaptability, mainly increasing farms' self-sufficiency. We developed a research project on self-sufficiency patterns and their environmental impacts assessment. Based on a participatory approach, we organised focus-groups on self-sufficiency definition and agro-environmental performances. We carried on 20 farmers' interview to collect data about practices and environmental features. Four self-sufficiency patterns were identified and a set of 20 indicators which addressed agronomical and environmental features was built. Feed self-sufficiency is different for each pattern. The main differences of environmental impacts (based on input use) are linked to the Organic pattern. The use of wide diversity of meadows and species increases the concentrate sufficiency. This study is an important milestone to implement agroecological practices in dairy sheep production.

Keywords. Agroecology – Livestock farming system – Feed self-sufficiency – Diversity – Milk ewe.

Développer l'autonomie pour des systèmes ovin lait durable : modèles et problèmes environnementaux

Résumé. L'agroécologie peut fournir un cadre pour assurer la durabilité des systèmes agricoles, en particulier face aux enjeux environnementaux de l'agriculture. En élevage, l'amélioration des systèmes d'alimentation est un moyen de limiter leurs impacts environnementaux. Dans le sud de la France, le développement de la production de lait de brebis en zone Roquefort a conduit la plupart des exploitations agricoles à augmenter les intrants. Cependant au cours des dernières années, des groupes d'agriculteurs ont partagé des expériences et des idées pour tester des pratiques innovantes et durables pour améliorer leur capacité d'adaptation, en augmentant leur autonomie alimentaire. Ce projet de recherche vise à expliciter les différentes formes d'autonomie et d'évaluer leurs impacts environnementaux. Dans le cadre d'une démarche participative, nous avons organisé des « focus-group » pour définir l'autonomie et ses impacts agro-environnementaux. Nous avons réalisé 20 enquêtes d'éleveurs pour collecter des données sur les pratiques et les caractéristiques environnementales des fermes. Quatre modèles d'autonomie ont été identifiés et 20 indicateurs agronomiques et environnementaux ont été élaborés. L'autonomie se révèle liée aux différents modèles d'autonomie. Les principales différences d'impacts environnementaux, basé sur l'usage d'intrants sont à relier avec le modèle d'élevage biologique. L'usage d'une large diversité de prairies et d'espèces cultivées contribue à améliorer l'autonomie en concentré des élevages. Cette étude est une étape importante dans la mise en œuvre de pratiques agroécologiques en production de lait de brebis.

Mots-clés. Agroécologie – Système d'élevage – Autonomie alimentaire – Diversité – Lait de brebis.

I – Introduction

Mainly in less favoured areas, the model of development based on agriculture intensification weakens the sustainability of farms and jeopardises their adaptation to global change (Darnohfer *et al.*, 2010). As an alternative way, agroecology is a theoretical and conceptual framework suggested to address the challenges of global change adaptation of agricultural systems: on one hand to increase and on the other hand to secure feed production (Altieri, 2002). Within this framework, five principles were suggested by Dumont *et al.* (2013) to design agroecological livestock systems. Thénard *et al.* (2014) proposed a method to translate these agroecological principles into levers for action to design and to assess new farming systems based on agroecological properties. In some cases, the feed self-sufficiency of animals is a favoured stake to design agroecological livestock systems. In southern France, the development of dairy sheep production under the Roquefort label has led most farms to use a high level of input. We developed a participative project with a farmers' group who wants to improve the feed self-sufficiency of their farms. We examined how farmers develop different patterns for self-sufficiency and we proposed to assess these patterns using some agronomical and environmental indicators. We present different patterns of self-sufficiency identified and some indicators to assess the agroecological value of these farms.

II – Methodology

1. A participatory research with a group of dairy sheep farmers

The study site is the PDO Roquefort cheese made with raw ewe's milk. Traditionally, sheep grazed local grassland regarded as less-favoured pastures. To overcome the constraints of the area milk production has increased the feed purchases and inputs in farms. Until the 2000s, intensification increased forages harvesting to the detriment of grazing. A wide gradient of resources are used by farmers. Since 2000, the PDO specifications have included new requirements: ewes should be fed with forage coming for 75% from the PDO area and ewes should graze two or three months during the grazing period.

Since 2012, we have carried out a research project with a group of ten farmers supported by a farm adviser. The farmers called themselves "Economical and Locally grown Farms" (ELF): they seek to use the local forage resources and to reduce farm input requirements. The main stake of this participatory research is to test innovative sustainable practices to improve farms adaptability. To limit the dependence on fluctuating input prices and climate variability farmers want to improve the feed self-sufficiency of farms. In the first study, we exposed practices diversity and identified four contrasting farming systems (Thénard *et al.*, 2014). While all farmers want to limit inputs, we observed that the level of self-sufficiency achieved could be different. We then conducted a second study on how self-sufficiency was built by farmers and proposed some indicators to assess the different patterns.

2. Methods to analyse and assess different patterns of self-sufficiency

Within the agroecological framework, we used a participatory approach in order to favour exchanges between farmers, advisers and researchers. In a first step, we carried out work sessions to share the different views on the practices linked to self-sufficiency; and to explain the consequences of self-sufficiency on the farms, their agronomical properties and their impact on the environment. The sessions gave us which main stakes were identified by farmers to assess the impact of their practices on environmental issues. The exchanged knowledge highlighted the influence of practices on four main environmental stakes (soil preservation, no renewable resources use, wild and cultivated biodiversity). Also a set of 20 indicators were identified with farmers to assess the agronomical and environmental impacts of self-sufficient practices. In a second step, we surveyed farmers to describe

the diversity of self-sufficiency practices and to collect data used to calculate the indicators. During spring 2014, 3-hours semi-directive interviews were carried out among 20 farmers from the “ELF” group and others selected by experts as pursuing self-sufficiency. Farms were described in relation to different practices: concentrates purchase, fertilisation, diversity of meadows and crops, pure legume stands, tillage and the pesticides used. Data was analysed with a comprehensive method (Girard, 2006) to define patterns of self-sufficiency practices. Kruskal-Wallis test and Nonparametric Multiple Comparisons were performed to identify significant differences between patterns. Statistical analyses were computed with R software (R Core team, 2012).

III – Results and discussion

Four self-sufficient patterns were identified based on the practices (Fig. 1): a Standard pattern limiting input, while most of the farms use input, this pattern limits them increasing diversity of forages; a Diversity pattern limiting input while increasing diversity of species in crops and forages; a Sufficiency pattern with no ewe-feed purchase; and an Organic pattern without N-mineral and pesticides input but with concentrates purchase. The farms with Standard or Diversity patterns produce milk mainly during the winter period, with harvested forages. These farms ought to produce more milk per ewe (although there were not significative differences – Table 1) and they were not sufficient for concentrates. On the other side, farms which developed Self-sufficient and Organic patterns produce milk mainly during spring. Only the Sufficiency pattern purchased no forage and no concentrate. The use of fuel to produce forages and crops is common and non-discriminating.

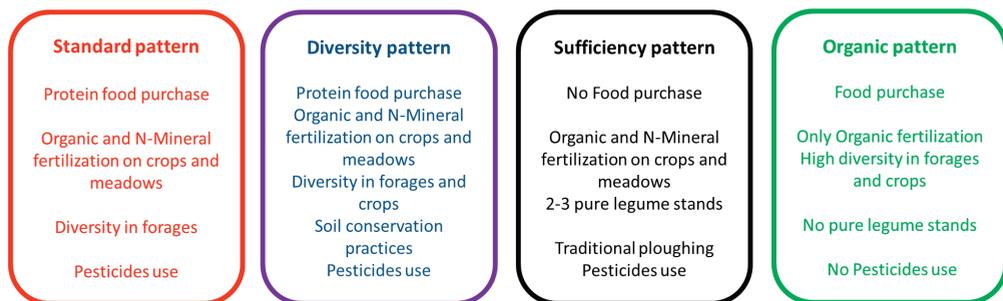


Fig. 1. Classification of the self-sufficiency patterns developed by farmers.

The set of indicators is presented in the Table 1, and all significant differences are detailed. **Standard pattern** was developed in farms with few intensive meadows mainly harvested and based on simple covers like alfalfa and orchard-grass. Farmers had difficulties to achieve self-sufficiency because the ewe requirements were important mainly during winter and farmers needed to buy protein concentrates. **Sufficiency pattern** was developed in farms with large parts of natural grassland combined to a wide diversity of sown meadows. Self-sufficiency was built with association of poor grassland used during summer and intensive meadows (pure stands and simple mixtures) harvested and grazed. **Diversity pattern** was developed in farms with a wide diversity of meadows mainly based on mixtures species, and crops mixtures for animal fed. Although farmers have engaged soil conservation practices, the related indicators were not significantly different in this group. Self-sufficiency was based on the wide diversity of forages included during summer period with specific meadows or original mixtures (alfalfa, sainfoin, grass). **Organic pattern** was developed mainly in farms producing milk for organic label. Because of organic label requirements, the con-

trast with the others groups was important for all indicators related to fertilisation and pesticides used. We observed that the duration of the meadows was longer and the parts of the mixtures in the meadows and crops were similar to the Diversity pattern.

Table 1. Set of indicators to assess agronomical and environmental impacts of the four different self-sufficiency patterns in dairy sheep farms

	Standard pattern	Diversity pattern	Sufficiency pattern	Organic pattern	P =
Number of farms	5	4	6	5	
Milk per ewe (l)	270	276	231	217	0.129
Forage sufficiency	97%	99%	100%	88%	0.168
Concentrate sufficiency	80% a	77% a	100% b	77% a	0.043
Area of grassland/AA	29% ab	36% a	69% b	63% ab	0.080
Area with legumes/AA	64% ab	62% a	54% a	71% b	0.095
Annual crops/AA	36%	28%	34%	32%	ns
Meadows and crops mixtures /AA	29% ab	69% ac	27% b	84% c	0.006
Diversity of meadows (nb of meadows)	3 ab	5 b	5 b	3 ab	0.028
Duration of meadows (years)	4 a	5 ab	4.6 a	5 b	0.025
Species on meadows (nb)	2	2.7	2.9	2.75	ns
Hill Index [†]	1.03	1.21	1.38	1.40	ns
Area with manure/AA fertilised	50% a	35% a	59% a	100% b	0.000
N-mineral/Total Nitrogen used	49% a	45% a	49% a	0% b	0.000
N-mineral unit per ha	29 a	39 a	48 a	0 b	0.000
Nitrogen loses per ha AA	16.1 a	32.1 ab	20.5 ab	3.3 b	0.001
Nitrogen efficiency ^{††}	2.5	2.0	2.7	3.3	ns
Treatment frequency index (TFI) ^{†††}	2.5 a	5.3 a	2.4 a	0.0 b	0.000
Soil working index ^{††††}	2.7	2.2	3.9	2.3	ns
Fuel consumption (litre per cultivated ha)	37.0	36.1	42.8	41.6	ns
Cultural operations per field (nb)	5.7	5.8	6.9	6.0	ns

Medians for each group and P value for Kruskal-Wallis test. Within an indicator, medians with different letters differ at $P < 0.05$ for Nonparametric Multiple Comparisons.

[†] Hill Index assess the proportional abundance of cultivated species based on Shannon and Simpson index: $Hill = (1/D) / e^{H'}$ (with $1/D$: the inverse of Simpson index and $e^{H'}$: the exponential of Shannon index).

^{††} Nitrogen efficiency 2 (kg protein produced/ kg N introduced in farm).

^{†††} TFI is based on the calculation of frequency and dose for each pesticides used for crops at farm level.

^{††††} Soil working index is based on the depth soil working with 1 point for no-tillage, 2 for superficial soil working, 3 for no-deep tillage and 4 for deep tillage. Calculation is a weighted average by ha for each crop.

IV – Conclusion

Animal feed self-sufficiency is often defined as a way to increase sustainability of the farms, mainly in the less-favoured areas. Nevertheless this study showed that farmers could develop different patterns to improve self-sufficiency. The level of this feed sufficiency is linked to a trade-off between production, purchases and local resources use. Farms without purchases are probably very rare, and each self-sufficiency pattern should be assessed in relation to environmental issues. Agroecological transition needs to improve knowledge about agronomical practices and their environmental impacts. This study is an important milestone to improve the agroecological practices in dairy sheep production.

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Net Ecosystem Exchange responses to changes in crop management in a forage system in the Eastern Pyrenees

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Abstract. Croplands and grasslands are major land uses in Europe and provide fundamental ecosystem services, including carbon (C) cycling and storage. In general, croplands tend to be C sources while grasslands are considered as sinks, although this balance depends on local conditions and management. For instance, the role of the crop type and production intensity over the C stock has been thoroughly analyzed. However, little is known about the effect of mixed cropping, fallow and land uses rotation (cropland and grassland). Thus, we hypothesize that these practices may enhance carbon uptake and our objectives are: (1) to describe the Net Ecosystem CO₂ Exchange (NEE) temporal patterns in a mixed cropped-grazed system; (2) to assess the carbon sink/source behavior; and (3) to assess the influence of sown diversity, mixed cropping and land use rotation on NEE. The study site is Pla de Riart (42° 03' 48" N, 1° 30' 48" E, 1003 m a.s.l.), a cropland which is also used for grazing between sowings. The crop is usually a forage mixture, but occasionally it is also a monoculture of forage grass species. The site is equipped with an eddy covariance flux station from the FLUXPYR network that has been recording NEE and meteorological data since 2011. In addition, above and belowground biomass samples have been taken periodically and managing practices reported by the site owner. Preliminary analysis suggests that the carbon sink behavior is directly linked to the management and that crop mixtures (legumes and grasses) might contribute to climate change mitigation, increasing CO₂ uptake, while improving ecosystem productivity, compared to monocultures.

Keywords. CO₂ – Agroecosystems – Management – Net Ecosystem Exchange.

Réponse des échanges nets des écosystèmes aux changements dans la gestion des cultures dans un système fourrager dans les Pyrénées Orientales

Résumé. Les cultures et les prairies sont parmi les utilisations principales du territoire en Europe et elles fournissent des services écosystémiques fondamentaux, y compris le cycle et stockage du carbone (C). En général, les terres cultivées ont tendance à être des sources de C tandis que les prairies sont considérées comme des puits, bien que cet équilibre dépende des conditions locales et de la gestion. Par exemple, le rôle du type de culture et de l'intensité de la production sur le stock C a été analysé en profondeur. Cependant, on sait peu sur les effets de la culture mixte, de la jachère et de la rotation (cultures et prairies). Ainsi, notre hypothèse est que ces pratiques peuvent améliorer le stockage du carbone et nos objectifs sont : (1) de décrire les patrons temporels de l'échange net de CO₂ de l'écosystème (NEE) dans un système de culture-pâturage; (2) d'évaluer le comportement source/puit de carbone; et (3) d'évaluer l'influence de la diversité semée, des cultures mixtes et de l'utilisation des terres en rotation sur le NEE. Le site d'étude est Pla de Riart (42° 03' 48" N, 1° 30' 48" E, 1003 m a.s.l.), un terrain cultivé qui est également utilisé pour le pâturage entre les ensemencements. La culture est habituellement un mélange de fourrages, parfois une monoculture d'espèces de graminées fourragères. Le site est équipé d'une station de flux eddy covariance du réseau FLUXPYR qui enregistre le NEE et des données météorologiques depuis 2011. En outre, des échantillons de biomasse aérienne et souterraine ont été pris périodiquement et la gestion des pratiques ont été enregistrées par le propriétaire du site. L'analyse préliminaire sug-

gère que le comportement de puits de carbone est directement lié à la gestion et que les mélanges de cultures (légumineuses et graminées) pourraient contribuer à mitiger le changement climatique, augmentant le stockage de CO₂, tout en améliorant la productivité de l'écosystème, par rapport aux monocultures.

Mots-clés. CO₂ – Agroécosystèmes – Management – Exchange Net de l'Écosystème.

I – Introduction

Grasslands and pastures are highly relevant in the global carbon cycle, mostly because of their capacity for soil organic carbon storage (Soussana *et al.*, 2007). Soils are the biggest reservoir of carbon (C; Batjes, 1996). The preservation and accumulation of soil carbon is a relevant measure for climate change mitigation (Canadell *et al.*, 2007). Generally, grasslands act most as a sink for CO₂ and can preserve very effectively soil carbon (Soussana *et al.*, 2007, Schultze *et al.*, 2009). However, there is high uncertainty in the total contribution of grasslands as C sinks. An important part of this uncertainty is related to the high diversity of grasslands and grassland managements, from semi-natural to intensive. Furthermore, while information about grasslands from the Alpine range is rather abundant, more information is needed about the C storage dynamics in Pyrenean grasslands. In this study, we present the results from three years of continuous measurements of microclimatology and CO₂ fluxes in an intensively managed grassland in the Eastern Pyrenees. The grassland is managed according to common practices in this region, which usually combines crop growing and grazing (Sebastià *et al.*, 2011). In this particular grassland, a rotation of cereal with legume-grass forage mixtures coexists with cattle grazing during the fall. During the three years of the study, the specific crop and crop management varied, providing relevant data for assessing the effects of management on C fluxes, beyond the climatic conditions of the particular year. These results are relevant because they provide information about the effects of management on the C sinks. Practices contributing to increased C capture can lead to a net accumulation of C in soils of pastures and grasslands, thus sequestering atmospheric CO₂ (FAO 2010).

II – Materials and methods

1. Study site and experimental design

The study site is a sown forage grassland located in Pla de Riart (42° 03' 48" N, 1° 30' 48" E, Eastern Pyrenees), at 1003 m a.s.l. in the basal part of the montane altitudinal belt. Climate is Sub-Mediterranean, typical from mountain areas with Mediterranean influences. Mean annual precipitation is 750 mm and mean annual temperature around 11°C, including the summer drought period. In 2010, an eddy covariance tower was established in the grassland. This is a specialized infrastructure that measures continuously meteorological variables (radiation, temperature, precipitation, wind speed and direction, relative humidity), soil variables (temperature, moisture), and components of the atmospheric turbulent flux to calculate CO₂, water and energy exchange at the ecosystem level.

2. Eddy covariance measurements

Eddy covariance measurements can be processed as Net ecosystem Exchange (NEE), and be compartmentalized as ecosystem production (Gross Primary Productivity, GPP) and ecosystem respiration (Reco) during a given period. Here we present results of these three variables linked to the C balance, GPP, Reco and the difference between both, NEE, during three years, from 2011 to 2013. The eddy covariance technique measures the vertical turbulent transport of energy and matter through an imaginary plane at the sensor height. It is based on the capture of measurements

at high frequency of the three components of wind speed and the scalars of interest, here CO₂ concentration, and the calculation of the covariance among those measurements. Because of the high temporal resolution, those stations are particularly adequate to analyse the temporal behaviour of atmosphere-ecosystem interactions.

3. Eddy covariance analysis

Raw data provided by the sensors were processed and flux values calculated for 30' periods. Processing was carried out with the specialized program Alteddy3.9 (Elbers *et al.*, 2011). Standard algorithms were used to fill up the gaps in the data.

III – Results and discussion

The intra- and inter-annual flux dynamics in Pla de Riart were highly influenced by the management activities. Seasonally, the productive capacity of the system decreased with both harvesting and grazing, because of the reduction in vegetation. Regarding the variation among years, the carbon balance was highly dependent on the particular management of a given year (Table 1). Some years the farmer established a cereal forage crop. In this case, the field remained fallow after the summer harvest because of grazing and preparation for the next crop, which does not start accumulating biomass until the following spring. That happened in 2011 and 2012 (Table 1). On the contrary, in 2013 a forage mixture of triticale, oat and vetch was established. This sown grassland was harvested at different times throughout the year, and thus a second regrowth occurred in autumn.

Table 1. Gross Primary Productivity, ecosystem respiration and Net Ecosystem Exchange in Pla de Riart during the years 2011 to 2013. The crop cultivated each year is indicated

Year	Crop	Gross Primary Productivity (GPP, g C m ⁻²)	Ecosystem Respiration (Reco, g C m ⁻²)	Net Ecosystem Exchange (NEE, g C m ⁻²)
2011	Barley	439	- 677	- 238
2012	Triticale	580	- 643	- 63
2013	Triticale, oat and vetch	990	- 978	12

Our results show that Pla de Riart acted in terms of the C balance as a mixed system between extensively grazed grasslands and cultivated crops. The field was close to semi-natural grasslands when a mixture was established, and in this case, the C balance was close to zero. On the contrary, it acted more similarly to a crop in terms of the C balance when monocultures of forage grasses were established, being in those situations a source of CO₂. Thus, the use of crops in monoculture brought the system to loss carbon, with an amount that depended on the productivity of the crop. The dependence of the C balance on management has already been recognized for crops (Béziat *et al.*, 2009). Mountain grasslands host a high biodiversity and provide fundamental ecosystem services, including their potential role in climate change mitigation. In these systems, net ecosystem CO₂ exchange (NEE) is usually near to the equilibrium and grasslands can act as sources or sinks depending on local conditions (Gilmanov *et al.*, 2010). We show that the same field can act as a source of CO₂ or be neutral, depending on the management during a particular year.

IV – Conclusions

Management factors were the most important drivers of the CO₂ flux dynamics of the sown forage grassland ecosystem of Pla de Riart, both seasonally during a given year as well as across years. The particular sown crop and the management during a given year were critical to determine the global C balance, with forage mixtures showing the most favourable C balance compared with forage grass monocultures.

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A method to standardise meadow phenological observations: evaluation and applications

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Abstract. First hay cut is important for feed autonomy of livestock farms as it constitutes the largest part of the annual fodder production. Looking for the best compromise between fodder quality and quantity during first growth is therefore crucial to optimise meadow and feed rations management. In this context, phenology (i.e. development stages of plants) is a useful tool since it is closely related to fodder quality. Every spring since 1995, meadow phenological development is monitored on about 80 plots in western Switzerland to give farmers references of standardised development stage for different classes of elevation. The aims of this study are to present the “equivalent cocksfoot stage” method used to assess standardised phenological stage and to show the results of its robustness evaluation. The method was developed in 1994 on four years of phenological observations. Now with 21 years of data, it is possible to re-evaluate the method and to summarize trends of meadow spring development. Main findings are that relative development pace of the reference species is not changing with altitude gradient, nor with particular years (very late or early springs) and that there is an overall trend towards earlier meadow phenological development.

Keywords. Meadows – Phenology – Altitudinal gradient – Fodder quality.

Evaluation et applications d'une méthode utilisée pour standardiser les observations phénologiques des prairies de fauche

Résumé. La première fauche est importante pour l'autonomie fourragère des élevages car elle représente la majeure partie du foin produit sur l'année. Aussi, chercher le meilleur compromis entre la qualité et la quantité lors de la première pousse est crucial pour pouvoir optimiser la ration et la gestion des prairies de fauche. Dans ce contexte, la phénologie offre un outil précieux, car elle est en lien étroit avec la qualité du fourrage. En Suisse romande, depuis 1995, le développement printanier de prairies de fauche est suivi sur environ 80 parcelles pour donner des références aux éleveurs sur le développement phénologique standardisé pour différentes classes d'altitude. Les buts de cette étude sont de présenter la méthode « stade équivalent dactyle » qui permet de standardiser le développement d'une prairie et d'exposer les résultats de l'évaluation de la robustesse de cette méthode. Cette méthode a été développée en 1994. Actuellement avec 21 ans d'enquêtes, il est possible de réévaluer la méthode et d'étudier de manière globale les données. Les constats principaux sont que les fonctions permettant de décrire le développement des espèces les unes par rapport aux autres ne changent ni avec l'altitude ni lors d'années particulières (printemps très précoce ou tardif) et qu'il y a une tendance vers un développement phénologique des prairies de plus en plus précoce.

Mots-clés. Prairie de fauche – Phénologie – Gradient altitudinal – Qualité du fourrage.

I – Introduction

For mountain farming, grass has an essential role to play in cattle feed rations. Supplying cattle with fodder of quality in sufficient quantity has a positive impact on the feed ration, helping to reduce feeding concentrates, economic and environmental costs. Thus, assessing nutritive value of fodder before a cut is highly useful. It is therefore interesting to use phenological development as fodder quality indicator. Many studies (e.g. Buxton, 1996) show that forage nutritive value is linked

to the development stage of plants during the first growth. The increase in fibrous tissues like stem and spike and the ageing of the plant organs lead to a fall of digestibility of hay. Nonetheless, for meadows constituted of numerous species of different precocity, it is rather difficult to assess an average development stage precisely. This study presents the “equivalent cocksfoot stage” method to standardise the phenological observations (Meisser *et al.*, 2008). It has been developed in order to facilitate estimation of nutritive value of forage from multi-species meadows. Objectives of this study are (i) to evaluate the robustness of the method used to assess standardised phenological stage and (ii) to use the method for analysing 21 years of phenological observations.

II – Materials and methods

Every spring since 1995, phenological development of about 80 Swiss meadows is monitored by a network of observers (local advisers, teachers, farmers, etc.). Sites are distributed along an altitudinal gradient from 400 to 1,700 m of altitude, representing different climate conditions. The same protocol has been used since 1995, with the same

phenological scale (8 stages describing morphological development). Ten meadows species (5 forbs and 5 grasses, common in Swiss grasslands) were chosen in order to have a panel of plants of different precocity. The 21 years of survey allowed to follow 1,750 plots and to record 80,480 observations (combinations of “date × species × site × year”).

Cocksfoot (*Dactylis glomerata*) was chosen as the reference species because of its medium precocity and its ubiquity. The observed stages of the other nine meadow species are transposed into “equivalent cocksfoot stages” (ECS): a numerical index (ranging from 1 to 8) describing the stage that cocksfoot would display at the moment of observation.

This standardisation is done with nine equations given by each regression between cocksfoot observed stages and the other reference species stages. Those nine linear equations were established in 1994, after four years of phenological observations. The average of ECS obtained for the ten species at a particular date, characterise the mean stage of meadow development (Meisser *et al.*, 2008).

Each year, a table is published giving the mean development stage for 3-days periods and for 10 climate conditions (linked with altitude) (Amaudruz *et al.*, 2015). Those mean ECS stages are related to nutritive value parameters (Daccord *et al.*, 2006). Different parameters describing the nutritive value are proposed, such as “Net Energy for Milk production” [NEL MJ/kg DM] or “Crude Protein Content” [g/kg DM]. Those relations were established on a field experiment basis, where pure stands were grown, mowed and precisely analysed (Jeangros *et al.*, 2001). Those parameters are given for different botanical types and for three forage conservation stages. Figure 1 shows the main steps to estimate nutritive value from observed phenological stages.

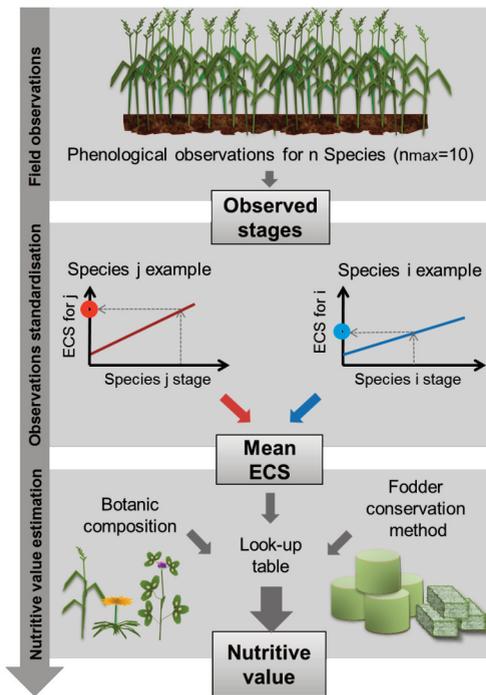


Fig. 1. Method to assess mean development stage of a meadow and its fodder nutritive value (ECS = “equivalent cocksfoot stage”).

III – Results and discussion

1. Robustness evaluation of “equivalent cocksfoot stage” method

Statistical tests (ANOVA, Kruskal-Wallis) were computed to assess if the parameters of the nine ECS equations were different for some class of altitude or for some specific years (very early or late springs). It was found that the parameters are not significantly changing with classes of altitude nor with particular years (data not shown). Hence it shows that the method is robust and that the equations can be the same for all classes of altitude or for every year (even during particular years). This assertion is true for the amplitude of climate encountered over those 21 years and over the different climate conditions of the sites. The Figure 2 illustrates the stability of the regression with an example of “equivalent cocksfoot stage” relation for *Poa trivialis*. In a second step, all observations (i.e. 21 years) were then used to fit new regressions (one for each species) to build more accurate ECS relations based on more years of survey (Vuffray *et al.*, In prep.).

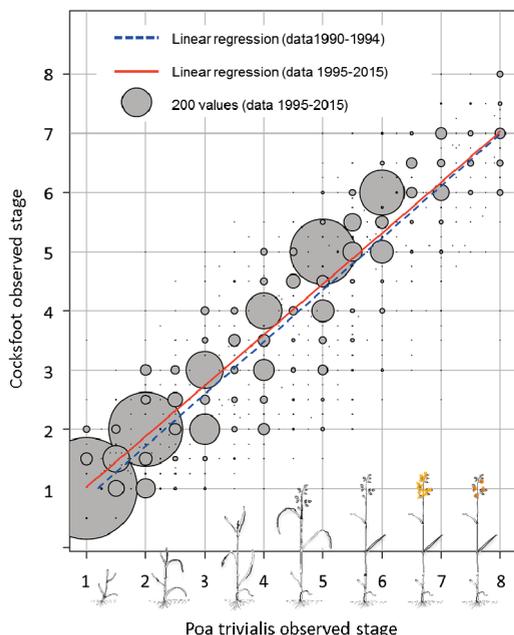


Fig. 2. Relation between cocksfoot and *Poa trivialis*. Dashed line: regression established in 1994. Solid line: regression established on data from 1995 to 2015 (7,979 obs., $R^2 = 0.814$, $y = 0.88 \cdot x - 0.4$). Points: data from 1995 - 2015 with size proportional to number of values (Vuffray *et al.*, in prep.).

2. Analysis of 21 years of phenological survey

As “equivalent cocksfoot stage” method is useful to sum up a large number of observations, it was used to analyse 21 years of survey. Mean ECS were calculated for each plot over spring growth periods and full heading dates were then extrapolated. Theil-Sen estimator was used to assess if there is an evolution in full heading dates over the 21 studied years in three main classes of altitude. Re-

sults illustrated in Figure 3, show that full-heading dates are becoming earlier every year in lowland altitudinal classes (around 2 to 3 days earlier every 10 years for fresh and very mild to mild classes). Temperature trends observed in Switzerland (Rebetez and Reinhard, 2007) are probably the reason of those earlier spring developments, as phenology is mostly driven by temperature.

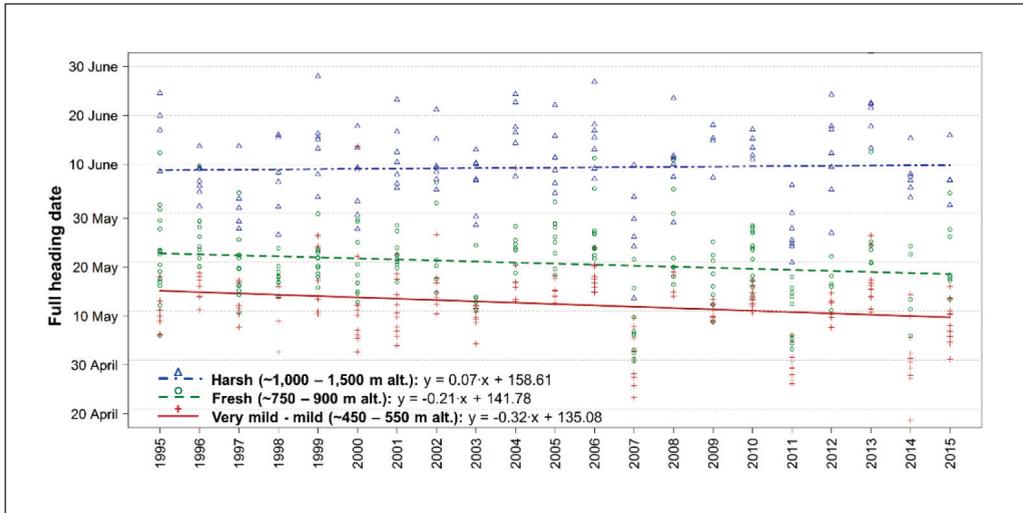


Fig. 3. Trend of full heading dates for three classes of climate (With Mann-Kendal trend test: P-value (harsh) = 0.56, P-value (fresh) = 0.02 and P-value (Very mild-mild) <0.001) (Vuffray *et al.*, In prep.).

IV – Conclusions

“Equivalent cocksfoot stage” method, despite its simplistic approach, allows to describe meadow mean phenological stages in a robust manner, across contrasting years and climate conditions. This method is used to give estimates of nutritive value, and is therefore recommended for practical issues. It is also appropriate to have global pictures of phenological changes as response of climate changes over several years.

Acknowledgments

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A concept proposal to take into account interactions between alpine pasture and farms: the alpine-pasture-farms system

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Abstract. Alpine pastures can be found in all European mountain regions. These management units present typical specific features: agronomic features (composition, seasonality), agricultural use through grazing during summer, good common status, importance of environmental and heritage issues, multiple non-agricultural use, etc. As a result, building a specific analysis framework is necessary to study the articulation between farms and alpine pastures management. We offer a bibliographic review in order to (1) identify the variety of topics related to interactions between alpine pastures and farms, and (2) analyze the consistency between topics and methodological approaches (systemic approach or not). Most of these papers deal with articulation of forage resources, linked with technical and economic issues, or in connection with the issue of long-term management of vegetation. Research generally focuses on a part of alpine pastures specific features, and rarely considers the interactions between the different farms that use a same alpine pasture. We propose the concept of alpine-pasture-farms system to compensate for this lack.

Keywords. Alpine pasture – Summer mountain pasture – Livestock farming system – Forage system.

Proposition d'un concept pour prendre en compte les interactions entre alpages et exploitations dans les systèmes agropastoraux : le système alpage-exploitations

Résumé. Les alpages ou estives sont des espaces pastoraux que l'on retrouve dans l'ensemble des massifs montagneux européens. Ce sont des espaces très particuliers à différents titres : caractéristiques agronomiques des ressources (composition, saisonnalité...), valorisation agricole par le pâturage, statut de bien commun, importance des enjeux environnementaux et patrimoniaux, multiusage, etc. La façon dont s'articule la gestion des exploitations avec celle des alpages nécessite de ce fait un cadre d'analyse spécifique. Nous avons réalisé une revue bibliographique afin i) d'identifier la diversité des thématiques ayant trait aux interactions entre alpages et exploitations, et ii) d'analyser la cohérence entre les thématiques étudiées et le type d'approche choisie (approche systémique ou non). La question de l'articulation entre alpages et exploitations se pose le plus souvent en termes d'articulation des ressources fourragères, vis-à-vis d'enjeux technico-économiques ou de gestion à long-terme des végétations. Les travaux étudiés ne prennent en compte qu'une partie des spécificités des alpages et s'intéressent très rarement aux articulations entre les différentes exploitations utilisatrices d'un même alpage. Pour mieux prendre en compte l'ensemble des spécificités des alpages et la façon dont ils interagissent avec l'ensemble des exploitations utilisatrices, nous proposons le concept de système alpage-exploitations.

Mots-clés. Alpage – Estive – Système d'élevage – Système fourrager.

I – Introduction

Alpine pastures are specific altitude spaces, both by the conditions of environment and their seasonal use by grazing and by their status of common goods or their multipurpose. The alpine pastures have some management autonomy, however interactions between alpine pastures and farms are strong and cannot be reduced to an articulation of feeding resources for livestock.

The alpine pastures, also referred as mountain pastures, summer mountain pastures, highland pastures, etc., appear as very special agricultural areas. These management units are used by a large variety of farms in European mountain regions, which utilize the altitudinal gradient and the associated grass growth. They are usually geographically distant from the farm and located above, valued by the grazing of a summer resource essentially. To cover the different designations that can take these management units, in the text we keep the generic term of “alpine pasture” (term widely used in all the Alpine arc). The alpine pastures are used by farms located in mountain, but also by plain farmers for grazing of all or part of their herds during three to five months, with often a blend of several farms herds (more than one-third of the mountain pastures of the Alpine massif for example).

Like other pastoral areas, alpine pastures represent an exceptional heritage, whether in landscape terms, biodiversity or culturally. This feature explains that they are often located within protected areas (national parks, Nature Reserves, Natura 2000 areas...) and that they are visited by a lot of tourists.

Be used in collective or individual manner by farms, alpine pastures are “common goods” (Ostrom, 1990). By this “common” character of the alpine pastures and their often public land status, environmental and heritage issues should strongly be taken into account in pastoral managing, as it is also needed for the multipurpose managing (tourism, forest...).

The alpine pastures are therefore very specific spaces different of other spaces used by farms. The relationship between farm-specific spaces and common areas like alpine pastures cannot be considered as a simple association of farm plots and led to distinguish three areas of concern related to the management of pastures: (i) the agricultural use of the pastures during a production cycle is strongly conditioned by the geomorphological and pedoclimatic specificities of the alpine pasture, as well as by the agronomic characteristics of the vegetation; (ii) long-term resources management is necessary, because of the status of common goods and the importance of environmental issues; and (iii) the sharing of space between various users, is also indispensable on the alpine pasture.

Research on farming systems (Gibon *et al.*, 1999) adopts a systemic vision to look at interactions “men-herd-resources”. Based on an analysis of practices, these research aims on one hand, to understand the choices made by the actors of an agricultural system and the reasons of these choices, and secondly, to analyse the overall coherence of this management. The articulation between alpine pastures and farms, however, remains little studied through these approaches. To characterize the management logic of the shepherd who must ensure the adequacy between herds needs and pastoral resources during the pasture season, Savini *et al.* (1993) propose a model of the functioning of the alpine pasture in which farms are considered as black boxes outside of the studied system. On the opposite, most of the work on the farms that use alpine pasture is not interested about what happens in alpine pasture and considers that the animals leave the system studied when they pass into the alpine pasture. However the interactions between alpine pastures and farms are numerous and are probably not limited to issues of joint resources. Taking into account the different specificities of the alpine pasture, it appears necessary to build a framework of analysis appropriate to analyse these interactions.

II – Materials and methods

We realized a literature review in the Scopus database about the articles dealing with interactions between alpine pastures and farms (Nettier *et al.*, 2015). All articles published until January 2015 and dealing with alpine pasture (or a synonym) and farm have been selected (search: TITLE-ABS-KEY [(“alpine pasture” OR “mountain pasture” OR “highland pasture” OR “summer pasture” OR “summer range*” AND farm *)]). In this selection of 202 articles, we have added four articles not referenced in Scopus, and we have excluded articles redundant or off-topics. At the end we got in the analysis 62 articles. For each, we identified the object studied and its boundaries, the associated themes, and the type of practices considered. We spotted the systemic approaches, and identified the functions of the alpine pastures considered in the research.

III – Results

1. Themes studied at the interaction between alpine pastures and farms and functions considered

The Fig. 1 shows the relation in the 62 articles between the main themes of the research (items under the graph) and the object considered (colors). Analysis of the feeding functions attributed to the alpine pastures enabled to determine their places in feeding systems. The management time step considered could be the year, or the animal career, and the thematic of interest could be related both to the grazing practices organization on this time step and to long-term livestock choices (animal selection genetic criteria, animal types produced, reproduction periods...). The functions of the alpine pasture towards the farms are not only related to the constitution of a diet for the herds: they may also deal with health, or participate to the production quality of farms (image, physicochemical or organoleptic quality of products), and enabled to reduce the work on farms.

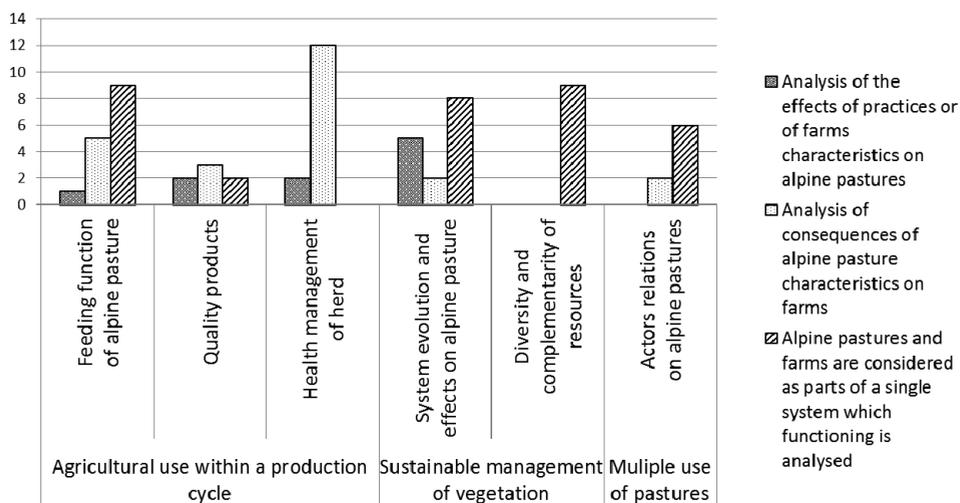


Fig. 1. Approaches chosen in selected articles: number of articles identified according to the themes covered. Six of the 62 articles appear in two thematic.

Farms use of alpine pastures is not reduced to the use during a period by an animal population that consumes a resource for animal production; it is also a way to combine this resource mobilization with other resources mobilization, with the objective of performing different functions (feeding, health, image support for products...) during an animal production cycle. These functions are determined by the characteristics of all the mobilized vegetation, they are also bound to the constraints of space organization, of socio-economic or political context and finally of expectations that may have farmers. These expectations can cover a strong symbolic dimension.

2. Proposal of a concept: the Alpine Pasture – Farms System

Most of the approaches at the farm level consider the alpine pasture as a spatial part of the farm and just take into account a part of its specificities (characteristics of the vegetation, or environmental issues, or multi-purpose...) and of interactions pastures-farms. Furthermore the interactions between farms using a same alpine pasture are very rarely considered. Towards a problematic requiring to take into account the different specificities of the alpine pastures, but which require also to consider different levels of interactions between alpine pastures and farms, one can be interested by a system consisting of an alpine pasture and the different farms that use it. So it corresponds to a system composed by a subsystem "alpine pasture" (seen as a management unit) and one or more subsystems "farm", in interaction (see Fig. 2). The analysis must strive to successfully integrate the specificities of the alpine pasture subsystem and to consider the functioning of farm(s) subsystem(s) as to understand the determinants of the use of the alpine pasture. We propose to call this system the "alpine-pasture-farms system". It can be applied to collective or individual alpine pastures.

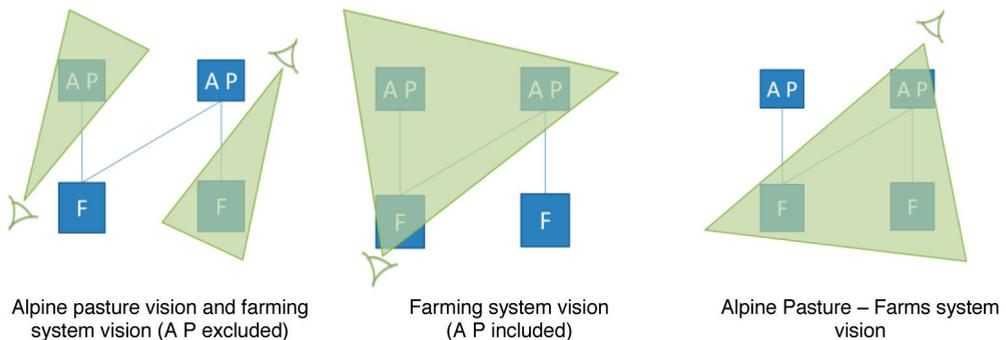


Fig. 2. Originality of the point of view proposed with the Alpine Pasture – Farms system (AP: Alpine Pasture; F: Farm).

By focusing on the alpine pasture, this system can allow a perspective change on the various themes that we have identified in the literature review, and more generally for the analysis of the triptych "men-herd-resources" of the livestock farming systems approach (Gibon *et al.*, 1999).

Thus on "men", the objectives on the alpine pasture become central in pastoral management objectives (including non-agricultural objectives); we can try to understand how they deal with the other objectives of the farm(s). Relations between farmers and shepherds become central in the decision process. From the point of view of work organization, the alpine pasture is no more considered as an autonomous management unit (alpine pasture vision), or that obliged to delegate the work, or specialize a worker during a bounded period (farm vision). We can look at the way in which work on the alpine pasture, with its specificities (isolation, remoteness, collective tasks such as sorting the animals or maintenance chores), articulates with work organization in the farms.

With regard to the herds, the approaches at alpine pasture level consider it has to “cope with” the summered herd (often consisting of animals with different needs and behaviors) and objectives expected by farmers. Approaches across the farm are aimed at achieving a livestock goal by the articulation of resources variety over the year (including the alpine pasture) and a livestock management, so to use at best the alpine pasture in the system. The analysis of the functioning of the alpine-pasture-farms system enabled to wonder how to best manage herd(s) over the year and at long-term for using different resources from the alpine pasture during the season and sustainably manage them. It also allows focusing on the alpine pasture specificities for health management and reproduction management, which have consequences on the entire animal production cycle.

Finally if one is interested in resources, in contrast to the approaches to the farm level, the analysis of the functioning of the alpine-pasture-farms system allows to consider the diversity of internal resources of the alpine pasture and the way they are structured among themselves and with the various farms resources within the forage system; it also focuses the question of the management of the resource renewal on the long-term.

In the case of collective alpine pastures, the alpine pasture-farms system allows to look at the relationship between individual farms management and collective alpine pasture management: coordination between farmers and shepherds for work organization (chores...), herd management (sanitary, reproductive...), connection with a diversity of forage systems, sometimes geographically distant. It led to look at the collective farmers governance bodies (which take the form of pastoral groups in the majority of cases in France).

IV – Discussion – Conclusion

The issue of adaptation to climate change of agro-pastoral systems could be considered through the prism of the alpine-pasture-farms system. This is an example of a problematic where the alpine pastures occupy a central place and where it is necessary to take into account their specificities and be interested in interactions with farms. Climate change, which has already resulted in an increase in frequency and intensity of extreme events, particularly droughts, is faster at high altitude, the vegetation degradation of alpine pastures are not easily reversible, and alpine pastures appear particularly vulnerable to climate change (Engler *et al.*, 2011). Adaptation of the alpine pastures to climate change requires also to look at farms that utilize alpine pasture, since flexibility can be found in the interaction between the alpine pastures and farms (Nettier *et al.*, 2011).

As conclusion, the thinking on the connection between alpine pastures and farms can be extended to other socio-economic contexts (Atlas, Rockies, Central Andes, etc.). A more general reflection on the relationship between common and individual resources could be transposed to other cases of agricultural systems combining the use of individual resources and common resources (that could be used individually or collectively). This may be the case for other pastoral resources, but also not pastoral resources (water, arable land, equipment...), since we want to focus on this resource while keeping a perspective on the coherence of the functioning of individual farms and their interactions with the common resource and between themselves.

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Session 2
**Livestock on mountain pastures:
animal performance and product quality**

The contribution of mountain pastures to the link to terroir in dairy and meat products

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Abstract. The existence in mountain areas of specific traditions and know-how for the agricultural production and food processing constitute an opportunity to develop differentiated mountain terroir products able to add value to the farmers. The aim of this text was to review the definition of terroir in the case of animal products and to identify the contribution of mountain pastures and associated farming practices. The terroir refers to a system of interactions between biophysical and human factors that were built during the history, that are specific from a geographical limited area and confer typicity to the products. This typicity results partly from the use of mountain pastures that influence the characteristics of milk and cheeses and carcass and meat. The secondary metabolites of the dicotyledonous plants found in mountain pastures like terpenoids or phenolic compounds are directly transferred to animal products or modify animal digestion and therefore influence indirectly fatty acid composition of animal product. The role of these molecules (and microbes in the case of raw milk cheeses) on meat and cheese sensory properties are often reported, and, even if not fully understood, they obviously contribute to the link to terroir. The way the mountain pastures are managed and the characteristics of the animals used (breed, physiological status) also influence the grazing selection and phenology of grazed herbage. Understanding the interconnections between these aspects refers back to the measures to be taken so that the animal products reflect the uniqueness and diversity of the terroir where they originate.

Keywords. Mountain Pasture – Terroir – Milk – Cheese – Carcass – Meat.

La contribution des pâturages de montagne au lien au terroir des produits laitiers et carnés

Résumé. L'existence dans les zones de montagne de traditions et de savoir-faire dans le domaine de la production et de la transformation des produits animaux constitue un atout pour le développement de produits de terroir capables d'assurer une plus-value intéressante pour les éleveurs. Le but de ce texte était de préciser la définition du terroir dans le cas des produits d'origine animale et d'identifier la contribution des pâturages de montagne et les pratiques agricoles associées. Le terroir se réfère à un système d'interactions entre les facteurs biophysiques et humains qui ont été construits au cours de l'histoire, qui sont spécifiques d'une zone géographique limitée et qui confèrent une typicité aux produits. Cette typicité résulte pour partie de l'utilisation des pâturages de montagne qui influencent les caractéristiques du lait et des fromages et de la carcasse et de la viande. Les métabolites secondaires des plantes dicotylédones très diverses trouvés dans les pâturages de montagne comme les terpènes ou des composés phénoliques sont directement transférés aux produits d'origine animale ou sont susceptibles de modifier la composition des acides gras des produits en raison de leur action sur le fonctionnement du rumen. Le rôle de ces molécules (et des microbes dans le cas des fromages au lait cru) sur les propriétés sensorielles de la viande et du fromage est souvent mentionné. Le mode de gestion des pâturages de montagne et les caractéristiques des animaux utilisés (race, état physiologique) influencent également les caractéristiques du couvert végétal (phénologie) et les choix alimentaires des animaux au pâturage. Comprendre les interconnexions entre les produits et les caractéristiques des couverts végétaux renvoie aux mesures à prendre pour que les produits d'origine animale reflètent au mieux le caractère unique et la diversité du terroir dont ils sont issus.

Mots-clés. Pâturages de montagne – Terroir – Lait – Fromage – Carcasse – Viande.

I – Introduction

In the EU, about 14% of the agricultural area (27 million ha) and 18% of the farms (2.4 millions) are located in mountain areas. This area hosts 12.5, 20.4 and 46.8 % of the EU cattle, sheep and goats respectively. Mountain cattle accounts for 10.4 and 13.3% of the total cattle milk and meat production and this share is higher for small ruminants that produce 32.0 of the total goat and ewe milk and 23.4% of the sheep meat (Santini *et al.*, 2013).

These data underline the quantitative importance of mountains outputs for the ruminant livestock sector that is also involved in maintaining the landscape and the rural social network. It is therefore one of the guarantors of the attractiveness of these territories and the development of other economic activities like tourism. Nevertheless, mountain farming faces several limitations related to the existence of permanent structural limitations that results in significant lower labour and land productivity (Martin *et al.*, 2014) and in higher production costs. Poor accessibility of mountain farms also affects the food industry due to increased collection and transport costs. In order to preserve the mountain ruminant sector, specific public policies dedicated to compensate partly the limitations of mountain agriculture were initiated for long in many European countries through specific measures of the national and Common Agricultural Policy. Currently, in most mountain areas, these subsidies contribute to a large part of farmer's income. They are essential for the economic viability of mountain farms and are justified by the multiple ecosystem services provided by mountain farming.

Nevertheless, the long term viability and attractiveness of mountain ruminant farming mainly relies on higher farm gate prices for productions. The gap between mountain and lowland prices is in general positive in the milk and meat sector but very different patterns according to the sectors and regions still exist. The success stories of some mountains areas rely on the dynamism of local stakeholders who proposed very specific and differentiated food products (Martin *et al.*, 2014) that add value for the entire food chain. The existence in mountain areas of specific traditions and know-how for the agricultural production and food processing is indeed an opportunity. The valorisation of the synergies between agricultural products issued from local history and culture, tourism, handcraft and gastronomy constitute a "basket of goods" (Mollard and Pecqueur, 2007) able to develop a long term added value for products issued from a specific terroir. The emblematic success stories of the Beaufort, Comté and Laguiole mountain areas in France or the Aosta Valley in Italy rely on the differentiation of a terroir product correctly identified and protected by a Geographical Indications. These models seem replicable in other mountain areas where farm density remains important (Dervillé and Allaire, 2014).

The aim of this text is to identify which are the farmer's practices important to consider within the mountain production systems of milk and meat products for the production of differentiated terroir products. We will first define the terroir notion then, for milk and meat products propose a literature review on the contribution of mountain pastures and associated farming practices to the link to terroir.

II – The link to terroir

1. The definition of terroir

Historically, terroir refers to an area, usually rather small, whose soil and microclimate impart distinctive qualities to food products. The word terroir was first associated with the production of wine. It is related to a doctrine that defines quality by reference to the geographical origin. It refers both to climatic and soil characteristics of the place and to the know-how of the men who exploit it. The most complete and operational definition of terroir arises from the deliberations of a French working group who define the terroir as follows (Casabianca *et al.*, 2006):

“a terroir is a geographical limited area where a human community generates and accumulates along its history a set of cultural distinctive features, knowledges and practices based on a system of interactions between biophysical and human factors. The combination of techniques involved in production reveals originality, confers typicity and leads to a reputation for goods originating from this geographical area, and therefore for its inhabitants”.

This definition refers to the close connections between environmental and human factors; human practices modify environment and *vice versa*. Terroir is considered as a construct; the historical dimension is important but terroirs are also living and innovative spaces that cannot be reduced only to tradition.

2. The application to the case of ruminant livestock products

In the case of cheeses, Grappin and Coulon (1996) define the terroir as “a geographic area characterized by environmental conditions and types of animals, that when exploited by humans, lead to specific products”. In the case of ruminant livestock products, *terroir* is therefore an inseparable package of (i) the physical environment including geology, geography, soil and climate, (ii) animals with the dominant breed and its genetic characteristics, and (iii) the man who can affect the physical environment and animals through cultural and husbandry practices and whose role is essential in the process of the raw material (muscle and milk). Dorioz *et al.* (2000) added a fourth element in this system; the fodders (or more generally the feedstuffs) produced on the terroir, with their botanical composition depending on both physical environment and farmers’ practices and the way they are included in the animal diet (phenology, grazed or preserved...). The characteristics of animal products are therefore the result of a long process from the physical environment to the product that implies in the case of cheeses two main complex fermenters; the rumen and the cheese. In comparison to wine, the complexity of the interactions in the development of the characteristics of the products is increased, especially because of the mobility of the animals and to the complexity of the vegetation used as fodder.

The influence of the terroir on the product characteristics may result from the specific influence of one of the basic components of the terroir. In this case, we can consider the direct flux of microorganisms or molecules from one of these components to the meat and cheese. We can also consider a succession of metabolic and chemical processes starting from one of the component and that finally influence the product characteristics. More systemic approaches taking into account the biological or physical interactions between the basic components of the terroir and including the farmer’s practices and the process are also necessary to explicit the link to terroir. These approaches are particularly complex, uneasy to study in experimental conditions and generally do not allow to understand all the biological mechanisms underlying. They are nevertheless necessary considering that the link to terroir cannot be restricted to a simple flux of microorganisms or molecules. The link to terroir also relies on a very important historical and cultural aspect that will not be considered in this text.

We will focus on the possible contribution of mountain pastures and associated management practices on dairy and meat product characteristics. The permanent grasslands found in mountain areas, are indeed not transferable because their characteristics and botanical composition depend on the soil and climate and associated management. They can therefore be considered as an important component of the terroir in the case of mountain products.

III – Dairy products

Empirical knowledge related to the influence of specific vegetal communities found in mountain grasslands on cheese sensory properties are known. It was developed by farmhouse cheese-

makers, especially in mountain conditions where vegetation gradients and contrasting plant mosaics are met even within the same pasture according to variable micro-climates, soil and agricultural practices.

1. Biochemical link

Based on the empirical knowledge of the farmers, the study of the effect of the botanical composition of forages on milk and cheese characteristic have been the first to be studied for the characterization of the terroir. Primarily, differences on sensory properties of cheese derived from animal grazing different vegetation or fed conserved forages with different botanical composition were investigated (Buchin *et al.*, 1999). These differences being found relevant, the further studies focused on the direct transfer of plant compounds, supposed to be responsible of the variation of the odours and aromas in cheese according to the forages fed to the animals. Plant secondary metabolites, such as terpenoids were known to vary widely according to the botanical species composing grasslands (Mariaca *et al.*, 1997). In particular, grasses are poor in terpenoids whereas these compounds are abundant and widely variable in forbs. Their direct transfer from herbage to milk was demonstrated (Viallon *et al.*, 2000), and several studies highlighted differences in milk terpenoids composition according to the botanical composition of pasture or hay (De Noni and Battelli, 2008). Relations between terpenoids and specific sensory traits (Buchin *et al.*, 1999; Bendall, 2001), such as stable, overripe fruit, manure, orange, fruity and green notes have been suggested. However, non-terpenoids compounds, such as indoles (skatole in particular), lactones, aldehydes, ketones, alcohols or esters resulted to determine much more milk and cheese sensory profile than terpenoids (Buchin *et al.*, 1999; Bendall, 2001). Furthermore, Tornambé *et al.* (2008) showed that the concentration of essential oils, rich in terpenoids, in milk to reach the threshold for sensory perception are ten folds higher than those achievable in milk by grazing animals, even on highly biodiversified pastures. The high variability of terpenes and the low repeatability of their analysis, moved the research of the origin of the sensory differences on other milk constituents. Among these, polyphenols are other plant metabolites that can be transferred to milk (Besle *et al.*, 2010). Herbage polyphenols composition varies largely according to pasture botanical composition (Reynaud *et al.*, 2010). However, the majority of phenolic compounds in milk and herbage are still unidentified and their direct effect on the sensory properties of dairy products have still to be demonstrated. Even though, plant secondary metabolites can have significant indirect effect on milk and cheese composition, as they can interact with rumen microflora, by partially inhibiting the biohydrogenation of dietary fatty acids in the rumen (Leiber *et al.*, 2005). Indeed, differences in milk fatty acid composition according to pasture botanical composition were shown by several authors on both fresh herbage (Falchero *et al.*, 2010) and conserved forages (Ferlay *et al.*, 2006). Collomb *et al.* (2002) correlated milk FA composition to the presence in grasslands of some botanical families or species. The main differences seemed to concern C18:3n-3, total PUFA, and the FA intermediate product of its hydrogenation in rumen, such as C18:1t11, CLAc9t11; C18:2t11c15 and other trans or cis isomers of C18:1 and C18:2 (Leiber *et al.*, 2005; Iussig *et al.*, 2015). As examples, an increase of about 0.20 g/100 g FA of CLAc9t11 and C18:3n-3 was shown on a grass-dominated pasture rich in forbs compared to one poor (Povolo *et al.*, 2013; Coppa *et al.*, 2015). Milk FA composition can affect cheese sensory properties (Martin *et al.*, 2005). High concentration of PUFA in milk resulted a lower fat melting point, with consequent less firm, softer and more melting texture of cheese (Coppa *et al.*, 2011a). The PUFA oxidation can also generate large amount of odour active compounds during ripening, with significant effect on cheese odour and aromas (Coppa *et al.*, 2011b). Cheese appearance can be affected by milk FA composition (Coppa *et al.*, 2011a) possibly because PUFA rich fat may oil-off during pressing and therefore interact with the development of moulds and yeasts.

Some recent researches have highlighted that other factors, related to pasture characteristics can have important effect on milk composition and cheese characteristics. Among these factors, the herbage phenological stage seems to have a great impact on milk carotenoids content (Calderon

et al., 2006). Carotenoids, are plant essential pigments derived from the chlorophyll, and can be transferred from diet to cow milk, especially the β -carotene. The herbage β -carotene content decreases with herbage maturation (Calderon *et al.*, 2006), resulting in lower concentration in milk from cows grazing mature herbage instead of herbage at the vegetative stage. Carotenoids are thus responsible for the yellow colour of milk issued from cows fed fresh herbage (Martin *et al.*, 2005) and the yellowness of cheese was shown to decrease of about the 20% when cows' grazed herbage at a late compared to an early phenology (Coppa *et al.*, 2011a). However, the transfer of β -carotene from diet to milk is a specificity of cows, as it is negligible in small ruminants (Martin *et al.*, 2005). The effect of phenological stage was shown to be important also on milk fatty acid composition. A decrease in total lipid, and in C18:3n-3 herbage content with herbage maturation results in a decrease in milk C18:1t11 and CLAc9t11 concentration comparable to those achievable by reducing of 30% the fresh herbage proportion in cow diet in on farm conditions (Coppa *et al.*, 2015). These differences are therefore greater than those observed among pastures with different botanical composition (Coppa *et al.*, 2015).

Furthermore, animal grazing selection at pasture could interact with the botanical composition (Iusig *et al.*, 2015) and change during the season according to herbage phenology development (Farrugia *et al.*, 2014). On continuous grazing on biodiversified and heterogeneous pastures, cows often overgraze the preferred vegetation type, dominated by grasses, and the selection of dicotyledonous species increases only in the late season, when the regrowth of grasses is not sufficient to cover cow herbage requirements (Farrugia *et al.*, 2014). This pattern may have important effect on milk fatty acid composition, cheese yellowness and sensory profile (Coppa *et al.*, 2011a; Farrugia *et al.*, 2014). The grazing selection depends also on the grazing management adopted, decreasing with the increase of stoking density. Thus, in the rotational grazing systems, shorter is the duration of paddock utilisation, lower is the selection by cows (Coppa *et al.*, 2015). A lower selection among species results in grazing by layers, with a consequent significant change in the nutritive quality of ingested herbage from the upper leafy layers to the lower layers, rich in stems (Coppa *et al.*, 2015). The result is a wide variation in milk FA concentration during the few days occurring from the beginning to the end of paddock utilisation (-1.71 and -0.41 g/100 g FA for C18:1t11 and CLAc9t11, respectively), with range of variation comparable or even larger than those observed for the effects of herbage phenology, or botanical composition (Coppa *et al.*, 2015).

2. Microbial link

The raw milk microbiota, that prints the milk production system, is another important aspect to be considered in order to explicit the link to terroir is the case of raw milk cheeses. Furthermore, its role on the cheese sensory properties (especially the flavour) was demonstrated for long, even when starters are used to fasten acidification of fresh cheeses (Montel *et al.*, 2014) and some observations suggest that the effects of animal feeding on cheese sensory properties are partly eclipsed when milk is pasteurized. Knowledge about the raw milk microbiota is increasing rapidly thanks to the application of rRNA-based culture-independent high-throughput amplicon sequencing (Montel *et al.*, 2014). For example, the ITS-PCR fingerprinting of raw milks from Alpine pasture were distinguished from lowlands by higher diverse bacterial communities (Bonizzi *et al.*, 2009). Composition of milk microbiota results of a combination of human factors (milking practices, breeding practices), animal physiology, animal health, animal feeding, and environmental factors (air, faeces, milking equipment) (Vacheyrou *et al.*, 2011; Monsallier *et al.*, 2012). Defining the contribution of each factor is not an easy task. In particular, the effect of feeding is difficult to disassociate from that of animal housing (inside -outside) or cleanliness.

Some reservoirs of milk microbial diversity have been identified but we are still lacking of information about microbial transfers from reservoirs to farm milk. The theoretical microbial transfer pathway can be schematised as indicated in Fig. 1 and teats are the essential vectors of microorganisms from animal environment to raw milk.

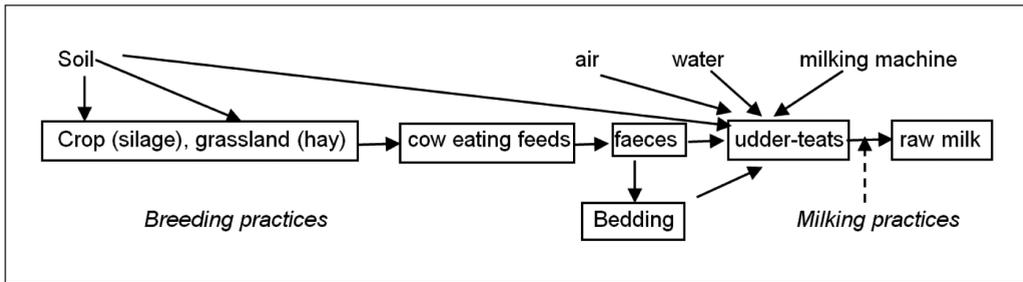


Fig. 1. Theoretical microbial transfer pathway from reservoirs to farm milk.

Different researches underline that animal feeding (grassland, silage and hay) may be an indirect source of micro-organisms for milk. For example, grassland of Normandy contains high levels of Gram negative bacteria (*Pseudomonas*, *Enterobacteriaceae*) coryneform bacteria and yeasts, but low levels of *Lactococcus lactis* ssp *lactis* (Denis *et al.*, 2004). Lactobacilli were found in alfalfa and grass (Chunjian *et al.*, 1992) and at high level in milk from animal grazing or green-fed in the barn (Elmoslemany *et al.*, 2010). Fungal genera such as *Eurotium* sp., *Aspergillus* sp., and Gram positive (*Curtobacterium* sp., *Bacillus* and *Paenibacillus* sp.) and Gram negative rods (*Pantoea* and *Pseudomonas* sp.) have been found in hay (Vacheyrou *et al.*, 2011). Milks from animals grazing had lower microbial population and level of *Streptococcus agalactiae* (possible cause of mastitis) than those from animal confined and fed with concentrates and preserved fodders (Goldberg *et al.*, 1992). The transition to the grass could enrich milk with coagulase negative *Staphylococcus* (Hagi *et al.*, 2010). Levels of microbial groups (total bacteria, Gram negative bacteria, yeasts, moulds, lactic acid bacteria, ripening bacteria) of the surface teats of dairy cows at pasture were shown 10 to 1000 times lower than those of dairy cows confined in the barn (Verdier-Metz *et al.*, 2012). But the number of microbial species was higher on teats of cows on a pasture with high floristic diversity than those of cow confined (72 at pasture versus 43 indoor) (Verdier-Metz *et al.*, 2012).

These recent researches underline the role of the milk microbiota in order to explicit the link to terroir. They also stress the importance of maintaining the possible microbial transfers from farm reservoirs to milk and therefore to avoid milking or cheesemaking practices (like pasteurisation, for example) able to disrupt this link.

IV – The case of meat products

In comparison to dairy products, explicating the links between animal husbandry and meat characteristics is even more complex due to the fact that, unlike milk whose characteristics vary in the short term according to the diet, carcass and meat characteristics are shaped during the entire life of the animals. Nevertheless, many researches show that the current tendency for changing indoors to grass production systems, affects meat characteristics. One of the most affected traits is the colour, the most important attribute taken into account by consumers in their purchase decision. The magnitude of their influence on carcass and meat quality remains unclear, especially in young animals fed on their dams' milk until slaughter.

1. Lamb's performance, carcass and meat quality in mountain areas

The production of lambs in Mediterranean areas is based on young lambs slaughtered as suckling lambs (10-12 kg live-weight, LW) or as light lambs (22-24 kg LW, younger than 90 days) to produce light carcasses. Suckling lambs are fed only their dams' milk, whereas light lambs after wean-

ing at 45-50 days are fattened indoors with concentrates. In these systems, ewes are stalled around parturition and fed indoors hay or straw with concentrates during the lactation period. Meat of light lambs from these production systems is very homogeneous, its colour is pale pink and it has white fat. Alternatively in Mediterranean mountain pastures, light lambs can be raised by their dams during the spring season (Joy *et al.*, 2012b) or on alfalfa pastures between late spring and early autumn (Ripoll *et al.*, 2014a) with minimum or even no detrimental effects on lamb performance and carcass quality. The effect of these feeding managements (grazing mountain pasture vs. indoors concentrate feeding) on fat colour in light lambs is minor as the subjective scores were similar (Carrasco *et al.*, 2009). However, subcutaneous fat of lambs from grazing systems had greater yellowness (b^*), associated with the presence of carotenoids, flavonoids and α -tocopherol in their diet (Prache and Theriez, 1999), than those from concentrate-based diets. Similarly, fat from suckling lambs whose dams grazed had greater yellowness and redness than that from lambs whose dams were fed hay (Joy *et al.*, 2012b). This might be due to the small grass intake by the lamb (Álvarez-Rodríguez *et al.*, 2007) in addition to the intake of milk carotenoids (Prache *et al.*, 2005). Grass-fed lambs may provide meat with a low degree of fatness and red meat colour (Priolo *et al.*, 2002).

Grass feeding of dams is effective improving the meat quality of lambs raised exclusively on maternal milk (Valvo *et al.*, 2005), due to the healthiness of milk from grazing sheep (Atti *et al.*, 2006). Lamb intake of milk from grass-fed ewes led to a higher proportion of linolenic acid in intramuscular fat. The feeding strategy around parturition and lactation affects the milk FA profile (Joy *et al.*, 2012a). The most affected by grazing are CLA, C18:1t11 and PUFA, n-6/n-3 ratio, with a positive effect for human health. Pre-partum grazing, regardless of post-partum feeding, can modify the FA composition, increasing the CLA content in meat. The extent of the increase of CLA, C18:1t11 and PUFA n-3 of grass-based diets in comparison to grain-based diets depends on the maturity, variety and preservation of the forage (Dewhurst *et al.*, 2006). Green grass is a source of n-3 PUFA, haymaking processes lead to a loss of FA precursors of CLA, while modest losses are recorded in wilting prior ensiling (Dewhurst *et al.*, 2006).

2. Cattle performance and meat quality in mountain fattening systems

Suckler cattle farms located in Mediterranean mountain areas traditionally produce weaned calves, which are fattened under intensive conditions in feedlot farms in the plains. Despite this general trend, some mountain farms have undertaken on-farm fattening activities, either individually or in a cooperative way (García-Martínez *et al.*, 2009), as a strategy to retain a higher share of the added value of the product sold into the market. This is also common in other mountain areas in Central Europe. Since a high growing rate is expected in fattening animals, weanlings are fattened on valley meadows, while the less productive pastures are used more efficiently by other types of cattle. In these production systems, the growth rates on pasture of entire males sold as yearlings (12 months) or young steers (18 months) depend on the pasture quality and quantity available and the amount and type (barley, maize or concentrates) of supplement offered to young bulls and steers, but gains over 1 kg/day are always achieved (Blanco *et al.*, 2014). Several studies that compared concentrate-, hay- and grass-fed cattle had different end-weight, and found that dressing percentage and meat quality differed among diets (Serrano *et al.*, 2007). However, carcass weight influences carcass and meat quality and effects can be confounded. In cattle slaughtered at the same body weight, grazing generally reduces subcutaneous fat cover, dressing percentage and fat deposition in veal calves (Ripoll *et al.*, 2013) and young bulls (Blanco *et al.*, 2011). Dressing percentage did not differ after a 2-month finishing period on concentrates in young bulls (Blanco *et al.*, 2011) but decreased after a 2-3 month finishing period on a total mixed ration in 18-month old steers. Nevertheless, finishing on concentrates or on a total mixed ration increased the deposition of fat in the carcass (Blanco *et al.*, 2014, Ripoll *et al.*, 2014b). Fat colour was greatly affected by the grass-feeding, yellowness and the estimator of carotenoids being the most affected parameters (Blanco *et*

al., 2010) due to a high deposition of carotenoids in fat. Therefore, fat colour can be used to trace and guarantee forage feeding. A finishing period of 2 months on a total mixed ration did not affect fat colour (Ripoll *et al.*, 2014b) but 2 months on concentrates affected yellowness and the estimator of carotenoids of subcutaneous fat (Blanco *et al.*, 2011).

Meat colour and toughness were affected to a lower extent by grazing (Blanco *et al.*, 2010) when carcasses had an appropriate fat cover. In fact, grazing had a negative impact in meat colour of veal calves (Ripoll *et al.*, 2013), probably due to the scarce subcutaneous fat cover. A 2 month finishing period on concentrates after grazing had no effect in the colour and toughness meat from young bulls (Blanco *et al.*, 2010) but a 2 month finishing period on a total mixed ration improved toughness in meat aged for 9 days but not in meat aged for longer periods (Ripoll *et al.*, 2014b). Regarding the chemical composition, grazing had a major effect on the fatty acid profile at a similar deposition of intramuscular fat. Grazing improved the fatty acid profile in veal calves (Ripoll *et al.*, 2013) and young bulls (Blanco *et al.*, 2010), increasing n-3 PUFA content. The difference between grazing and finished cattle depended on the type of feed offered during the finishing period, if concentrates were offered total PUFA decreased and n-6:n-3 ratio increase (Blanco *et al.*, 2010); if a total mixed ration was offered the fatty acid profile was not affected (Ripoll *et al.*, 2014b).

V – Conclusions

The terroir basically refers to a system of interactions between biophysical and human factors that were built during the history and that are specific from a geographical limited area. The typicity of animal products originating from a terroir results from specific traditions and know-how for animal production and processing. In addition to the historical and cultural aspects of the link to terroir, the results presented here underline the primary contribution of the mountain pastures animal products typicity. The specific botanical composition and biodiversity of mountain pastures is governed by geo-climatic conditions and agronomic practices (fertilization, stoking density, grazing management) and has a direct influence on meat and cheese composition. Both direct and indirect fluxes of molecules from mountain grasslands to meat and cheese are now well documented. In most cases, the secondary metabolites of the very diverse dicotyledonous plants found in mountain pastures are involved. These molecules allow in some cases to authenticate through analytical techniques, the mountain and/or pasture origin of meat and dairy products. The role of these molecules (and microbes in the case of raw milk cheeses) on meat and cheese sensory properties are often reported, and even if not fully understood they obviously contribute to the link to terroir. The way the mountain pastures are managed and the characteristics of the animals used (breed, physiological status) also influence the grazing selection and herbage phenology. The interconnections of these aspects can be considered as an adaptation of a farming system itself (considered under agro-environmental, human and animal components) to a specific geographical context that make unique a terroir and its animal products. Understanding this system of interactions refers back to the measures to be taken so that the animal products reflect the uniqueness and diversity of the terroir where they originate.

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Alpine grasslands: relations among botanical and chemical variables affecting animal product quality

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Abstract. In alpine farms, forage composition is considered as the most important factor influencing the quality of grazing ruminant productions. This study aimed at analysing the complex relationships existing among botanical composition, chemical composition and some plant community variables of different alpine grassland communities. Thirty-nine vegetation surveys were carried out within some of the most common alpine grassland communities in the western Italian Alps. The botanical composition was determined, and mean values of Landolt's ecological indicators, biodiversity indices, phenological stage, and pastoral values (PV) were computed. Representative samples of grass were collected and analysed for dry matter (DM), crude protein (CP), fibre, and fatty acid (FA) composition. The relationships among the considered variables were assessed computing Pearson's correlation coefficients and performing a canonical correspondence analysis (CCA). A hierarchical cluster analysis identified two main grassland ecological groups: (i) mesophilic grasslands (MG), including *Poa pratensis*, *Lolium perenne* and *Festuca nigrescens* types; and (ii) dry grasslands (DG), including *Bromus erectus*, *Brachypodium rupestre* and *Helianthemum nummularium* types. Independent sample *t*-tests showed that MG and DG were comparable ($P > 0.05$) in terms of phenology, biodiversity indices and proportion of botanical families. The CCA clearly separated MG and DG along the first axis (32.1% of explained variance): MG species were associated with higher CP, total FA, α -linolenic, linoleic and palmitic acids contents, while DG species were associated with higher DM, fibre and oleic acid contents. Interestingly, the PV (a synthetic vegetation index) was strictly linked with the plant concentration of α -linolenic acid. These findings highlight that ruminants grazing on MG can benefit from forage of higher palatability, nutritive value and concentration of precursors for the synthesis of beneficial FA (e.g., ruminic acid and omega-3 fatty acids) in dairy and meat products.

Keywords. Canonical correspondence analysis – Forage quality – Grazing ruminants – Fatty acids.

Prairies alpines: relations entre variables botaniques et chimiques qui influencent la qualité des produits animaux

Résumé. Dans les fermes d'alpage, la composition des fourrages est considérée comme le plus important des facteurs qui influencent la qualité de la production des ruminants au pâturage. Cette étude visait à analyser les relations complexes qui existent entre la composition botanique, la composition chimique et certaines caractéristiques des communautés végétales de différentes prairies alpines. Trente-neuf relevés de végétation ont été effectués dans certaines des communautés végétales les plus courantes dans les prairies alpines de l'ouest des Alpes italiennes. La composition botanique a été déterminée, et les valeurs moyennes des indicateurs écologiques de Landolt, des indices de biodiversité, du stade phénologique et des valeurs pastorales (VP) ont été calculées. Des échantillons représentatifs d'herbe ont été recueillis pour les analyses de la matière sèche (MS), de la protéine brute (PB), des parois et de la composition en acides gras (AG). Les relations entre les variables considérées ont été évaluées au moyen des coefficients de corrélation de Pearson et d'une analyse canonique des correspondances (ACC). L'analyse des données botaniques par classification hiérarchique a permis d'identifier deux principaux groupes écologiques: (i) les prairies mésophiles (PM), incluant les typologies à *Poa pratensis*, *Lolium perenne* et *Festuca nigrescens*; et (ii) les prairies sèches (PS), incluant les typologies à *Bromus erectus*, *Brachypodium rupestre* et *Helianthemum nummularium*. Les *t*-tests ont montré que PM et PS étaient comparables ($P > 0,05$) en termes de phénologie, d'indices de biodiversité et de proportion des familles botaniques. L'ACC sépare clairement PM et PS le long du premier axe (32,1% de la variance expliquée): les espèces PM ont été associées avec les plus hautes teneurs

de PB, AG totaux, acides alpha-linolénique, linoléique et palmitique, tandis que les espèces PS ont été associées avec les plus hautes teneurs de MS, parois et acide oléique. Il est intéressant de noter que la VP (un indice de végétation synthétique) est strictement liée à la concentration d'acide alpha-linolénique détectée dans le fourrage. Ces résultats mettent en évidence que les ruminants qui pâturent sur des prairies PM peuvent bénéficier de fourrage caractérisé par une palatabilité élevée, une meilleure valeur nutritive et une plus haute concentration des précurseurs pour la synthèse des AG bénéfiques (par exemple, l'acide ruménique et les acides gras oméga-3) que l'on retrouve dans les produits laitiers et la viande.

Mots-clés. Analyse canonique des correspondances – Qualité des fourrages – Ruminants au pâturage – Acides gras.

I – Introduction

Herbaceous species vary in their contents of proximate constituents and fatty acids (FA) (Bovolenta *et al.*, 2008). As a consequence, grasslands with different botanical composition can significantly affect the chemical and sensory properties of ruminant derived food products (Lourenço *et al.*, 2009). Considering various grassland types typical of alpine European communities, this work was planned to study the relationships existing among the botanical, ecological and chemical variables of grasslands potentially affecting dairy and meat quality.

II – Materials and methods

Different grasslands were chosen in the Piedmont region, within an altitude range from 250 to 2000 m a.s.l. Thirty-nine vegetation surveys were carried out from September 2013 to September 2014. The grasslands were characterized in terms of botanical composition, phenological stage of plants, Landolt's ecological indicators, plant biodiversity, and forage pastoral value (PV), according to the procedures described in Lambertin (1990) and Orlandi *et al.* (2016). During each vegetation survey, representative grass samples were harvested, split into two aliquots and frozen at -80°C until analysed. The first aliquot was dried and ground, and then used for the determination of dry matter (DM), crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF). The second aliquot was freeze-dried and analysed for the FA composition. The proximate and FA compositions were expressed as g/100 g DM. The followed analytical procedures are reported in Renna *et al.* (2012).

Pearson correlations were performed among the botanical, chemical and plant community variables (IBM SPSS 22). A hierarchical cluster analysis was used to classify vegetation surveys into homogeneous vegetation types and ecological groups (Clustan Graphics 5.27). The relationships existing between chemical (main matrix) and botanical (second matrix) data were also assessed with a canonical correspondence analysis (CCA), where plant community variables were included in a supplementary matrix (PAST 3.08). Independent sample Student's t-tests were then used to evaluate differences in the botanical composition, chemical composition and plant community variables between the two main grassland ecological groups identified by the cluster analysis (IBM SPSS 22).

III – Results and discussion

The total fatty acid (TFA) content as well as the concentrations of palmitic (C16:0), linoleic (C18:2 n6) and α -linolenic (C18:3 n3) acids were negatively correlated with DM and fibre and positively correlated with the CP content of the grass samples; an opposite trend was observed for oleic (C18:1 n9) acid (Table 1). The concentration of C18:3 n3 was positively correlated with the relative abundance of *Fabaceae* and negatively correlated with *Poaceae*. The obtained results confirm known relationships among various chemical variables and phenology in plants (Nelson and

Moser, 1994; Glasser *et al.*, 2013). Interestingly, the PV (a synthetic vegetation index) was significantly and positively (C16:0, C18:3 n3) or negatively (DM, NDF, ADF) correlated with some of the considered chemical parameters.

Table 1. Dataset variability (mean \pm SD) and most significant Pearson's correlation coefficients among botanical, chemical and plant community variables (n = 39)

Mean \pm SD	DM: 29.6 \pm 10.51 g/100 g; CP: 12.0 \pm 2.83 g/100 g DM; NDF: 52.3 \pm 7.43 g/100 g DM; ADF: 32.8 \pm 5.37 g/100 g DM; C16:0: 0.30 \pm 0.057 g/100 g DM; C18:0: 0.04 \pm 0.013 g/100 g DM; C18:1n9: 0.09 \pm 0.049 g/100 g DM; C18:2n6: 0.32 \pm 0.093 g/100 g DM; C18:3n3: 0.81 \pm 0.358 g/100 g DM; TFA: 1.66 \pm 0.480 g/100 g DM; PV: 34.5 \pm 12.54; F: 2.4 \pm 0.34; N: 2.9 \pm 0.48; R: 3.2 \pm 0.28; Phenology: 312 \pm 214.5; Poaceae: 51.4 \pm 13.44 % of relative abundance; Fabaceae: 10.7 \pm 5.50 % of relative abundance
DM	CP (-0.78***), NDF (0.70***), ADF (0.81***), C16:0 (-0.65***), C18:1 n9 (0.57***), C18:2 n6 (-0.43**), C18:3 n3 (-0.79***), TFA (-0.71***), PV (-0.40*), Phenology (0.33*), F (-0.51**), R (0.64***), N (-0.63***), <i>Poaceae</i> (0.34*)
CP	NDF (-0.77***), ADF (-0.84***), C16:0 (0.81***), C18:1 n9 (-0.46**), C18:2 n6 (0.45**), C18:3 n3 (0.79***), TFA (0.76***), Phenology (-0.33*), F (0.40*), R (-0.54***), N (0.55***)
NDF	ADF (0.80***), C16:0 (-0.81***), C18:2 n6 (-0.48**), C18:3 n3 (-0.81***), TFA (-0.82***), PV (-0.35*), F (-0.45**), R (0.50***), N (-0.47**), <i>Fabaceae</i> (-0.54***), <i>Poaceae</i> (0.36*)
ADF	C16:0 (-0.69***), C18:1 n9 (0.55***), C18:2 n6 (-0.35*), C18:3 n3 (-0.78***), TFA (-0.70***), PV (-0.46**), F (-0.51***), R (0.63***), N (-0.66***), <i>Fabaceae</i> (-0.38*)
C16:0	C18:0 (0.38*), C18:2 n6 (0.75***), C18:3 n3 (0.79***), TFA (0.90***), PV (0.34*), F (0.46**), R (-0.49**), N (0.53***)
C18:0	C18:1 n9 (0.60**), C18:2 n6 (0.44**)
C18:1 n9	C18:3 n3 (-0.41**), Phenology (0.40*), R (0.44**), N (-0.35*)
C18:2 n6	C18:3 n3 (0.56***), TFA (0.77***), <i>Poaceae</i> (-0.36*)
C18:3 n3	TFA (0.95***), PV (0.36*), F (0.44**), R (-0.56***), N (0.50***), <i>Fabaceae</i> (0.42**), <i>Poaceae</i> (-0.34*)
TFA	F (0.40*), R (-0.49***), N (0.45**), <i>Fabaceae</i> (0.36*), <i>Poaceae</i> (-0.37*)

F: Landolt's soil moisture; R: Landolt's soil reaction; N: Landolt's nutrient supply.

*** $P \leq 0.001$; ** $P \leq 0.01$; * $P \leq 0.05$.

The cluster analysis (data not shown) identified two main ecological groups: i) mesophilic grasslands (MG), including *Poa pratensis*, *Lolium perenne* and *Festuca nigrescens* types and ii) dry grasslands (DG), including *Bromus erectus*, *Brachypodium rupestre* and *Helianthemum nummularium* types (Cavallero *et al.*, 2007). In the CCA, the first and second axis explained 53.1% of total variance and MG and DG were well separated along the first axis (Fig. 1). The CCA confirmed the results obtained with the Pearson's correlation analysis. The *t*-tests showed that MG and DG were comparable ($P > 0.05$) for phenology, biodiversity and proportion of botanical families. However, MG species were associated with higher CP, TFA, C16:0, C18:2 n6 and C18:3 n3 contents, while DG species were associated with higher DM, fibre and C18:1 n9 contents (Table 2).

IV – Conclusions

Ruminants grazing on MG can benefit from forage of higher palatability, nutritive value and concentration of precursors (e.g., C18:3 n3) for the synthesis of beneficial FA (e.g., ruminic acid and omega-3 FA) in dairy and meat products. MG are related to higher soil moisture content and more intensive management; it is therefore recommended to maintain the agro-pastoral practices that have promoted the affirmation of those grasslands in order to obtain animal products richer in nutraceutical compounds. Further research is needed to evaluate if significant differences can be also found among different grassland types belonging to the MG group.

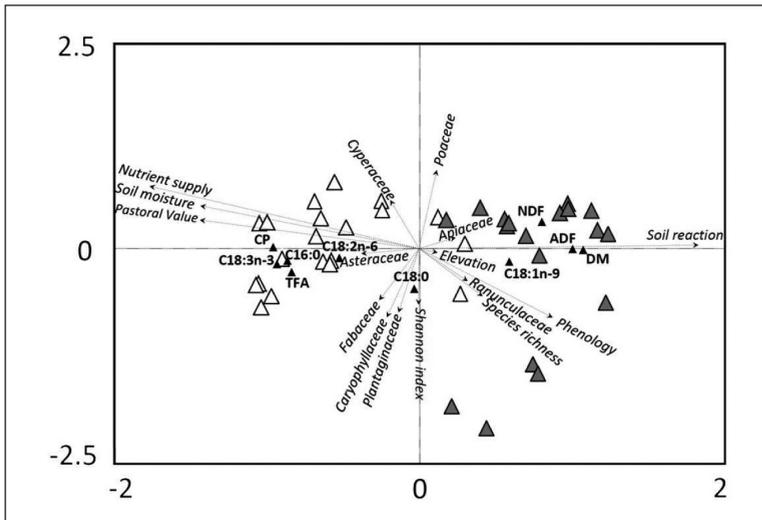


Fig. 1. Canonical correspondence analysis ordination biplot. White triangles: mesophilic grasslands; grey triangles: dry grasslands.

Table 2. Differences in terms of chemical and plant community variables between mesophilic and dry grasslands

	MG	DG	s.e.m.	P		MG	DG	s.e.m.	P
DM, g/100 g	22.3	38.1	1.68	***	C16:0, g/100 g DM	0.33	0.27	0.01	***
CP, g/100 g DM	13.6	10.2	0.45	***	C18:1 n9, g/100 g DM	0.07	0.12	0.00	**
NDF, g/100 g DM	48.9	56.3	1.19	***	C18:2 n6, g/100 g DM	0.34	0.28	0.01	*
ADF, g/100 g DM	29.5	36.6	0.86	***	C18:3 n3, g/100 g DM	0.98	0.60	0.06	***
Landolt's Soil moisture (F)	2.6	2.2	0.05	***	TFA, g/100 g DM	1.88	1.41	0.08	**
Landolt's Nutrient supply (N)	3.3	2.6	0.08	***	PV	40.0	27.9	2.01	**
Landolt's Soil reaction (R)	3.0	3.5	0.05	***					

Variables which did not significantly differ between ecological groups (i.e., Poaceae, Asteraceae, Fabaceae, Cyperaceae, Apiaceae, Plantaginaceae, Other forbs, Stearic acid, Phenology, Species richness, Shannon diversity index) are not displayed in the table.

*** P ≤ 0.001; ** P ≤ 0.01; * P ≤ 0.05.

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Clustering forage types according to their feed nutritive value

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Abstract. The aim of the study was to evaluate the nutritive value of forages produced in the Spanish Pyrenees and whether they may fulfil nutrient requirements of growing beef calves. Forages produced at mountain farms (16) were sampled and classified as grassland forage (fresh, $n = 17$; hay, $n = 35$; silage, $n = 29$) or other fibre sources (cereal straw and hulls, $n = 14$). Samples were analysed for dry matter, crude protein (CP), ash, neutral and acid-detergent fibre (NDF and ADF). A cluster analysis was performed to group the forages into homogenous categories according to these variables. The lowest quality group (relative forage value, RFV = 75.8 ± 3.4) was mainly represented by hays (45% of the total), while the best quality group (RFV = 148.6 ± 3.7) consisted mainly of pasture silages (60.7% of the total). Forage diets for fattening calves were designed with the three groups, but they differed widely. In case of the poorest forage group (CP $6.6 \pm 0.6\%$, RFV 75.8 ± 3.4) it was not possible to design a diet including 60% forage due to its low nutritive value. The best quality forages (CP 17.1 ± 0.7) met the estimated energy (UFV) requirements but they failed to meet protein requirements (PDIE) of growing-finishing beef calves with high growth potential. In this Pyrenean area, only around one third of the roughages used may allow meeting energy and protein requirements of growing-finishing beef cattle under a forage-based strategy.

Keywords. Grassland – Protein – Fibre – Beef – Productive performance.

Regroupement des types de fourrages en fonction de leur valeur nutritive

Résumé. Le but de l'étude était d'évaluer la valeur nutritive des fourrages produits dans les Pyrénées espagnoles et d'examiner s'ils peuvent satisfaire les besoins nutritionnels des veaux de boucherie. Des fourrages produits en fermes de montagne (16) ont été échantillonnés et classés comme fourrages de prairies (frais, $n = 17$; foin, $n = 35$; ensilage, $n = 29$) ou autres sources de fibres (paille et enveloppes de céréales, $n = 14$). Les échantillons ont été analysés pour : matière sèche, matières azotées (CP), cendres, fibre neutre et fibre acido-détergente (NDF et ADF). Une analyse de cluster a été réalisée pour grouper les fourrages en catégories homogènes selon ces variables. Le groupe à moins bonne qualité (valeur relative du fourrage, RFV = $75,8 \pm 3,4$) est principalement représenté par les foins (45% du total), tandis que le meilleur groupe (RFV = $148,6 \pm 3,7$) se composait notamment d'ensilages de pâtures (60,7% du total). Des régimes fourragers pour l'engraissement ont été conçus avec les trois groupes, mais ils diffèrent largement. Dans le cas des fourrages le plus pauvres (CP $6,6 \pm 0,6\%$), il n'a pas été possible de concevoir un régime alimentaire contenant 60% de fourrage en raison de sa faible valeur nutritive. Les meilleurs fourrages (CP $17,1 \pm 0,7\%$) répondaient aux besoins en énergie estimée (UFV), mais ils ont échoué à satisfaire les besoins en protéines (PDIE) des veaux de boucherie à potentiel de croissance élevé. Dans cette zone des Pyrénées, seulement un tiers environ des fourrages utilisés peut satisfaire les besoins énergétiques et protéiques des bovins de boucherie dans une stratégie basée sur fourrage.

Mots-clés. Pâturage – Azote – Fibre – Bovin à viande – Performances de production.

I – Introduction

Mountain livestock farms at the Pyrenees have used traditionally conserved forages from permanent grasslands. Hays and silages have been commonly used to feed adults animals during winter period whereas young animals were fattened indoors using high concentrate diets, usually at lowland. Growing beef cattle (< 12 months of age) in the Catalonian Pyrenees and its surround-

ing area (Lleida, Barcelona and Girona provinces) accounts for 22.5% of the total census in Spain. In addition, beef cattle managed under organic production systems in this area has increased evenly and cattle intended for beef nowadays represents around 20% of the organic beef sector in Spain (MAGRAMA, 2016).

To meet the organic production regulations, calves must be fed at least 60% of their diet as roughage, but when they have concentrate and forage offered both ad libitum they prefer eating concentrate (Casasús *et al.*, 2011). The nutritive value of forages should be tailored to animal requirements so that a reduction of concentrate supplementation and thereby feeding costs could be achieved. Therefore, there is increasing interest in feeding finishing cattle at mountain livestock farms by means of on-farm conserved forages. The aim of the study was to evaluate the nutritive value of forages produced in the Spanish Pyrenees and whether they may fulfil nutrient requirements of growing and finishing beef calves.

II – Materials and methods

1. Roughage sampling

A total of 95 roughages (2 kg approximately, on a fresh matter basis) were sampled in spring, summer and autumn from 16 mountain farms from the east-southern Pyrenees between years 2008 and 2015. The roughages were normally provided ad libitum to adult cattle and/or they were supplemented with concentrate ad libitum to growing and finishing cattle. The roughages were classed as grassland forage (fresh, $n = 17$, $29.8 \pm 17.9\%$ dry matter (DM); hay, $n = 35$, $88.9 \pm 8.9\%$ DM; silage, $n = 29$, $46.8 \pm 19.8\%$ DM) or other fibre sources (cereal straw and hulls, $n = 14$, $89.3 \pm 4.9\%$ DM) according to FEDNA (2004). Fresh samples were collected by clipping with an electric mower all plant material above 2 cm of ground level in two $1\text{ m} \times 0.25\text{ m}$ quadrats per paddock. Sampling was done before the animal started to graze the paddock. The grassland forage was mainly formed of plants belonging to the *Molinio-Arrhenatheretea* phytosociological class.

2. Chemical analyses

Fresh and silage samples were dried at $60\text{ }^{\circ}\text{C}$ until constant weight and mill-ground (1 mm screen). All the roughages were analysed in duplicate for ash (A, incineration at $550\text{ }^{\circ}\text{C}$), ether extract (EE, Soxhlet method), crude fibre (CF, Weende method) and protein (CP, nitrogen $\times 6.25$, Kjeldahl method) contents and corrected for DM content ($102\text{ }^{\circ}\text{C}$ for 24 h). Neutral-detergent fibre (NDF) and acid-detergent fibre (ADF) analyses were carried out with an Ankom²⁰⁰ fibre analyser (Ankom technology, Macedon NY, USA) and their results were corrected for ash-free content. The relative forage value (RFV) was estimated based on fibre analyses by means of the formula: $\text{RFV} = [(88.9 - (0.779 \times \text{ADF}(\%)) \times (120 / \text{NDF}(\%))] / 1.29$. Roughage quality is considered excellent if $\text{RFV} > 151$, first quality if $\text{RFV} 125\text{-}150$, and very low quality if $\text{RFV} < 75$ (FEDNA, 2004).

3. Statistical analyses

A cluster analysis was performed to group the forages into homogenous categories according to these variables. Firstly, the variables defining chemical quality of roughages were simplified into two principal components that were used to calculate Euclidean distances between observations. Based on this distance a k-means clustering method with three groups has been performed. The proc CLUSTER (SAS v9.4, Cary, NC) was used to perform the clustering analysis. Secondly, the data were analysed with a general linear model by considering the cluster obtained in the earlier analysis as a fixed factor. Multiple comparisons were performed by the t-Student test. The level of significance was set at 0.05.

III – Results and discussion

The two principal components explained 70% of the variability. The first component was related positively with CP and ash, whereas it was negatively related with NDF and ADF. The second component was related basically with DM. The clusters generated were clearly segregating by the first principal component.

A high variability in chemical composition was detected (coefficient of variation around 45% for CP, and around 34% for NDF and ADF), being the clusters related to feed CP and fibres. The lowest quality group (RFV = 75.8 ± 3.4) was mainly represented by hays (45% of the total) and roughage sources as cereal straw and bran (39%), while the best quality group (RFV = 148.6 ± 3.7) consisted mainly of pasture silages (60.7% of the total) and fresh pastures (32%). The intermediate forage quality group was made of pasture hays (55.9% of the total). The RFV results, which are based on fibre components, were in line with CP and ether extract values, but they were not in agreement with the ash contents, whose values were opposite to the RFV of the samples. Probably, the origin of most of the samples in this group may contain remaining soil particles that increased their mineral content.

The identified groups differed consistently among them in their nutritive value parameters (Table 1). The three groups were considered significantly different for CP, ash, NDF and ADF values. However, the high and intermediate quality groups did not differ in ether extract and crude fibre values. Hence, these last chemical parameters may be avoided in routine analyses to determine the nutritive value of roughages.

Table 1. Chemical composition of the roughages according to the different clusters obtained (g/100 of dry matter; least square means \pm standard error)

	1-High quality	2-Low quality	3-Medium quality
n	28	33	34
Crude protein	17.09 ± 0.65^a	6.64 ± 0.60^c	11.97 ± 0.59^b
Ash	15.68 ± 0.61^a	7.10 ± 0.56^c	8.86 ± 0.56^b
Ether extract	3.23 ± 0.53^a	1.58 ± 0.56^b	2.11 ± 0.63^{ab}
Crude fibre	27.89 ± 1.30^b	39.64 ± 1.55^a	29.49 ± 1.55^b
Neutral-detergent fibre	43.75 ± 1.33^c	70.14 ± 1.22^a	52.95 ± 1.21^b
Acid-detergent fibre	27.05 ± 0.92^c	41.97 ± 0.85^a	34.59 ± 0.83^b
Relative forage value (RFV)	148.63 ± 3.65^a	75.77 ± 3.36^c	110.47 ± 3.3^b

Within each row, different letter denotes statistical differences ($P < 0.05$) among clusters.

The different roughages groups differed widely in their ability to meet energy and protein requirements of beef calves (INRA, 2007) having different growth potential and managed under 60:40 forage to concentrate ratio (Table 2). Energy content in terms of net energy for meat production (UFV) was 0.92, 0.47 and 0.52 for cluster groups 1, 2 and 3 respectively. Forages should contain UFV > 0.9 to be considered very ingestible (Baumont *et al.*, 2009). It is noteworthy that the most limiting factor of diets including low quality group roughages was its high filling value (high fibre content) exceeding the voluntary intake capacity to support nutrient requirements. Only the best quality forages met the energy requirements of beef calves both in growing (250 kg of live-weight) and finishing (450 kg of live-weight) periods, regardless of the growth potential of the animals. Concerning protein requirements, they may be nearly met with high and intermediate quality groups if the calves have low growth rate. However, if calves have high growth potential (>1.2 kg/day), supplying a 60:40 forage to concentrate diet by means of these roughages would result in a deficiency in true protein absorbable in the small intestine because rumen fermentable energy (organic mat-

ter) would be limiting microbial protein synthesis in the rumen (PDIE), both in high and intermediate quality groups. A minimum of 13% of forage CP is required to avoid a deficiency in dietary protein (balance between PDIN and PDIE in the rumen) (Baumont *et al.*, 2009). This could be achieved by advancing the harvest date of pasture hays (late spring to early summer) or by improving the botanical diversity of pastures through reseeded with perennial legumes. Consequently, the use of good quality forages may improve the meat quality of beef (Blanco *et al.*, 2011).

Table 2. Adjustment of energy and protein requirements in the different clusters when supplying roughages to growing (250 kg of live-weight) and finishing (450 kg of live-weight) calves under a 60:40 forage to concentrate ratio

	1-High quality				2-Low quality				3-Medium quality				
	ADG [†]	FU ^{††}	UFV ^{†††}	PDIN ^{†††}	PDIE ^{†††}	FU	UFV	PDIN	PDIE	FU	UFV	PDIN	PDIE
250 kg	1	y	110%	100%	90%	n	76%	114%	90%	y	74%	127%	93%
	1.2	y	103%	104%	90%	n	81%	114%	90%	y	67%	90%	84%
	1.4	y	96%	94%	81%	n	83%	114%	90%	y	63%	90%	76%
	1	y	107%	118%	103%	n	66%	90%	82%	y	72%	118%	97%
450 kg	1.2	y	103%	106%	92%	n	64%	90%	74%	y	68%	90%	88%
	1.4	y	97%	97%	84%	n	60%	85%	67%	y	64%	90%	80%

[†] ADG= expected average daily gain (kg/day).

^{††} Adjustment of diets to the voluntary intake capacity (FU; fill units): yes(y) or no (n).

^{†††} Percentage of energy (UFV, %), and protein requirements (PDIN and PDIE, %) met. The concentrate used for simulations contained 1.02 UFV and 13.7% of CP.

IV – Conclusions

In this Pyrenean area, the best quality roughages sources consisted mainly of on-farm harvested pasture silages. Only around one third of the roughages may allow meeting energy and protein requirements of growing-finishing beef calves fed forage-based diets, suggesting the need of tailoring certain farming practices to improve the nutritive value of forages.

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Effects of forage feeding and the inclusion of Quebracho in ewes' diet on suckling lamb's meat quality

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Abstract. Churra Tensina ewe-lamb pairs grazed in mountain pastures ($n = 20$; Pasture) or were fed hay indoors ($n = 19$; Hay). Half of the ewes of each treatment received daily 300 g/head of a commercial concentrate (Control) or 300 g/head of the same concentrate with 10% of Quebracho (*Schinopsis Balansae*) with 75% of condensed tannins (QUE). Lambs suckled their dam's milk, being slaughtered when reached 10-12 kg live weight. The effects of forage, the inclusion of QUE in the dam's diet and the lamb's sex were evaluated on intramuscular fat content (IMF), color (Lightness (L^*), redness (a^*), yellowness (b^*), Hue angle (H^*) and Chroma (C^*)), and lipid oxidation at 0, 2, 5, 7 and 9 days of ageing in the *Longissimus dorsi* muscle. Meat of Hay lambs had greater IMF, L^* , b^* and H^* than that of Pasture lambs ($P < 0.001$), but meat had similar lipid oxidation ($P > 0.05$). The inclusion of QUE had no effect on IMF ($P > 0.05$) but affected color, meat of QUE lambs having greater L^* , b^* and H^* than that of Control lambs ($P < 0.05$). Lipid oxidation tended to be lower in QUE than in Control lamb meat ($P = 0.07$). Regarding the effect of sex, meat of females had greater IMF ($P < 0.01$) and lower b^* and C^* than that of males ($P < 0.05$) with no differences on lipid oxidation.

Keywords. Sex – Condensed tannins – Color.

Effets, sur la qualité de la viande des agneaux allaitants, de la distribution de fourrage et de l'inclusion de Quebracho dans le régime des brebis

Résumé. Des paires brebis-agneau de race Churra Tensina ont été mises en pâturages de montagne ($n = 20$; Pasture) ou alimentées en stabulation avec du foin ($n = 19$; Hay). La moitié des brebis de chaque traitement recevait par jour 300 g/tête d'un concentré commercial (Control) ou 300 g/tête du même concentré avec 10% de Quebracho (*Schinopsis balansae*) avec 75% de tannins condensés (QUE). Les agneaux tétaient le lait de leur mère et étaient abattus à 10-12 kg de poids vif. Les effets du fourrage, de l'inclusion de QUE dans la diète des mères et du sexe des agneaux ont été évalués pour la teneur en gras intramusculaire (IMF), la couleur (Lightness, L^*), le rouge (a^*), le jaune (b^*), l'angle de la teinte (Hue angle, H^*) et la saturation (Chroma, C^*), et l'oxydation des lipides à 0, 2, 5, 7 et 9 jours de maturation dans le muscle *Longissimus dorsi*. La viande des agneaux recevant du foin (Hay) présentait des valeurs plus fortes de IMF, L^* , b^* et H^* que celle des agneaux de pâturage (Pasture) ($P < 0,001$), mais la viande avait une oxydation des lipides similaire ($P > 0,05$). L'inclusion de QUE n'avait pas d'effet sur IMF ($P > 0,05$) mais affectait la couleur, la viande des agneaux QUE ayant un niveau plus élevé pour L^* , b^* et H^* que celle des agneaux Control ($P < 0,05$). L'oxydation des lipides tendait à être plus faible pour la viande des agneaux QUE que pour celle des agneaux Control ($P = 0,07$). Concernant l'effet du sexe, la viande des femelles avait une plus grande IMF ($P < 0,01$) et de plus faibles b^* et C^* que celle des mâles ($P < 0,05$) sans différences sur l'oxydation des lipides.

Mots-clés. Sexe – Tannins condensés – Couleur.

I – Introduction

In dry mountain areas, as the Pyrenees, ewes are usually stalled around parturition and hay-fed plus concentrate during lactation. To produce a traditional food product, the suckling lambs are fed exclusively on maternal milk from birth to slaughter (average age of 40 days and body weight of 10-12 kg). However, grazing pasture is an interesting alternative (Joy *et al.*, 2012) because ewes and lambs had good performance and the use of natural resources is increased. The inclusion of

condensed tannins in the ewe's diet has been studied to reduce methane emissions and to improve production parameters, but it depends on the dose and the type of tannins (Ramírez-Restrepo and Barry 2005). Condensed tannins affected positively meat quality of fattening lambs because they are antioxidants (Vasta and Luciano, 2011). However, there is scarce information of their effect on meat quality of suckling lambs.

Therefore, the aim of this study was to evaluate the effect of two types of forages (pasture vs. hay) and the inclusion of condensed tannins from Quebracho in the concentrate fed to Churra Tensina lactating ewes on meat quality of the suckling lambs.

II – Materials and methods

The experiment was conducted in the facilities of La Garcipollera Research Station, in the mountain area of the Southern Pyrenees (North-Eastern Spain, 42° 37'N, 0° 30' W, 945 m a.s.l.). The experimental and slaughter procedures met the guidelines of Council Directive 86/609/EEC on the protection of animals used for experimental and other scientific purposes.

Spring-lambing adult ewes of Churra Tensina breed ($n = 39$; at lambing: age: 6.9 ± 0.54 year; body-weight (BW): 47 ± 1.0 kg; body condition score (BCS) 2.4 ± 0.05) and their single-reared lambs (BW at birth: 4 ± 0.1 kg) were used in a 35-day feeding trial. At lambing, ewe-lamb pairs were randomly distributed, according to BW, BCS and age of ewe and sex of the lamb, to 1 of 4 treatments in a 2 x 2 factorial experimental design, with 2 forages: Pasture vs. Hay; and 2 pelleted concentrates: a Control concentrate vs. a QUE concentrate with 10% of Quebracho extract (SYLVAFEED ByPro Q, Spain). The extract contained 75% of condensed tannins. Pasture dams and lambs had access to a permanent pasture, where samples were taken weekly and analysed (239 g crude protein (CP)/kg dry matter (DM), 175 g of neutral detergent fibre (NDF)/kg DM and 16.45 MJ metabolizable energy (ME)/kg DM). The remaining pairs were stalled and ewes received hay (69 g CP/kg DM, 633 g NDF/kg DM and 8.24 MJ ME/kg DM). The concentrates were available only for the dams, which were daily fed 300 g/head. Half of the dams of each type of forage were fed the QUE concentrate (141 g CP/kg DM, 175 g NDF/kg DM and 16.45 MJ ME/kg DM) while the other half were fed the Control concentrate (140 g CP/kg DM, 249 g NDF/kg DM and 15.13 MJ ME/kg DM). Lambs suckled their dams and had access to pasture or hay. Water and mineral blocks were offered *ad libitum*.

When the lambs reached the target slaughter weight (10-12 kg), they were slaughtered weekly, in the experimental abattoir of the Research Centre. Carcasses were hung by the Achilles tendon and chilled at 4 °C for 24 h in total darkness. After this time, the *Longissimus thoracis et lumborum* (LTL) muscle was extracted and sliced into five 2.5-cm samples. One slice was lyophilized to determine the intramuscular fat content. The other 4 slices were used to determine the color and lipid oxidation during storage. The samples were randomly placed in 4 trays, wrapped with oxygen-permeable PVC film and kept in darkness (4°C) for 2, 5, 7 and 9 days. The 0 d samples were bloomed for 1 h before color measurement. Immediately after the color measurement, the samples were vacuum-packed and frozen (-20°C) until TBARS analysis.

Lyophilized meat samples were minced to determine the intramuscular fat (IMF) using an Ankom (USA, NY). The color was measured using a Minolta CM-2006d spectrophotometer (Konica Minolta Holdings, Inc., Osaka, Japan) in the CIELAB space. The lightness (L^*), redness (a^*) and yellowness (b^*) were recorded, and the hue angle (H^*) = $\arctan(b^*/a^*) \times 57.29$, expressed in degrees, and $C^* = (a^{*2} + b^{*2})^{0.5}$ were estimated. To determine the lipid oxidation, TBARS analysis was carried out as described by Ripoll *et al.* (2013), and results were expressed as mg of malonaldehyde (MDA) per kg of muscle.

Data were analysed using the SAS statistical software (SAS V.9.3). Intramuscular fat was analysed with a general lineal model (GLM) with forage feeding, the inclusion of QUE, lamb sex and their interaction as fixed effects. Color and lipid oxidation of LTL muscle were analysed with a mixed model

(MIXED procedure) for repeated measures including the forage feeding, the inclusion of QUE in the concentrate, lamb sex, the storage time, and their interactions as fixed effects and the lamb as the random effect. Results were reported as least square means and their associated standard errors (SE). Differences were significant or a trend at a probability value of $P < 0.05$ and $P < 0.10$, respectively.

III – Results and discussion

The interactions between the type of forage, inclusion of QUE and lamb sex were not significant in the parameters studied. Consequently, results are presented separately for the main effects in Table 1.

The forage fed to the ewe affected meat intramuscular fat content, lightness, yellowness and hue angle value ($P < 0.001$), but did not affect the lipid oxidation of the muscle of suckling lambs. Hay treatment had 27% greater IMF than Pasture one. This difference can be due to the longer time animals spend walking and eating in pasture, increasing the energy requirement for maintenance (Osuji, 1974). The differences in the color are in line with Joy *et al.* (2012) between suckling lambs from pasture- and hay-fed ewes in autumn.

The inclusion of Quebracho in the ewe's diet increased lightness, yellowness, hue angle value ($P < 0.05$) and tended to reduce lipid oxidation of suckling lamb, which could prolong meat shelf life. The greater lightness has been previously reported by other authors with the inclusion of different tanniferous plant species in lamb diets (Priolo *et al.*, 2002; 2005). In the same sense, several authors observed that the inclusion of different tanniferous plant species in lamb diets originates a reduction in the lipid oxidation (Francisco *et al.*, 2015; Jerónimo *et al.*, 2012). In contrast, Luciano *et al.* (2009) studying the inclusion of Quebracho in fattening diets of lambs did not find effect on lipid oxidation. There is controversy about the absorption of tannins and its depots in animal tissues. Quebracho tannins seems not to be degraded or absorbed in gastrointestinal tract (López-Andrés *et al.*, 2013), what can involve the lack of the antioxidant effect expected.

The sex of the lambs affected IMF content, yellowness and hue angle value ($P < 0.01$). Females presented 19% greater IMF content than males according with Diaz *et al.* (2003) and Santos *et al.* (2015) in Manchego suckling lamb and “Cordeiro Mirandês”, respectively. Males had greater yellowness and chroma than females but similar lightness and redness.

As expected, time affected all color traits studied and lipid oxidation of the LTL muscle ($P < 0.001$). Meat oxidation increased during the 9 days of storage, reaching 1 mg MDA/kg muscle at 7 day, which is an acceptability limit in meat of light lambs (Ripoll *et al.*, 2011).

Table 1. Effect of type of forage (F), the inclusion of Quebracho in the concentrate (C), lamb sex (S) and time of storage (T) on intramuscular fat (IMF), color and lipid oxidation (TBARS) of the LTL muscle

	Forage		Concentrate		Sex		SE	Significance			
	Pasture	Hay	QUE	Control	Female	Male		F	C	S	T
IMF, %	8.10	10.34	9.17	9.28	10.00	8.45	0.52	***	NS	**	-
L*	41.73	43.95	43.39	42.29	42.53	43.15	0.335	***	*	NS	***
a*	12.05	11.81	11.77	12.09	11.71	12.14	0.178	NS	NS	NS	***
b*	6.18	7.37	7.11	6.44	6.39	7.15	0.185	***	*	**	***
H*	27.06	31.70	30.90	27.87	28.43	30.34	0.879	***	*	NS	***
C*	13.63	13.97	13.80	13.80	13.44	14.16	0.168	NS	NS	**	***
TBARS	0.73	0.88	0.71	0.90	0.79	0.82	0.078	NS	†	NS	***

L*: Lightness; a*: redness; b*: yellowness; H*: Hue; C*: Chroma.

Significance level: $P < 0.05^*$; $P < 0.01^{**}$; $P < 0.001^{***}$; $P < 0.1^\dagger$; $P > 0.05$ NS.

IV – Conclusions

The use of condensed tannins from Quebracho in the ewe diet at a dose of 7.5%, showed a tendency to decrease the lipid oxidation in meat of suckling lambs. The type of forage offered to dams affected most of the color parameters but did not affect the lipid oxidation.

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Differences in nutritional quality of milk produced from ewes reared in mountain versus valley areas

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Abstract. In the present study, fat content and fatty acid (FA) composition of milk from ewes reared in valley and mountain pastures was investigated. Six flocks of Latxa ewes were selected (3 from valley and 3 from mountain) and milk was collected in triplicate in May and June, during the grazing period at late lactation. Mountain milk was fatter than valley milk ($p \leq 0.001$). Interaction between pasture type and sampling week was significant ($p \leq 0.05$) for saturated FA (SFA), monounsaturated FA (MUFA), conjugated linolenic acid (CLA) and non-conjugated dienes, where mountain milk provided less SFA, more MUFA, and more CLA, mainly 9cis(c), 11trans(t)-18:2. Looking closer at the nutritionally interesting FAs, in all milk samples 11t-18:1 was the major trans-18:1 isomer (average of 55.6%), while the 10t-/11t- ratio was below 1 in all milk samples. In addition, mountain milk samples provided higher values ($p \leq 0.001$) for branched-chain FA, cis-MUFA and polyunsaturated FAs (PUFA) content, and higher P/S ratio. In general, mountain milk provided higher contents of metabolites related to the biohydrogenation n-3 PUFA like 9c, 11t, 15c-18:3, 11t, 15c-18:2 and 11t, 13c-18:2 and a lower n-6/n-3 ratio. Therefore, the milk from ewes reared in the mountain grasslands had a healthier FA profile and could provide value-added cheese of commercial benefit.

Keywords. Commercial sheep flocks – Fatty acids – Grassland altitude – Grazing – Vaccenic acid.

Différences de qualité nutritionnelle pour le lait produit par des brebis élevées en zones de montagne versus zones de vallée

Résumé. La présente étude a examiné la teneur en matière grasse et la composition en acides gras (AG) du lait de brebis élevées sur des pâturages de vallée et de montagne. Six troupeaux de brebis de race Latxa ont été sélectionnés (3 pour la vallée et 3 pour la montagne) et le lait a été collecté en triple en mai et juin, durant la période de pâturage en fin de lactation. Le lait lié aux montagnes était plus gras que le lait des vallées ($p \leq 0,001$). L'interaction entre le type de pâturage et la semaine de prélèvement des échantillons était significative ($p \leq 0,05$) pour les AG saturés (AGS), les AG mono-insaturés (AGMI), l'acide linoléique conjugué (CLA) et les diènes non conjugués, où le lait de montagne a donné moins d'AGS, plus d'AGMI, et plus de CLA, principalement 9cis(c), 11trans(t)-18:2. En regardant de plus près les AG d'intérêt nutritionnel, dans tous les échantillons de lait, le 11t-18:1 était l'isomère trans-18:1 majoritaire (en moyenne 55,6%), tandis que le ratio 10t-/11t- était inférieur à 1 dans tous les échantillons de lait. En outre, les échantillons de lait de montagne ont montré des valeurs plus élevées ($p \leq 0,001$) pour la teneur en AG à chaîne ramifiée, cis-AGMI et AG poly-insaturés (AGPI), et un ratio P/S plus élevé. En général, le lait de montagne apportait de plus grandes teneurs en métabolites liés aux AGPI n-3 de biohydrogénation tels que 9c, 11t, 15c-18:3, 11t, 15c-18:2 et 11t, 13c-18:2 et un ratio n-6/n-3 plus faible. Donc le lait des brebis élevées en pâturages de montagne avait un meilleur profil santé pour les AG et pourrait apporter au fromage une valeur ajoutée commercialement bénéfique.

Mots-clés. Troupeaux ovins commerciaux – Acides gras – Altitude des pâturages – Pâturage – acide vaccénique.

I – Introduction

In the last years, efforts have been made by European countries to give an added value to those food products produced under specific conditions and methods, and protecting these products with quality labels like PDO (Protected Designation of Origin) and others. This is the case for Idiazabal cheese produced in the Basque Country (northern Spain) that is made exclusively from raw milk of Latxa ewes, and has a PDO label. The milking period of Latxa flocks extends from February (early lactation) to late June (late lactation), and after May flocks are managed under extensive grazing. While most flocks during lactation remain in valley grasslands close to farms, in May some flocks are taken to mountain grasslands. It has been previously reported that differences in botanical composition of grasslands located at different altitude may confer differences in milk composition when produced in these areas (Falchero *et al.*, 2010). According to some studies, milk and cheese produced in mountain areas are richer in n-3 polyunsaturated fatty acids (PUFA) and conjugated linoleic acids (CLA) than those produced in lowland areas (Leiber *et al.*, 2005). In this sense, the objective of the present study was to compare the fatty acid (FA) composition of milk from Latxa ewes reared in valley and mountain grasslands.

II – Materials and methods

For the present study, six commercial flocks of 150-250 Latxa ewes each were selected, three reared in valley and three reared in mountain grasslands. Before sampling, a three week adaptation period was provided to flocks reared on mountain pastures. Tank milk was collected in triplicate and in two different weeks (May and June) during the extensive grazing period at late lactation. Total fat content of milk samples was determined by NIR (ENAC certified method No 174/LE 381; Dairy Institute of Lekunberri, Lekunberri, Spain). For the FA composition, lipids were separated by centrifugation of milk and cream as described in Luna *et al.* (2005), and FA methyl esters (FAME) were prepared using the miniaturized method described in Aldai *et al.* (2012). The FAMEs were analyzed by GC-FID combining the results obtained from a 100 m SP-2560 (175°C and 150°C programs; Kramer *et al.*, 2008) and a 100 m SLB-IL111 column (Delmonte *et al.*, 2011) from Supelco, Bellefonte, PA, USA. For peak identification purposes, individual FAME standards and retention times and elution orders reported in the literature were used (Alves & Bessa, 2009; Cruz-Hernandez *et al.*, 2006; Delmonte *et al.*, 2011; Kramer *et al.*, 2008). Identifications were also confirmed using FAME fractions obtained using Ag⁺-SPE (Belaunzaran *et al.*, 2014; Kramer *et al.*, 2008). SPSS IBM Statistics software version 21 (New York, USA) was used for statistical analysis of variance (ANOVA) according to the following fixed effect linear model: $Y = P + S + F(P) + P*S + \varepsilon$ where P was pasture type (valley, mountain), S was sampling week (May, June), F was the flock factor, and P*S was the interaction term. Three significant figures are used to express the data.

III – Results and discussion

Milk collected from flocks reared in mountain pastures provided a higher fat content (g per 100 g of milk) in comparison to milk collected from flocks reared in valley pastures ($p \leq 0.001$; Table 1).

Regarding the FA profile of the milk, interactions and the effect of the principal factor (pasture type) affecting the composition will be discussed. The interaction was significant for the major FA groups, saturated FAs (SFAs, $p \leq 0.01$) and monounsaturated FAs (MUFA, $p \leq 0.01$), and the minor groups, CLA ($p \leq 0.001$) and non-conjugated dienes (nc-dienes, $p \leq 0.01$; Table 1). The SFA content was significantly higher in milk collected from ewes grazed on valley compared to milk from ewes grazed on mountain pastures. However, the opposite was true for the MUFA content, being higher in mountain milk. A significant interaction was evident for the *trans*-MUFA content where mountain milk provided higher levels of *trans* than valley milk. Interestingly, 11*t*- and 13*t*/14*t*- were the major *trans*-18:1 isomers

Table 1. Fat content (g/100g of milk) and fatty acid composition (g/100g fat) of milk samples from ewes reared in valley and mountain pastures and collected in May and June

	Valley		Mountain		SEM	Significance		
	May	June	May	June		P	S	P*S
Fat	7.43	7.96	8.34	8.55	0.0870	***	*	ns
SFA	62.5	58.7	56.4	55.1	0.381	***	***	**
BCFA	2.73	2.68	2.89	2.86	0.0383	***	ns	ns
MUFA	26.1	29.4	29.6	31.1	0.269	***	***	**
<i>cis</i> -MUFA	20.5	23.2	21.7	23.9	0.268	***	***	ns
<i>trans</i> -MUFA	5.58	6.18	7.95	7.21	0.104	***	ns	***
10 <i>t</i> -18:1	0.389	0.412	0.404	0.380	0.00682	ns	ns	**
11 <i>t</i> -18:1	2.44	2.79	4.39	3.74	0.0851	***	*	***
13 <i>t</i> /14 <i>t</i> -18:1	0.701	0.697	0.754	0.714	0.00890	*	ns	ns
10 <i>t</i> /11 <i>t</i>	0.171	0.152	0.0924	0.103	0.00514	***	ns	*
PUFA	3.32	3.45	4.02	4.22	0.0491	***	*	ns
n-6	2.17	2.25	2.18	2.31	0.0270	ns	*	ns
18:2n-6	1.72	1.70	1.69	1.81	0.0243	ns	ns	*
20:4n-6	0.150	0.171	0.169	0.166	0.00213	*	*	**
n-3	1.15	1.20	1.84	1.91	0.0301	***	ns	ns
18:3n-3	0.816	0.828	1.36	1.43	0.0228	***	ns	ns
22:5n-3	0.147	0.155	0.221	0.229	0.00425	***	ns	ns
n-6/n-3	1.92	1.93	1.19	1.22	0.0376	***	ns	ns
P/S	0.0539	0.0603	0.0722	0.0776	0.00110	***	***	ns
CLA	1.69	2.04	2.81	2.62	0.0561	***	ns	***
9 <i>c</i> ,11 <i>t</i>	1.39	1.68	2.39	2.22	0.0507	***	ns	***
7 <i>t</i> ,9 <i>c</i>	0.0473	0.0558	0.0555	0.0555	0.00102	*	*	*
11 <i>t</i> ,13 <i>c</i>	0.0679	0.0844	0.154	0.131	0.00354	***	ns	***
nc-dienes	1.31	1.45	1.77	1.71	0.0281	***	ns	**
9 <i>c</i> ,13 <i>t</i> -18:2 [†]	0.386	0.421	0.461	0.464	0.00677	***	*	ns
11 <i>t</i> ,15 <i>c</i> -18:2	0.309	0.323	0.547	0.483	0.0129	***	*	***
nc-trienes	0.292	0.274	0.414	0.376	0.0105	***	*	ns
9 <i>c</i> ,11 <i>t</i> ,15 <i>c</i> -18:3	0.155	0.131	0.198	0.155	0.00815	***	***	ns
9 <i>c</i> ,11 <i>t</i> ,15 <i>t</i> -18:3	0.0491	0.0619	0.0830	0.0740	0.00210	***	ns	**

[†] Coelute with 8*t*,12*c*- and other *c*,*t*-18:2. SEM, standard error of the mean; P, pasture type (valley, mountain); S, sampling week (May, June); P*S, interaction term. *, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.001$; ns, not significant ($p > 0.05$). SFA, saturated fatty acids; BCFA, branched-chain fatty acids; MUFA, monounsaturated fatty acids; *c*, *cis*; *t*, *trans*; PUFA, polyunsaturated fatty acids; P/S, PUFA/SFA; CLA, conjugated fatty acids; nc, non-conjugated.

(Figure 1). Expressed as relative percentages, the interaction was significant for most of the isomers except 10*t*- and 15*t*-18:1. Vaccenic acid (VA, 11*t*-18:1) was the only isomer with higher relative percentages in mountain than in valley milk. In this respect, it is well-known the relationship between pasture based diets and the higher content of VA in dairy products (Valdivielso *et al.*, 2015), together with the low 10*t*-/11*t*- ratio (<1 in all cases) which is indicative of no 10*t*-shift (Bessa *et al.*, 2015).

Overall, CLA content was higher in mountain than in valley milk. This is also directly associated with the VA content as ruminic acid (RA, 9*c*,11*t*-18:2), the major CLA isomer, can be synthesized by the activity of $\Delta 9$ -desaturase in the mammary gland (Bauman *et al.*, 1999). Similar to the changes that occur in the *trans*-18:1 profile, 11*t*,13*c*-18:2 was the second most abundant among the CLA isomers, especially in mountain milk. In the nc-diene and triene groups, 11*t*,15*c*-18:2 and 9*c*,11*t*,15*c*-18:3 were the major metabolites, respectively, and they were significantly higher in mountain milk compared to valley milk possibly related to the metabolism of 18:3n-3 (Destailats *et al.*, 2005).

The effect of pasture type was significant ($p \leq 0.001$) for the branched-chain FA, *cis*-MUFA and PUFA content, and also associated ratios (n-6/n-3, P/S). They provided higher values in mountain compared to valley milk except the n-6/n-3 ratio. In general, the results obtained are in good agreement with the unique FA profile reported in alpine milk (Kraft *et al.*, 2003) and studies on the milk and cheese composition of ruminant origin produced in mountain areas (Hauswirth *et al.*, 2004; Leiber *et al.*, 2005).

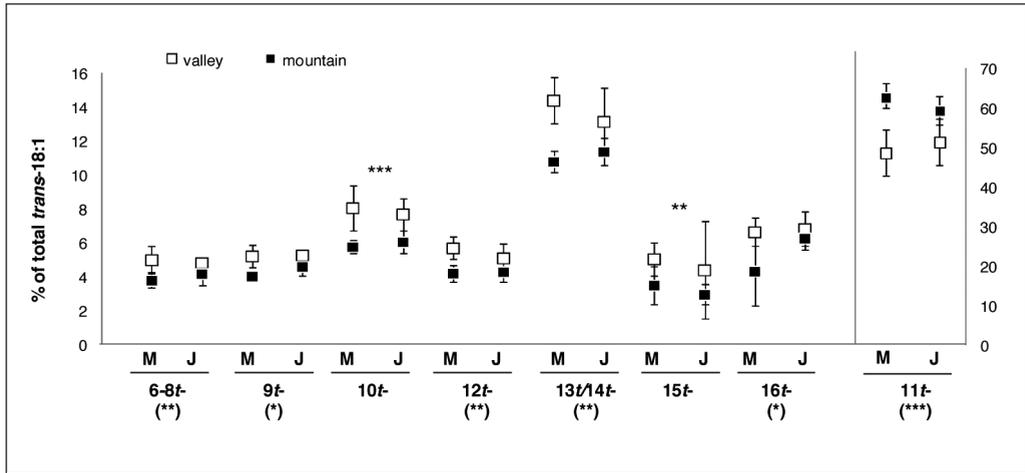


Fig. 1. Relative percentages of individual *trans*-18:1 isomers of milk samples from ewes reared in valley and mountain pastures and collected in May (M) and June (J).

In the graph, vaccenic acid (11*t*-18:1) is depicted on the right Y-axis. The effect of pasture type (valley, mountain) is indicated above the symbols while interaction effect is given in brackets along the X-axis.

*, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.001$.

IV – Conclusions

Milk from ewes reared in mountain pastures provided a higher fat content with a healthier FA profile. Mountain milk had higher P/S but lower n-6/n-3 ratio, and higher content of VA, RA and 11*t*, 13*c*-18:2 in comparison to milk produced in valley pastures. Overall, the milk FA profile was characteristic of the biohydrogenation of linolenic acid. These results could contribute to the added-value of PDO cheeses produced in mountain areas in order to reduce the progressive abandonment of shepherding in these areas.

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Are the specific sensory properties of pasture cheeses linked to milk fat composition and bacterial dynamics?

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Abstract. The aim of this research was to determine the specific influence of milk fat composition on the sensory properties of cheeses derived from cows fed either pasture or a maize silage-based diet. Uncooked pressed Cantal cheeses were manufactured from skimmed milk with an identical chemical and microbial composition and two different pasteurized creams obtained from cows fed either pasture or maize silage. Cheeses produced from the pasture-derived cream were creamier, more elastic, more adhesive, and less firm than cheeses made from the maize silage-derived cream. The rind of pasture-derived cream cheeses was thinner and the relative abundance of *Staphylococcus*, *Brachybacterium* and *Yaniella* were higher than on the rind of the cheeses made with the cream derived from maize silage where *Lactococcus* was relatively abundant. These results confirm the direct role of fat composition, richer in unsaturated FA with low melting point when cows grazed pasture, on the cheese texture and suggest that the milk fat composition could change the microbiota of cheese rind, which in return can explain differences in cheese rind appearance. The flavour and the microbiota of the core of the cheeses made with the different creams were very similar, indicating that the milk fat composition plays a minor role on the flavour development of cheeses. Other diet-dependent aspects of milk biochemical or microbial composition may explain the stronger and more diverse flavour of cheeses that is frequently reported when cows are fed pasture.

Keywords. Pasture – Cheese fat composition – Cheese sensory quality – Cheese bacterial community.

Les propriétés sensorielles particulières des fromages fabriqués à partir de lait de pâturage sont-elles dues à la composition de la matière grasse laitière et la dynamique bactérienne?

Résumé. Les objectifs de ce travail étaient de comprendre l'influence de la composition de la matière grasse laitière sur les propriétés sensorielles de fromages. Des fromages à pâte pressée non cuite de type Cantal ont été fabriqués avec des laits écrémés qui avaient une composition chimique et microbiologique identique mais qui étaient additionnés de crèmes pasteurisées produites soit par des vaches au pâturage, soit nourries avec de l'ensilage de maïs. Les fromages fabriqués avec la crème des vaches au pâturage avaient une texture plus crémeuse, plus élastique, plus adhésive et moins ferme que les fromages fabriqués avec la crème des vaches nourries avec l'ensilage de maïs. La croûte des fromages fabriqués avec une crème issue du pâturage était plus fine et *Staphylococcus*, *Brachybacterium* et *Yaniella* étaient relativement plus abondant que *Lactococcus*. Ces résultats confirment l'effet direct de la composition de la matière grasse du lait, plus riche en acides gras insaturés avec un point de fusion bas lorsque les vaches sont au pâturage, sur la texture des fromages. Ils suggèrent que la composition de la matière grasse est susceptible de modifier le microbiote de la croûte du fromage et serait à l'origine de fromages d'aspect différent. La flaveur et le microbiote des fromages fabriqués avec les deux crèmes étaient très voisins, montrant que la composition de la matière grasse joue un rôle mineur dans le développement de la flaveur des fromages. D'autres aspects de la composition du lait expliquerait la flaveur plus diversifiée et plus forte qui est souvent attribuée aux fromages issus du pâturage.

Mots-clés. Alimentation des animaux – Composition de la matière grasse – Qualité sensorielle – Communauté bactérienne.

I – Introduction

Several studies have been conducted over the last years to understand the effect of animal diet on cheese sensory properties. The effects of forage type (e.g. pasture, hay, grass silage, maize silage) are well-known (Martin *et al.*, 2005). Pasture-derived cheeses have a thinner rind, their colour is yellower, their texture is smoother and their flavour is more diverse and intense compared to maize silage-derived cheeses (Coppa *et al.*, 2011; Coulon *et al.*, 2004). These colour and texture features were attributed in particular to milk fat composition that is affected by animal diet. When cows grazed fresh grass, milk fat is richer in plant pigments (carotenoids) and in unsaturated fatty acids (FA) with a low melting point (Martin *et al.*, 2005). It was suggested that the decrease in fat cohesion of these cheeses could cause a loss of butter-oil on cheese rind, creating a favourable environment for the development of a mould *Sporendonema casei* that gives its typical appearance to Cantal cheeses rind (Coppa *et al.*, 2011; Lerch *et al.*, 2015). The stronger and more diversified flavour of cheeses from pasture is still far from being understood. Current hypothesis is linked (i) to a possible higher oxidation of polyunsaturated FA, (ii) cheese microbiota which is also known to vary according to animal diet (Verdier-Metz *et al.*, 2012); and (iii) to possible interactions between milk fat and microbiota. The aim of this study was to determine the specific influence of milk fat composition on sensory properties of Cantal cheeses, with a focus on the development of cheese microbiota.

II – Materials and methods

Uncooked pressed Cantal cheeses were manufactured from skimmed milk with an identical chemical and microbial composition and two different pasteurized creams obtained from two groups of cows fed either pasture (**P**) or a maize silage-based diet (**M**). The P cows (14 Montbéliarde and 14 Holstein cows) grazed on a mountain grassland in September and were supplemented with 2 kg of concentrate and the M cows (6 Montbéliarde and 6 Holstein cows) were kept indoors and fed a diet composed daily of 15 kg DM of maize silage, 2.5 kg DM of straw and 4 kg of concentrate. Twelve ten-kilogram Cantal cheeses were made during 6 days, using either raw (3 dates of cheesemaking) or pasteurized (3 dates of cheesemaking) P-derived skimmed milk, each added with either P- or M-derived pasteurized cream. The FA composition was analysed by gas-chromatography in milks and in five month-ripened cheeses (rind and core). The total bacterial DNA was extracted from the same samples, and then the variable region V3-V4 of the 16S rRNA gene was amplified prior to meta-barcoding sequencing on an Illumina MiSeq instrument. The sequence data were analysed using FROGS pipeline on Galaxy interface (Escudie *et al.*, 2015). The cheese sensory properties were described by a panel of 10 assessors who gave an intensity score between 0 and 10 for 35 attributes (7 for appearance, 5 for texture, 9 for odour, 9 for aroma, 5 for taste). Data concerning FA composition were processed by Student's t-Test. Sensory data were analysed using a mixed model where the cow diet was the fixed factor, and the assessor was the random factor. A principal component analysis (PCA) was performed on the most abundant bacterial "species" (>0.05% of the total sequences) of cheese rind. The higher Shannon's diversity index, the higher bacterial diversity is important.

III – Results and discussion

Cheeses produced from P cream were creamier, more elastic, more adhesive, and less firm than cheeses made from M cream both added to raw or pasteurised skimmed milk (Table 1). The P cheese cores were richer in unsaturated FA (*cis*-MUFA, *trans*-MUFA, and PUFA), conjugated linoleic acids (CLA), C18:0, and *cis*9-C18:1 and poorer in short- and medium-chain saturated FA (C6:0+C8:0+C10:0 and C12:0+C14:0) and C16:0 (Table 2). These results confirm the direct role of P cream, richer in unsaturated FA with low melting point, on cheese texture (Martin *et al.*, 2005).

The rind of P cheeses was thinner (lower spot salience and quantity) than that of M cheeses (Table 1) and the differences between P and M cheeses were more important in raw than in pasteurised milk. Similar results were obtained by Coppa *et al.* (2011) in a study comparing cheeses made with milk from grass- or hay-based diet. Metagenetic profiling showed that the bacterial balance of rind of raw milk cheeses was also different between cheeses produced from P or M cream (Fig. 1). From 3-month of ripening, the relative abundance of *Lactococcus* (Firmicutes) was higher on the M cheese rind while that of *Staphylococcus* (Firmicutes) and *Brachybacterium* and *Yaniella* (Actinobacteria) was higher on the P cheese rind. The Shannon's diversity index including all the "species" was higher on P cheese rind (1.319) than on M cheese rind (1.167). These results suggest that the milk fat composition could change the bacterial balance of cheese rind ecosystem, which in return may explain differences in cheese rind appearance.

Table 1. Sensory properties of Cantal cheese made with a same skimmed milk (raw or pasteurized) and pasteurized cream issued from cows fed pasture or a maize silage based diet

Parameters	Raw				Pasteurized			
	Pasture	Maize	SEM	p value	Pasture	Maize	SEM	p value
Texture (score 0-10)								
firm	5.25	6.59	0.215	<0.001	5.61	6.79	0.193	<0.001
elastic	3.98	3.04	0.232	0.002	4.09	3.12	0.245	<0.001
creamy	4.96	3.84	0.256	0.021	4.95	3.30	0.259	<0.001
adhesive	4.20	3.41	0.251	0.055	4.02	2.83	0.250	0.009
Appearance of cheese (score 0-10)								
spot salience	6.24	7.26	0.191	0.002	3.92	4.25	0.262	0.502
spot quantity	7.12	7.94	0.158	0.006	4.59	5.11	0.271	0.341

Table 2. Fatty acid composition of the core and the rind of cheese made with a same raw skimmed milk and pasteurized cream issued from cows fed pasture or a maize silage based diet

Fatty acids (g/100gFA)	Core			Rind		
	Pasture	Maize	p value	Pasture	Maize	p value
C6:0+C8:0+C10:0	4.93 ± 0.06	5.67 ± 0.17	0.002	3.75 ± 0.15	4.57 ± 0.55	0.067
C12:0+C14:0	11.6 ± 0.19	13.9 ± 0.30	<0.001	10.0 ± 90.27	13.3 ± 0.16	<0.001
C16:0	24.2 ± 0.48	34.0 ± 0.98	<0.001	26.8 ± 0.60	37.0 ± 2.69	0.003
<i>cis</i> 9-C18:1	22.5 ± 0.44	19.1 ± 1.03	0.006	21.0 ± 0.49	17.9 ± 1.68	0.037
Σ CLA	2.25 ± 0.11	0.69 ± 0.06	<0.001	1.86 ± 0.08	0.60 ± 0.06	<0.001
Σ SFA	60.2 ± 0.24	69.1 ± 1.06	<0.001	62.1 ± 0.30	70.6 ± 1.95	0.002
Σ <i>cis</i> -MUFA	27.1 ± 0.35	24.6 ± 1.06	0.018	24.9 ± 0.51	22.5 ± 2.08	0.127
Σ <i>trans</i> -MUFA	5.30 ± 0.15	2.08 ± 0.07	<0.001	5.72 ± 0.23	2.20 ± 0.08	<0.001
Σ PUFA	5.86 ± 0.04	3.31 ± 0.05	<0.001	5.91 ± 0.04	3.78 ± 0.15	<0.001
<i>cis</i> 9-C18:1/C16:0	0.93 ± 0.04	0.56 ± 0.05	<0.001	0.78 ± 0.04	0.49 ± 0.08	0.004

Mean values (± standard deviation; n = 3); FA: fatty acids; CLA: conjugated linoleic acids; SFA: saturated FA, PUFA: poly-unsaturated FA; LCPUFA: long-chain PUFA; MUFA: mono-unsaturated FA.

The flavour of P and M cheeses was very similar (results not shown) both in raw and pasteurised skimmed milk cheeses while previous results (Martin *et al.*, 2005) reported that pasture-derived cheeses have a more intense and diversified flavour by comparison to maize silage cheeses. This discrepancy may link to the fact that in the present study, only the cream composition changed, whereas skimmed milk biochemical and microbial composition remained the same between the

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The interest of a mountain dairy cow breed to cope with Mediterranean summer heat stress

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Abstract. The Tarentaise cow, a rustic breed from the norther part of the French Alps, is well adapted to the mountain harsh conditions, in particular during the summer season due to its ability to use efficiently the highland pastures. The Tunisian farmers also consider that the Tarentaise cows are well adapted to the Mediterranean climate. The aim of this work was to quantify the effect of summer heat stress on milk yield and quality of Tarentaise cows in comparison to Holstein cows. A dataset was collected for 441 Tarentaise and 560 Holstein cows reared in 21 farms in Tunisia from 2009 to 2014. This data comprising 16,400 monthly individual records of milk yield, fat, protein, urea and somatic cell count was merged with meteorological data from 5 public stations relative to the 21 farms. The temperature-humidity index (THI) calculated as a combination of ambient temperature (Ta) and relative humidity (RH) was used to characterize heat stress. Tarentaise and Holstein cows produced 11.4 and 14.8 kg/d of milk respectively. When THI increased from an average value of 53.7 in winter to 75.4 in summer, the Holstein and Tarentaise cows decreased their production by 0.93 and 0.15 kg/d respectively. Milk fat, protein and urea content decreased similarly in both breeds (-0.22 g/kg, -0.14 g/kg and -14 mg/L respectively) and milk somatic cell count increased for Holstein cows (+352,000 /mL) while it decreased slightly for Tarentaise cows (-160,000 /mL). The Tarentaise cows seem to be more resistant to heat stress than Holstein cows, especially when THI is over 78.

Keywords. Tarentaise cow – Heat stress – Temperature-humidity index – Milk yield – Milk composition.

L'intérêt d'une race bovine laitière de montagne pour faire face aux conditions de stress thermique méditerranéen

Résumé. La race Tarentaise, originaire des Alpes françaises, est particulièrement adaptée aux conditions montagneuses, précisément pendant la saison estivale. Cette race rustique est aussi appréciée des éleveurs tunisiens qui la considèrent comme bien adaptée au climat méditerranéen. L'objectif de cette étude était de quantifier l'effet du stress thermique sur les performances de production de la race Tarentaise en comparaison avec la race Holstein. Une base de données contenant 16 400 contrôles laitiers individuels de 441 Tarentaise et 560 Holstein élevées dans 21 exploitations en Tunisie, a été collectée entre 2009 et 2014 puis fusionnée avec les données météorologiques de 5 stations publiques. A partir des températures ambiantes et des humidités relatives, un index humidité-température (THI) a été calculé afin de comparer entre les deux races son effet sur la production laitière, le taux butyreux (TB), le taux protéique (TP), l'urée et le comptage des cellules somatiques (CCS). Les vaches Tarentaise et Holstein ont produit respectivement 11,4 et 14,8 kg/j de lait. Quand le THI passe d'une valeur moyenne de 53,7 en hiver à 75,4 en été, la production laitière de la Holstein et la Tarentaise baissent respectivement de 0,93 et 0,15 kg/j. Le TB, le TP et l'urée ont aussi chuté pour les deux races (-0,22 g/kg, -0,14 g/kg et -14 mg/L, respectivement) alors que le CCS a augmenté pour les Holstein (+352 000 /mL) et a baissé légèrement pour les Tarentaise (-160 000 /mL). La Tarentaise semble mieux résister au stress thermique que la Holstein, notamment quand le THI est supérieur à 78.

Mots-clés. Vache Tarentaise – Stress thermique – Index température-humidité – Production laitière – Composition du lait.

I – Introduction

High temperatures associated with elevated relative humidity are the principal origin of heat stress. This may prompt physiological dysfunction that negatively affects animal's production capacity. A temperature-humidity index (THI) was established to allow modeling the impact of heat stress on production traits of dairy cattle (Johnson, 1985). According to Johnson (1985) and Du Preez *et al.* (1990), the milk production is not affected when the THI is between 35 and 72. Moreover, under Mediterranean climatic conditions of Tunisia, Bouraoui *et al.* (2002) reported that milk yield began to decline when THI reached 68; and as the THI values increased from 68 to 78 during the summer period, heat stress reduced daily cow's milk yield by 21%. Some observations (Nickerson, 1987; Du Preez *et al.*, 1990) have suggested that heat stress is often associated with changes in milk composition and milk somatic cell count (SCC). On the other hand, the effect of heat stress is increased for high producing cows, as Holstein cows. According to Smith *et al.* (2013), selecting most suitable cattle for heat stress tolerance can be reached by discovering differences between dairy breeds. In Tunisia, Tarentaise cow, a mountain breed originating from the French Alps, was imported to achieve self-sufficiency in meat and milk. Dairy producers consider that Tarentaise cows are well suited to the Mediterranean climate of Tunisia. The aim of the present study is to compare the milk yield and composition of Tarentaise and Holstein cows under the climatic conditions of Tunisia.

II – Materials and methods

A dataset, provided by the genetic improvement direction of Sidi Thabet (Tunisia), contained individual data of 441 Tarentaise and 560 Holstein cows from 21 farms, obtained monthly between 2009 and 2014. This dataset included 16,400 individual records of milk yield, fat, protein, urea and somatic cell count. A meteorological dataset comprising monthly records of ambient temperature (T_a , in °C) and relative humidity (RH, in %) was obtained from 5 public weather stations in Tunisia, relative to the 21 herds over the five years. The THI index was calculated using equation as follows: $THI = 1.8 \times T_a - [1 - RH] \times [T_a - 14.3] + 32$ (Kibler 1964).

The THI was merged with production traits by assigning each dairy control of each farmer to the monthly weather records from the nearest weather station. Dairy cows were considered under hot climatic condition when THI is over 72. Later, Silanikove's (2000) classification of THI was used where heat stress is categorized as: without effect, light, moderate and extreme. The corresponding THI thresholds were: $THI < 70$, $70 \leq THI < 75$, $75 \leq THI < 78$ and $THI \geq 78$. The aim of this classification was to have a better visualisation of the effect of heat stress on production traits of Tarentaise and Holstein cows. Days in milk classes (DIM) were established according to the following thresholds: <120, 120-179, 180-300, and >300. Additionally, parity of all cows was classified into 4 ranges corresponding to the rank of lactation: first, second, third and "four and more".

The final data were analysed using Proc Mixed of SAS (version 9.4; SAS Institute, 2013). The effects of heat stress, breed and the interaction (THI × breed) on milk yield, milk components and SCC (expressed in \log_{10}/mL) were tested using the following model: $Y_{ijklmn} = \mu + t_i + b_j + tb_{ij} + f_k + d_l + p_m + c(f)_n + e_{ijklmn}$ where Y_{ijklmn} is a measurement of milk yield, fat, protein, urea or SCC; μ is the population mean; t is the fixed effect for numeral THI (or in classes for the second milk yield analyse) i ; b is the fixed effect for breed j ; tb is the interaction THI × breed ij ; f is the fixed effect for farmer k ; d is the fixed effect for DIM class l ; p is the fixed effect for parity class m ; $c(f)$ is the random effect for cow nested within the farmer (f) n ; and e_{ijklmn} is the residual error.

III – Results and discussion

The milk traits of both breeds were significantly affected by heat stress (Table 1). As expected, the average milk yield was higher for Holstein than for Tarentaise cows (+3.4 kg/d, $P < 0.001$). Moreover,

there is a significant interaction between THI and breed for milk yield. As THI increased from 53.7 in winter (mean value of the coolest months where $T_a = 11.8^\circ\text{C}$ and $\text{RH} = 76\%$) to 75.4 in summer ($T_a = 27.0^\circ\text{C}$ and $\text{RH} = 59.8\%$), Holstein milk yield decreased by 0.93 kg/d (-6%) while Tarentaise milk yield decreased by 0.15 kg/d (-1%). The decline in milk yield under heat stress conditions was also highlighted in earlier studies, confirming that exposure of dairy cows to high values of THI causes a reduction in milk yield from 10 to 34% (Du Preez *et al.*, 1990; Itoh *et al.*, 1998). Smith *et al.* (2013) found that when THI exceeds 72, Holstein milk yield decreased from 35.6 to 34.2 kg/d (-3.9%).

Table 1. Effects of breed and temperature-humidity index (THI) on milk yield and milk composition

	Holstein	Tarentaise	THI	Breed	THI × breed
Milk yield (kg/d)	14.8	11.4	***	***	***
Fat (g/kg)	38.2	37.2	***	NS	NS
Protein (g/kg)	31.8	32.6	***	NS	NS
Urea (mg/L)	212	213	***	NS	NS
SCC (\log_{10}/mL)	5.47	5.42	NS	***	***

NS (non-significant) $P > 0.05$; *** $P < 0.001$.

The effect of heat stress on milk yield is not linear but it increases with high THI (Silanikove, 2000; Smith *et al.*, 2013). The 4 ranges Silanikove's classification gave an appropriate visualisation of the non-linear effect of THI (Fig. 1). The decline in milk yield for the Holstein cows started as THI changed from 'without effect' range to 'light' range. Moreover, this decline in milk yield was more rapid for Holstein cows than Tarentaise between the ranges 'moderate' and 'extreme' (-0.82 vs. -0.13 kg/d).

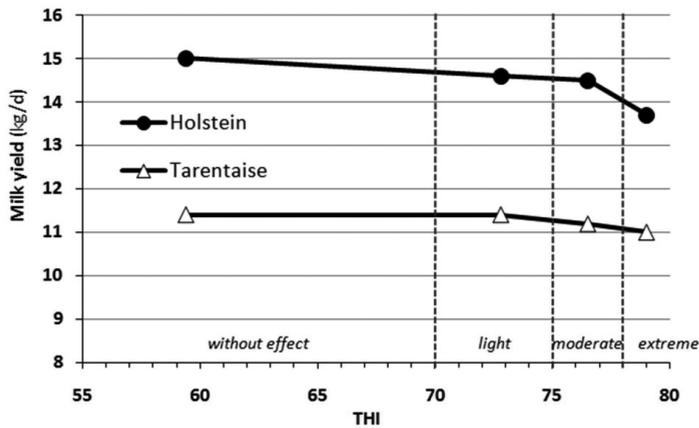


Fig. 1. Average milk yield by breed and Silanikove's ranges of temperature-humidity index (THI).

There was no difference between the two breeds regarding the milk composition. However, THI affected milk fat, protein and urea contents in both Holstein and Tarentaise cows (Table 1). Temperature-humidity index decreased milk fat content (-0.22 g/kg), which agrees with the reduction from 3.79 to 3.65% when THI rose from 65.6 to 83.9 in summer (Rejeb Bellil, 2014). Conversely, other studies carried on Holstein cows reported that heat stress either increased ($\text{THI} > 68$; Bouraoui

et al., 2002) or did not have an effect on milk fat (THI>72.4; Wheelock *et al.*, 2010). Milk protein percentage also decreased with THI (-0.14 g/kg) between winter and summer. These results are in agreement with those reported by Barash *et al.* (2001). In addition, concentration of urea in milk decreased by 14 mg/L between winter and summer season. However, Hojman *et al.* (2004) reported higher milk urea concentration during the summer months and a lowest concentration in November (181 vs.118 mg/L). These authors suggested that it was probably due to changes in the nutritional content of the cow's diet.

The SCC of the milk reflected the interaction between breed and THI (P<0.001). On average, Holstein had higher SCC than Tarentaise cows (P<0.001). During heat stress, the SCC from Holstein cows increased by 352,000 /mL while the SCC from Tarentaise cows decreased by 160,000 /mL. This result is counter to the common idea that elevated THI is often associated with greater SCC. Hammami *et al.* (2013) explained the higher SCC in milk observed in heat stress by the depressive immune function during the hot season.

IV – Conclusions

According to the current results, heat stress decreased milk yield and induced changes in milk composition for both breeds. However, Tarentaise cows seem to be more resistant than Holstein cows, especially when THI is over 78 as very often in the summer climatic conditions of Tunisia. The next step of this study is to quantify the metabolic and physiologic responses of Tarentaise cows under heat stress conditions.

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Grazing behaviour and body-weight gains of steers grazing at Cantabrian mountain pastures

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Abstract. Steer meat is highly appreciated but its production in northern Spain is deficient to attend the meat consumers' demand. Yearling steers could be managed in summer pastures of Cantabrian Mountains to obtain a valued product utilizing natural resources. The objective of this work was to compare the grazing behaviour and productive performance of two local breeds of yearling steers, Asturiana de los Valles (AV) and Asturiana de la Montaña (AM), grazing in mountain pastures consisting in 70% grassland and 30% heathland with broom scrublands. Body weight (BW) changes from a total of 42 steers (half of each breed) were recorded during four grazing seasons (from June to October). In two years, plant community selection and grazing times were recorded in July and September by visual monitoring during daylight hours. Results indicated that grazing time increased from July to September (488 vs. 557 min/day; $P < 0.001$) as sward height in the grassland decreased. AM steers grazed for more proportional time in heathlands and less in grasslands than AV steers (21.5 vs. 12.5%; $P < 0.01$). No differences between breeds were observed in the utilization of other plant communities. Steers from both breeds rejected browsing on brooms. In general, AM steers showed greater mean BW gains than AV steers (332 vs. 199 g/day; $P < 0.05$). AM steers seem to be better suited than AV steers to these mountain pastures, supporting previous evidence on the better performances achieved by smaller breeds under less favoured conditions.

Keywords. Grazing behaviour – Steers – Gains – Breeds.

Comportement de pâturage et gains de poids corporel de bouvillons pâturant dans les Montagnes Cantabriques

Résumé. La viande de bouvillons est fortement appréciée mais sa production dans le nord de l'Espagne ne suffit pas à répondre à la demande des consommateurs. Des bouvillons d'un an ont été conduits en pâturages d'été dans les Montagnes Cantabriques pour obtenir un produit de valeur en utilisant les ressources naturelles. L'objectif de ce travail était de comparer le comportement de pâturage et les performances productives de bouvillons d'un an de deux races locales, Asturiana de los Valles (AV) et Asturiana de la Montaña (AM), pâturant des alpages consistant à 70% de prairie d'herbe et à 30% de broussailles de bruyères et genêts. Les changements de poids corporel (BW) d'un total de 42 bouvillons (la moitié de chaque race) ont été notés durant quatre saisons de pâturage (de juin à octobre). Sur deux ans, la sélection de communautés de plantes et les temps de pâturage ont été notés en juillet et septembre par suivi visuel pendant les heures de jour. Les résultats indiquent que le temps de pâturage a augmenté de juillet à septembre (488 vs. 557 min/jour; $P < 0,001$) à mesure que diminuait la hauteur dans la prairie d'herbe. Les bouvillons AM ont pâture pendant un temps plus proportionnel dans les bruyères et moins dans les prairies d'herbe que les bouvillons AV (21,5 vs. 12,5%; $P < 0,01$). Aucune différence entre races n'a été observée concernant l'utilisation d'autres communautés de plantes. Les bouvillons des deux races ont refusé de brouter les genêts. En général, les bouvillons AM ont montré un GMQ plus élevé que les bouvillons AV (332 vs. 199 g/jour; $P < 0,05$). Les bouvillons AM semblaient être mieux adaptés que les bouvillons AV à ces pâturages de montagnes, allant dans le sens des résultats précédents qui montraient de meilleures performances des races plus petites sous conditions moins favorables.

Mots-clés. Comportement de pâturage – Bouvillons – Gains – Races.

I – Introduction

Steer meat is a quality product that is highly demanded by consumers, although its production in the North of Spain is deficient. Meat production is mostly focused on beef from young or yearling calves. Extensive steer meat production could be economically sustainable because of lower production costs and reduced reliance on food purchased outside the farm. Furthermore, this kind of system may promote a better use of pastures, which is important from an environmental point of view.

The typical beef cattle management system in Asturias (northern Spain) is the valley-mountain system. On this system, animals graze in common high mountain pastures during the summer, from May-June to September-October. In spring and autumn animals are grazing in lowland pastures and they are housed to pass the winter. This system promotes a more efficient use of grazing resources. In Asturias, the two local cattle breeds are Asturiana de los Valles (AV) and Asturiana de la Montaña (AM). Despite the confusing names of their origin (valleys and mountains, respectively), AV is the most abundant cattle breed throughout the region, whereas AM, with a smaller body size, is declared endangered and is mostly restricted to the mountain areas of eastern Asturias.

The objective of this work was to compare the productive performance (body weight changes) and grazing behaviour (plant community selection) of yearling steers from AV and AM breeds, grazing during summer in mountain pastures consisting in 70% grassland and 30% heathland with broom scrublands.

II – Materials and methods

1. Study site and experimental animals

The study was conducted during four years (2011 to 2014) in Puertos de Agüeria, Quirós, Asturias. The vegetation of the experimental field (33 ha, 1600-1750 m a.s.l.) consisted of 70% grasslands (mostly *Festuca rubra-Agrostis capillaris-Nardus stricta*) and 30% *Calluna vulgaris* heathland interspersed with broom (*Genista florida*) scrublands. Other minor plant communities were also present, such as *Carex* spp. fens, calcareous rocky pastures, furze (*Genista occidentalis*) shrublands, and barberry (*Berberis vulgaris*) formations.

A total of 42 yearling steers, half of AV breed and half of AM breed, born during winter-spring between 2010 and 2013 were utilized. As suckling calves, they stayed with their mothers at the experimental site in the preceding summer. Calves were weaned when returned to lowlands with 7-10 months of age, and when they were one year old, they were castrated by surgical removal of the testicles. Grazing season at the summer pasture extended from mid June to late September or early October.

2. Measurements

Animals were weighed at the beginning, middle (August) and at the end of the grazing season. Body weight (BW) changes were calculated for the different periods. In two years (2013 and 2014), grazing times at each plant community were recorded in July and September by visual observations every 15 minutes during daylight hours in two consecutive days. The availability of preferred pasture was assessed by monthly measuring the sward height in the grassland areas using a sward stick.

3. Statistical analysis

We used factorial ANOVA to analyse individual animal performance (BW changes), examining the fixed effects of breed, year and their interaction. Grazing behaviour data were analyzed by repeated measures ANOVA, examining the effects of breed, year, season (two repeated measures at July and September) and their interactions.

III – Results and discussion

Both breeds were grazing for a similar time, but we observed that time increased from July to September (from 488 to 557 min/day; $P<0.001$; Fig. 1) while grass availability decreased (from 6.85 to 3.09 cm in 2013; from 5.36 to 3.64 cm in 2014). In 2013 steers spent more time grazing than in 2014 (547 vs. 498 min/day; $P<0.05$).

AV steers grazed for more proportional time on herbaceous pastures (and less on shrublands) than AM steers (81.3 vs. 73.3%; $P<0.05$). *Festuca-Agrostis* grasslands were utilized at a higher rate by AV steers than by AM steers (75.4 vs. 66.8%; $P<0.05$). There were no differences between breeds in the times spent grazing on other herbaceous communities. Both fens and rocky pastures in general were more utilized in July than in September (9.2 vs. 3.6%; $P<0.01$; Fig. 1), although there were season \times year interactions ($P<0.01$). Regarding shrubby communities, AM steers grazed for longer on heathlands than AV steers (21.5 vs. 12.5%; $P<0.01$). Higher grazing times on heathlands were observed in 2013 than in 2014 (21.5 vs. 12.5%; $P<0.01$). In general, both breeds increased the time grazing on heathlands as summer progressed, except in the case of AM steers in 2013, resulting in a triple interaction breed \times year \times season ($P<0.05$). There were no differences between breeds in the time grazing on broom scrublands, but it was superior in 2014 than in 2013 (6.3 vs. 3.4%; $P<0.05$). Remarkably, although steers grazed a mean percentage time of 4.9% on these scrublands, no observation was recorded on steers browsing the small-leaved shoots of brooms; instead they grazed below on the herbaceous or dwarf-shrub layer. It has been observed in previous studies that cattle usually reject browsing on these woody legumes, unlike sheep, which browse on them intensely (Osoro *et al.*, 2000). Other shrubby communities were scarcely utilized, around 1% of the grazing time in September.

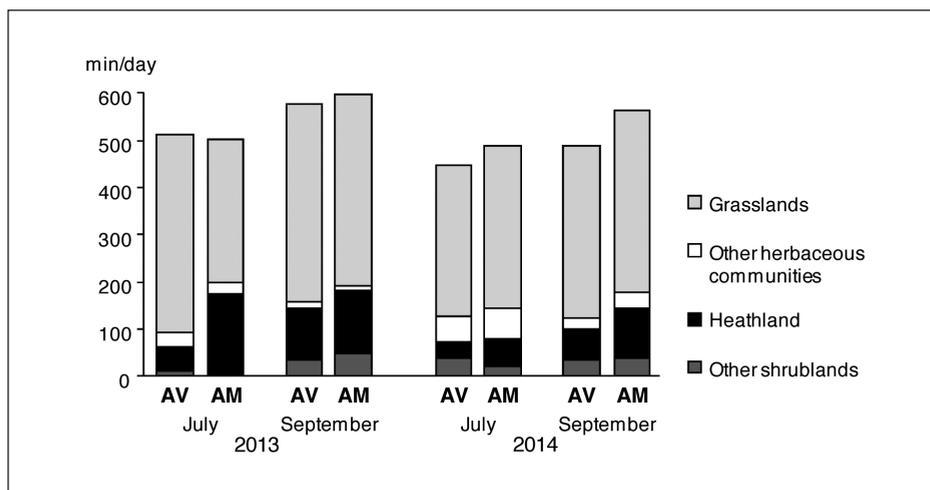


Fig. 1. Grazing times on each plant community by Asturiana de los Valles (AV) and Asturiana de la Montaña (AM) steers at Cantabrian mountain pastures.

Regarding animal performance, during the first half of the grazing season (from June to August) AM steers gained more BW than AV steers (487 vs. 360 g/day; $P<0.01$). From August to October, when grassland herbage availability and its nutritive quality was reduced, AV steers lost BW on average, whereas AM steers continued gaining BW, although less than in the former period (Table 1). During the whole grazing season, AM steers achieved higher BW gains than AV steers (332 vs. 199

g/day; $P < 0.01$). In a previous study in similar conditions, no differences between these breeds were found in the BW changes of cows and calves (Osoro *et al.*, 1999). There were also differences in BW gains between years, particularly during the second half of the grazing season ($P < 0.001$). The maximum mean BW gain during the whole grazing season was observed in 2012 (408 g/day), while in 2013 steers only gained 109 g/day. It could be related to weather conditions and grass availability. The interaction breed \times year was not significant in any period. When animals are grazing on high mountains usually present low BW gains due to several causes, such as the low nutritive quality of available pastures and adverse weather conditions, among others (Casasús *et al.*, 2002). Animals have higher energy costs because they have to move through a more difficult terrain. It is important to underline that, despite the lower gains achieved in mountain pastures, these steers showed a compensatory growth relative to those managed in lowlands, once they grazed on quality pastures during autumn (Román-Trufero *et al.*, 2015).

Table 1. Body weight (BW) changes of steers from Asturiana de los Valles (AV) and Asturiana de la Montaña (AM) breeds grazing at Cantabrian mountain pastures during summer (least squares means of four years)

	Breed			Significance		
	AV	AM	SEM	Breed (B)	Year (Y)	B \times Y
Initial BW (kg)	371	300	9.3	***	NS	NS
BW change (g/day)						
From June to August	360	487	31.9	**	**	NS
From August to October	-12	120	45.5	*	***	NS
Overall	199	332	27.3	**	***	

NSSEM: standard error of the mean; NS: non-significant ($P > 0.1$); * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

IV – Conclusions

AM steers are better suited than AV steers to mountain conditions. Smaller breeds have a better performance under less favoured conditions. AM animals are more adapted to graze on heathlands and on pastures with a minor nutritive quality.

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Performance of two local beef cattle breeds in Cantabrian mountain pastures

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Abstract. In Cantabrian Mountains (N Spain), summer pastures are mostly utilized for beef cattle production. This work aimed to study cow and calf performance of two local breeds, Asturiana de los Valles (AV) and Asturiana de la Montaña (AM), grazing at different pasture mixtures from June to October. Data were recorded from 1995 to 2013 in a high mountain area, which was divided in two plots of 30 ha each: one with 70% grassland and 30% *Calluna*-heathland cover (C30), and another with 30% grassland and 70% heathland cover (C70). The effects of vegetation cover, breed, physiological status and their interactions on body weight (BW) and body condition score (BCS) changes were analysed. In general, AV cows showed worse ($P<0.001$) BW and BCS changes than AM cows (-81 vs. 18 g/day; -0.16 vs. 0.03 BCS units). In C30, cows gained 80 g/day and maintained BCS (0.00), whereas in C70 cows lost 143 g/day and 0.14 BCS points. An interaction ($P<0.01$) between breed and vegetation cover indicated that the differences between breeds mostly occurred in C70 plot. Lactating cows lost BW and BCS, whereas non-lactating cows used to gain BW and BCS (-253 vs. 190 g/day; -0.22 vs. 0.09 BCS units; $P<0.001$). Regarding calf growth, no differences were found between breeds in spite of the greater mature BW size in AV breed, while greater BW gains were observed in C30 than in C70 (769 vs. 557 g/day; $P<0.001$). Cattle from AM breed present a better adaptation to high mountain conditions, particularly when the availability of quality pasture is limiting.

Keywords. Suckler cows – Autochthonous breed – Vegetation cover – Body weight.

Performances de deux races locales de bovins à viande dans les pâturages des Montagnes Cantabriques

Résumé. Dans les Montagnes Cantabriques (Nord de l'Espagne), les pâturages d'été sont surtout utilisés pour la production de bovins à viande. Ce travail visait à étudier les performances des vaches et veaux de deux races locales, Asturiana de los Valles (AV) et Asturiana de la Montaña (AM), pâturant différentes prairies mélangées de juin à octobre. Les données ont été notées de 1995 à 2013 dans une zone de haute montagne, qui était divisée en deux parcelles de 30 ha chacune: une avec couvert à 70% de prairie d'herbe et 30% de bruyères *Calluna* (C30), et l'autre avec un couvert à 30% de prairie d'herbe et 70% de bruyères (C70). Les effets de couvert végétal, race, état physiologique et de leurs interactions sur les changements de poids corporel (BW) et de note d'état corporel (body condition score, BCS) ont été analysés. En général, les vaches AV ont montré de moins bons changements ($P<0,001$) de BW et de BCS que les vaches AM (-81 vs. 18 g/jour; -0,16 vs. 0,03 point de BCS). Sur C30, les vaches ont gagné 80 g/jour et le BCS s'est maintenu (0,00), tandis que sur C70 les vaches ont perdu 143 g/jour et 0,14 point de BCS. Une interaction ($P<0,01$) entre la race et le couvert végétal indiquait que les différences entre races se produisaient principalement dans la parcelle C70. Les vaches allaitantes ont perdu en BW et BCS, tandis que les vaches non allaitantes ont en général gagné en BW et BCS (-253 vs. 190 g/jour; -0,22 vs. 0,09 point de BCS; $P<0,001$). Concernant la croissance des veaux, aucune différence ne fut rencontrée entre races malgré la plus grande taille à poids corporel adulte chez la race AV, tandis qu'un GMQ supérieur fut observé pour C30 par rapport à C70 (769 vs. 557 g/jour; $P<0,001$). Les bovins de race AM présentaient une meilleure adaptation aux conditions de haute montagne, en particulier lorsque la disponibilité de pâturage de qualité était limitante.

Mots-clés. Vaches allaitantes – Race autochtone – Couvert de végétation – Poids corporel.

I – Introduction

Beef cattle breeds may differ in their body size, nutrient requirements, grazing behaviour, etc., so they can show different productive responses under particular vegetation conditions. As well, physiological state and derived energy demands will also affect body reserves and animal performance (Osoro *et al.*, 1998, 1999). Regarding the offspring, different growth potential and dams' milk yield may lead to differences between breeds in calf performance when raised on mountain pastures (Casasús *et al.*, 2002). In Asturias, there are two local beef cattle breeds, Asturiana de los Valles (AV) and Asturiana de la Montaña (AM), which use to graze on mountain pastures during summer. In a typical valley-mountain management system (short-haul transhumance), cows calve in late winter, and after using lowland pastures during spring and being mated, they are moved in June to summer mountain pastures where they nurse their calves. When they are downloaded from the mountain, calves are usually weaned to be sold on traditional fairs.

The objective of this work was to study the productive performance of beef cattle (body weight and body condition score changes of lactating cows and their calves and non-lactating cows), comparing the two local breeds, AV and AM, when they graze on summer mountain pastures with different vegetation cover (grassland/heathland ratio).

II – Materials and methods

1. Study site and experimental animals

The study was carried out in Puertos de Agüeria (1600-1800 m a.s.l.), located in the nature park of Las Ubiñas-La Mesa (Quirós, Asturias, N Spain). The experimental field was divided in two plots of ~30 ha each, one with 70% *Festuca-Agrostis* grassland and 30% *Calluna* heathland cover (C30), and another with 30% grassland and 70% heathland cover (C70). We studied the performance of two local cattle breeds, AV and AM, grazing in mountain pastures during the summer (from mid June to late September or early October). Data were collected from 14 years (1995-1997, 1999-2003, 2008-2013), totalling 684 cows (381 AV, 303 AM).

Calving took place during winter to early spring. At the experimental site, two thirds of the cows were lactating their calves, and one third were non-lactating cows, being almost all pregnant. Managed stocking rates ranged from 0.6 to 1.1 cows/ha across years (mean \pm SE: 0.81 ± 0.03 in C30; 0.79 ± 0.04 in C70).

Animals were weighed at the beginning and at the end of the summer grazing season. At the same time, body condition score (BCS) of cows was evaluated in a scale of 1 to 5 according to Lowman *et al.* (1976) criteria. Body weight (BW) and BCS changes were calculated for the grazing season.

2. Statistical analysis

Animal performance data were analysed using factorial ANOVA. We examined the effects of year (Y), breed (B), vegetation cover (V), physiological state (P) and their interactions on cows' BW and BCS changes. As data were unbalanced across years, the 3-way interaction Y×B×P and the 4-way interaction were not included in the model. To analyse calves' BW gains, we used factorial ANOVA including the effects of Y, B, V and their interactions. Tukey's test was used for comparison of means.

III – Results and discussion

There were great differences among the 14 years examined ($P < 0.001$) in the BW and BCS changes experienced by cows, ranging from a minimum of -380 g/day in 2001 to a maximum of 182 g/day in

2009. This was due to the great differences among years in climatic conditions and available good quality pasture. In general, AV cows lost more BW than AM cows (-81 vs. 18 g/day; $P < 0.001$; Table 1). Animals from AM breed are smaller and more rustic than those from AV (Osoro *et al.*, 1999), so AM breed would be better suited to these harsh conditions. There was a year \times breed interaction ($P < 0.001$), because during the first experimental years (1995 and 1996) AM cows lost more BW than AV cows, while in the rest of years AV cows showed less favourable BW changes than AM cows. Regarding vegetation cover, cows grazing at C30 plot lost less BW than those grazing at C70 (80 vs. -143 g/day; $P < 0.001$). The C30 plot was dominated (70%) by *Festuca-Agrostis* grassland, which has a better nutritive quality than heathland (Hodgson *et al.*, 1991), which is the community that dominates the C70 plot. There was an interaction year \times vegetation cover ($P < 0.001$) as the differences between plots varied among years depending on the available pasture. There was an interaction breed \times vegetation cover ($P < 0.01$); on average, differences between breeds in BW change were small at C30 (60 vs. 101 g/day in AV and AM, respectively; $P = 0.17$), but greater differences in favour of AM were observed at C70 (-221 vs. -65 g/day in AV and AM, respectively; $P < 0.001$; Table 1). This genotype \times environment interaction has been observed in other works, with smaller genotypes thriving better under unfavourable conditions of available forage because of their lower absolute nutrient requirements compared to larger genotypes (Fitzugh, 1978; Wright *et al.*, 1994; Osoro *et al.*, 1999).

Studying the effect of physiological status, on average lactating cows lost BW, whereas non-lactating cows gained BW (-253 vs. 190 g/day; $P < 0.001$) because of the greater energy demand for milk production. Besides an interaction year \times physiological state ($P < 0.05$), there was an interaction vegetation cover \times physiological state ($P < 0.05$) as greater differences between lactating states were observed at C70 (C30: -116 vs. 277 g/day; C70: -390 vs. 104 g/day in lactating and non-lactating cows, respectively; Table 1).

Table 1. Body weight (BW) and body condition score (BCS) changes in lactating (L) and non-lactating (NL) cows from Asturiana de los Valles (AV) and Asturiana de la Montaña (AM) breeds grazing during summer at Cantabrian mountain pastures with different vegetation cover (C30: 70% grassland, 30% *Calluna* heathland; C70: 30% grassland, 70% *Calluna* heathland)

Vegetation cover	C30				C70				Significance						
	AV		AM		AV		AM		SEM	B†	V††	P†††	B×V	B×P	V×P
Breed	L	NL	L	NL	L	NL	L	NL							
Physiological status	L	NL	L	NL	L	NL	L	NL	SEM	B†	V††	P†††	B×V	B×P	V×P
Initial BW (kg)	523	535	430	433	520	532	429	428	10.7	***	NS	NS	NS	NS	NS
BW change (g/day)	-129	248	-103	305	-468	26	-311	181	43.0	***	***	***	*	NS	*
Initial BCS	2.64	2.99	2.73	2.99	2.69	3.03	2.72	3.16	0.06	*	*	***	NS	NS	NS
BCS change	-0.13	-0.07	-0.16	0.37	-0.32	-0.14	-0.28	0.20	0.06	***	***	***	NS	***	NS

† Breed; †† Vegetation cover; ††† Physiological status. Effects of year and its interactions are not shown. All 3-way interactions were non-significant. SEM: standar error of the mean; NS: non-significant ($P > 0.05$); * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

The influence of the different factors on BCS variations was generally similar to that exerted on BW changes, with more favourable BCS changes in AM than in AV cows (0.03 vs. -0.16; $P < 0.001$). There was an interaction year \times breed ($P < 0.001$). Cows grazing in C70 lost 0.14 BCS points while cows at C30 maintained BCS ($P < 0.001$). There was an interaction year \times vegetation cover ($P < 0.05$). Regarding the effects of physiological status, while lactating cows lost on average 0.22 BCS points, non-lactating cows earned 0.09 points ($P < 0.001$). There was an interaction year \times physiological state ($P < 0.001$). In contrast to BW changes, an interaction breed \times physiological status was observed for BCS changes ($P < 0.001$), with greater differences found in AM than in AV cows (Table 1).

There were not differences between breeds on calf BW gains, in spite of the higher growth potential of AV compared to AM (Osoro *et al.*, 1999), as can be seen in the greater initial and final BW in the former breed (Table 2). Calves that spent the summer in C30 gained 769 g/day while those at C70 gained 557 g/day ($P<0.001$). This difference was probably due to the higher mobilization of body reserves in the dams at C70, reducing their milk production, although it might also be partly due to lower forage intakes attained by the calves at C70 (Bailey and Lawson, 1981; Osoro *et al.*, 1998).

Table 2. Body weight (BW) gains in nursing calves from Asturiana de los Valles (AV) and Asturiana de la Montaña (AM) breeds during summer at Cantabrian mountain pastures with different vegetation cover (C30: 70% grassland, 30% *Calluna* heathland; C70: 30% grassland, 70% *Calluna* heathland)

Vegetation cover	C30		C70		SEM	Significance		
	AV	AM	AV	AM		B [†]	V [†]	B×V
Initial BW (kg)	141	114	143	122	3.2	***	NS	NS
Final BW (kg)	215	181	200	177	4.0	***	**	NS
BW gain (g/day)	794	754	547	579	34.2	NS	***	NS

[†] B Breed; ^{††} V Vegetation cover; SEM: standar error of the mean; NS: non-significant ($P>0.05$); * $P<0.05$; *** $P<0.001$.

IV – Conclusions

Cattle from AM breed show a better adaptation to mountain conditions than AV. Smaller sized cattle have a greater ability to adapt to situations of low herbage availability. This aptitude is decreased when cows are lactating, because of increased energy demand. Calf BW at weaning was greater in AV breed, but AM calves achieved similar BW gains to AV calves.

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Beef cattle performance, carcass and meat quality traits to discriminate between pasture-based and concentrate diets

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Abstract. The aim of this work was to identify general relationships between the fattening diet and weight gains, carcass and meat quality across experiments, using data from bulls (n = 90) and steers (n = 56) of Parda de Montaña and Pirenaica breeds collected in 7 experiments. The different factors considered were diet (1. pasture+supplement; 2. pasture+supplement and indoor finishing for <3 months; 3. concentrates), breed and sex. Dietary energy and protein, forage:concentrate ratio, animal performance (weight gain, dry matter intake, age at slaughter), carcass (weight, conformation and fat scores, fat colour) and meat quality (intramuscular fat, colour and texture) were registered. The relationships between variables were studied with a Principal Component Analysis. Three factors explained 50% of the total variability: Factor 1 (21% of variability) was associated positively with fat yellowness and colour intensity, and negatively with daily gains during fattening; Factor 2 (15%) with meat yellowness, lightness and tenderness; and Factor 3 (14%) with meat redness and colour intensity. These factors were influenced by diet, sex and/or weight or age at slaughter, but not by breed. A discriminant analysis classified animals by fattening diet, with total accuracy for concentrate-fed diets (100%), intermediate for pasture+supplement (97%) and lower for cattle finished after grazing (91%), probably because of their intermediate meat and carcass characteristics.

Keywords. Attening diets – Cattle performance – Product quality – Discriminant analysis.

Utilisation des performances, de la qualité de la carcasse et de la viande pour discriminer entre les régimes à base de fourrages ou de concentrés dans les des bovins à viande

Résumé. Le but de ce travail était d'identifier des relations générales entre le régime d'engraissement et les performances, la qualité de la carcasse et de la viande des bovins, en utilisant données de males entiers (n = 90) et bouvillons (n = 56) de deux races, recueillis dans 7 expériences. On a considéré le régime (1. pâturages+supplément; 2. pâturages+supplément et finition à l'intérieure pendant <3 mois; 3. concentrés), la race et le sexe. On a enregistré la quantité et qualité des aliments ingérés, les performances, la qualité de la carcasse (conformation, engraissement, couleur du gras) et de la viande (graisse intramusculaire, couleur et tendreté). Les relations entre eux ont été étudiées avec une analyse de composantes principales. Trois facteurs expliquaient 50% de la variabilité: Facteur 1 (21%) associée avec l'intensité du couleur jaune de la graisse, et négativement avec des gains; Facteur 2 (15%) avec le couleur jaune de la viande, sa luminosité et tendreté; et Facteur 3 (14%) avec l'intensité de rouge de la viande. Ils étaient influencés par le régime alimentaire, le sexe et/ou le poids ou l'âge à l'abattage, mais pas par la race. Une analyse discriminante a classé les animaux selon leur régime alimentaire, avec précision totale pour les régimes de concentré (100%), intermédiaire pour le pâturage+supplément (97%) et inférieure pour les bovins finis après pâturage (91%), peut-être parce qu'ils avaient des caractéristiques intermédiaires entre les autres.

Mots-clés. Régimes d'engraissement des bovins – Performance – Qualité – Analyse discriminante.

I – Introduction

Beef cattle performance and product quality are greatly dependant on the animal type or the feeding management. Forage feeding is currently given increasing interest as compared to concentrate fattening diets, due both to economic efficiency and consumer demands. These requests are based

on perceptions of animal well-being, environmental sustainability and meat nutritional quality (leaner and with a more healthful fatty acid profile) (Van Elswyk and McNeill, 2014), and have led to the development of different methods to authenticate meat produced with forage-rich diets (Blanco *et al.*, 2011). The aim of this work was to identify relationships between the fattening diets of cattle and weight gains, carcass and meat quality.

II – Materials and methods

1. Animals and diets

This study was conducted using existing data from seven experiments conducted at the facilities of CITA research stations (2003–2010). Performance and carcass and meat quality data were obtained from 90 bulls and 56 steers, of Parda de Montaña and Pirenaica beef cattle breeds, raised during their fattening period (5–13 months in the different studies) after weaning on several feeding strategies. They were classified into three fattening diets: (i) Concentrates: animals received *ad libitum* concentrates throughout the fattening phase (n = 62); (ii) Pasture+Supplement: animals grazed on pastures (alfalfa pastures or mountain meadows) with supplementation (maize, barley or concentrates) (n = 62); and (iii) Pasture+Finishing: animals grazed on pastures with supplements and finished indoors for less than three months, on diets with 40 to 90% concentrates (n = 22).

2. Measurements

The animals were weighed fortnightly throughout the fattening phase, and daily gains were calculated for the whole fattening period (ADG) and for the last 3 months (ADG3). Forage and concentrate intake was determined or estimated; the forage:concentrate ratio (F:C) was calculated for the whole fattening period and for the last 3 months. The chemical composition of the different feed-stuffs was determined to estimate the dietary energy and protein intake.

The animals were slaughtered in a commercial abattoir when they reached the target age (SA) or weight (SW) for each experiment (Table 1). Carcasses were visually graded for conformation (CONF, SEUROP system transformed into an 18-point scale) and fatness score (FS in a 15-point scale, from 1 for 1- to 15 for 5+). Subcutaneous fat colour (CIE lightness: L*fat, redness: a*fat, yellowness: b*fat, Chroma: C*fat and Hue angle: h*fat) was measured at the loin area with a spectrophotometer.

The *Longissimus thoracis* muscle was removed for meat analyses. Meat colour was determined with a spectrophotometer after 7 days of air exposure (L*meat, a*meat, b*meat, C*meat, H*meat). For instrumental texture analysis, steaks were aged for 7 days at 4°C for Warner-Bratzler shear force determination (maximum stress, STRESS) using an Instron machine. Intramuscular fat content (IMF) was quantified with an XT10 Ankom extractor.

Table 1. Mean (\pm s.d) of slaughter weight (SW), slaughter age (SA), carcass conformation (CONF), fatness score (FS) and subcutaneous fat colour, and meat colour, intramuscular fat (IMF) and toughness (STRESS) (n = 146)

SW, kg	SA, months	Carcass					Meat				
		CONF	FS	L*fat	a*fat	b*fat	L*meat	a*meat	b*meat	IMF, %	STRESS, N/cm ²
483	14.8	9.2	4.4	72.6	2.6	13.5	40.3	13.3	13	1.6	70.4
± 47	± 4	± 2.3	± 1.4	± 4	± 1.7	± 3.9	± 3.4	± 2.4	± 2.8	± 0.8	± 20.7

3. Statistical analyses

All the analyses were conducted with SAS (SAS 9.4, Cary, NC, USA). The relationships between the variables of performance (gains), carcass (dressing percentage, conformation, fatness score, subcutaneous fat colour) and meat quality (intramuscular fat content, meat colour and maximum stress) were studied with a Principal Component Analysis (PCA). New groups of variables (factors) that retained as much variance as possible were defined. These factors were analysed with a GLM procedure, using Diet, Breed and Sex as fixed effects, and SA and SW as covariates. The correlations between the factors obtained in the PCA and diet traits (F:C, energy and protein content) were performed using the CORR procedure. A discriminant analysis was performed using the DISCRIM procedure, to predict the dietary treatment a given observation belonged to, considering all response variables. Cross-validation was run by omitting each observation one at a time, recalculating the classification function with the rest and classifying the omitted observation.

III – Results and discussion

Three factors explained 50% of the total variability of the selected variables (Table 2). **Factor 1** was associated positively with fat colour intensity (C*fat), especially yellowness, and negatively with gains during the fattening phase. It was affected by Diet (Pasture+Supplement had the highest values and Concentrates the lowest) and Sex (higher values in steers than in bulls) but not by Breed. Higher SW led to higher values of Factor 1 ($p < 0.01$). **Factor 2** was related with meat yellowness, lightness and toughness. It was influenced by Diet (Pasture+Finishing and Concentrates had higher values than Pasture+Supplement) and Sex (higher in steers than in bulls) but not by Breed; and animals with higher SA had lower values of Factor 2 ($p < 0.001$). **Factor 3** was related with meat

Table 2. Contribution of response variables to the main factors in the PCA. Influence of diet, sex, breed, age and liveweight at slaughter on these factors

	Factor 1 (fat colour and gains)	Factor 2 (meat yellowness & toughness)	Factor 3 (meat redness)
% Variability explained	21%	15%	14%
Correlation[†] with response variables			
a*fat	0.65	-0.03	0.01
b*fat	0.99	0.08	-0.06
C*fat	0.99	0.07	-0.06
a*meat	0.14	-0.31	0.94
b*meat	-0.05	0.80	0.60
H*meat	-0.14	0.97	-0.15
C*meat	0.05	0.34	0.93
L* meat	-0.33	0.47	0.00
ADG	-0.65	0.06	-0.09
STRESS	0.24	-0.41	-0.08
ADG3	-0.58	0.32	0.01
Effects			
Diet	<0.001	<0.001	0.14
Sex	<0.001	<0.001	0.11
Breed	0.36	0.46	0.30
SA (covariate)	0.07	<0.001	0.06
SW (covariate)	0.01	0.17	0.02

[†] Only variables with correlation $> |0.4|$ (absolute value, in bold) with at least one factor are presented.

colour intensity and particularly redness. It was not influenced by any of the fixed effects, but animals with higher SA had lower values of Factor 3 ($p < 0.05$). The lack of breed differences agrees with results of Albertí *et al.* (2005), who classified them together as “medium meat producers” when compared with other Spanish beef breeds.

Diet composition and quality were correlated with the response variables and therefore with the factors obtained from the PCA. Focusing on forage-based diets, Factor 1 was highly correlated ($r > 0.60$) with the amount and proportion of forage in the diet, the energy and protein content of forage, and negatively ($r < -0.60$) with the amount and protein content of concentrate. These relationships indicate that diets with higher forage content led to more yellow subcutaneous carcass fat and lower gains. The fact that lower performances were achieved despite high forage nutritional quality may be due to a higher energy expenditure associated to these diets or a suboptimal nutrient synchrony (carbohydrate and protein fractions), which could be improved with specific supplements or timing supplement delivery (Hersom, 2008). Factors 2 and 3 were less related to diet characteristics.

The discriminant analysis based on the three factors classified animals into their actual fattening diets with a 4.1% error rate (up to 7.7% with cross-validation). The accuracy was 100% for concentrate-fed diets (all animals correctly classified), intermediate for animals fattened on pasture with supplements (97%) and lower for cattle finished indoors after grazing (91%) (Fig. 1), probably because the finishing diets of the latter group resulted in carcass and meat traits intermediate between the other two categories, as Blanco *et al.* (2011) described.

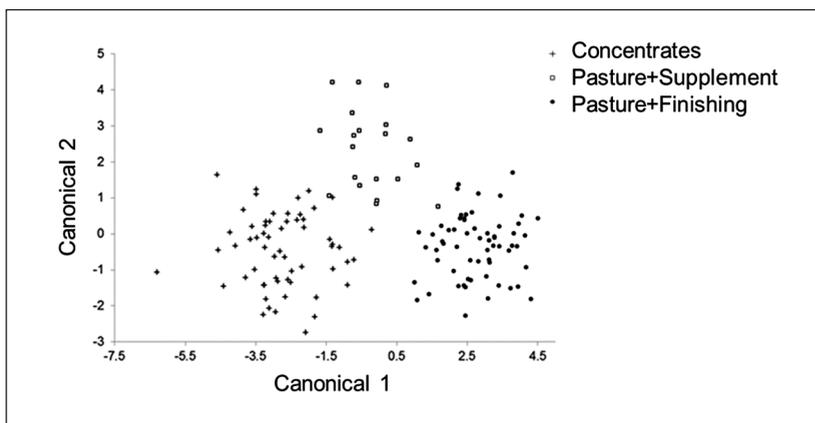


Fig. 1. Representation of animals fattened with the different diets in the canonical space obtained from the response variables.

IV – Conclusions

The fattening diets influenced cattle gains, fat colour and meat quality attributes. Therefore, these traits can be used to discriminate among feeding strategies based on pasture or concentrates, although accuracy will depend on the diet type.

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Influence of alpine grazing time on feeding behavior, milk yield and milking characteristics on Aosta Red-Pied cows

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Abstract. Alpine areas are characterised by extensive animal production systems and by the need to valorise alpine grasslands to produce high-quality dairy products through locally adapted breeds. The aim of this study was to evaluate the influence of the management system on milk production, milking characteristics and feeding behaviour of Aosta Red-Pied cows in an alpine environment. Eight multiparous cows per herd from two different herds were monitored in two alpine grazing management systems. The first herd was managed with a restricted grazing time (R), where the cows had free access to the pastures twice a day for up to 4 hours each. The second herd was managed with full-time open air grazing (O), where dairy cattle remained outside during the entire summer period. Measurements were made twice a month, during winter feeding, transition (from hay to fresh grass) and summer grazing. They included determination of feeding behaviour, milk yield, milking characteristics, and milk coagulation properties of individual cows. Although milk yield and coagulation properties did not differ between the two management systems, ingestion time was shorter and rumination-time/ingestion-time ratio was higher in R- than in O-cows ($p < 0.01$) during summer. Peak milk flow rate, average milking time and average milk flow rate were higher for R- than O-cows ($p < 0.05$) even under winter conditions, indicating that differences found in these parameters were independent from time allocated for grazing. These results show that Aosta Red-Pied cows can adapt their feeding behaviour to the time allocated for grazing without compromising either milk production or milk coagulation properties. Milking characteristics were not directly affected by the alpine farming system.

Keywords. Alpine farming system – Aosta Red-pied cows – Milking characteristics – Feeding behaviour.

Influence du temps de pâturage en alpage sur le comportement alimentaire, la production et les caractéristiques du lait des vaches Pied Rouge Valdôtaines

Résumé. Les régions alpines sont caractérisées par des productions animales extensives et par la nécessité des éleveurs d'exploiter les prairies alpines pour produire des produits laitiers de très haute qualité à l'aide de races locales adaptées à l'environnement. Le but de cette étude est d'évaluer l'influence de la conduite du système d'alpage sur la production laitière, la qualité du lait et le comportement alimentaire des vaches de race Pied Rouge Valdôtaine dans un milieu alpin. Huit vaches multipares de deux élevages différents ont été suivies au sein de deux systèmes de gestion d'alpage. Dans le premier, appelé restreint (R), les vaches pâturaient 2 fois par jour pour un total de 4 heures. Dans l'autre système (O), les vaches avaient libre accès à l'herbe sans restriction. Les échantillonnages ont été effectués 2 fois par période: pendant la période hivernale, pendant la transition alimentaire (passage du foin à l'herbe) et pendant 3 périodes d'alpage. Ces mesures comprenaient la détermination du comportement alimentaire, la production et les caractéristiques du lait ainsi que l'aptitude à la coagulation du lait de chaque vache. Si la production de lait ne montrait pas de différence entre les deux systèmes de gestion, le temps d'ingestion était par contre plus court et le rapport temps d'ingestion/temps de rumination plus grand pour les vaches du groupe R par rapport à celles du groupe O ($p < 0,01$) dans la période de l'alpage. Le débit maximal de lait, le temps moyen de traite et le débit moyen étaient plus élevés pour les vaches du groupe R ($p < 0,05$), aussi bien dans des conditions hivernales que d'alpage ce qui signifie que cela n'était pas le résultat du système de gestion des pâtures. Ces résultats montrent que les vaches Pied Rouge Valdôtaines peuvent adapter leur comportement alimentaire

au temps alloué au pâturage sans compromettre la production de lait et son aptitude à la coagulation. Les caractéristiques de traite ne sont pas directement concernées par les systèmes de gestion de l'alpage.

Mots-clés. Système de gestion des alpages – Vaches Pied Rouge Valdôtaines – Caractéristiques de traite – Comportement alimentaire.

I – Introduction

In alpine areas, farmers use high altitude pastures to feed animals in the summer season to produce high-quality dairy products through locally adapted breeds. Traditionally, in the Aosta Valley, a region located in the North-West of Italy, farmers use alpine barns during summer to house animals half of the day. However, nowadays the costs of renovating buildings are too high and farmers need alternative systems, like a 24 h/d outdoor system, never applied in this region before, with lower costs for maintaining the exploitation of alpine pastures with dairy cows. The interest to investigate the effect of the alpine pasture management systems, the traditional and the alternative 24 h/d outdoor system, is also based on the need to understand the interactions between the alpine pasture and farms (Nietter *et al.*, 2014). The aim of this study was to evaluate the influence of the management system on milk production and milking characteristics as well as feeding behaviour of indigenous Aosta Red-Pied cows in an alpine environment.

II – Materials and methods

This study was carried out in the Aosta Valley, a small alpine region located in the North-West of Italy. Winter and transition conditions were investigated in two farms in Aosta (45°44'14"N 7°19'14"E) at 600 m a.s.l. Summer grazing was studied in parallel in two locations, Rhêmes Notre Dame Valley (45°34'11.17"N 7°07'05.16"E), from 1500 to 2500 m a.s.l. for the restricted grazing time and in Vertosan Valley (45°42'31.32"N 7°08'25.8"E) for the 24 h/d outdoor system, at similar altitude. Two herds of Aosta Red-Pied cows were selected after their different alpine grazing management systems. In each herd eight multiparous cows were monitored. In winter both groups received the same diet based on hay and up to 4 kg/d of concentrate. In the transition period cows had access to fresh grass and hay for 1 month with an unchanged amount of concentrate. From the beginning of June till the end of September cows remained on high altitude pastures and received 1 kg/d of concentrate. The first herd was managed with a restricted grazing time (R), where the cows had free access to the pasture twice a day for up to 4 h each. For the rest of the day, animals were sheltered in the barn where they were milked twice a day. The second herd was kept in a full time *open air* grazing management system (O), where dairy cattle remained outside during the entire summer period for 24 h/d and were milked in a mobile milking parlour. This experiment was a continuation of the study of Berard *et al.* (2014) which, however, focused on primiparous cows. Both sites had similar grassland quality during the entire summer period (average grass chemical composition of the three summer periods for O-pastures and R-pastures, respectively: crude protein 138 vs. 127, crude fiber 216 vs. 232, crude lipid 28.3 vs. 28.0, NDF 459 vs. 464, ADL 60.3 vs. 60.8 and ADF 331 vs. 351 g/kg dry matter).

Measurements were made twice per sampling period: during winter feeding in the barn (Barn; Period A), during feeding transition period from hay to fresh grass (Trans; Period B) and, in order to investigate three summer pasture altitudes, three times during the summer grazing period (Alp; Period C, 1400 m a.s.l.; D, 1700 m a.s.l.; E, above 2000 m a.s.l.). The O-condition started with summer grazing. Sampling included feeding behaviour, milk yield, milking characteristics, (like milk peak flow rate, average milking time, average milk flow rate, traits that could be affected by the different milking procedures) and milk coagulation properties as determined for individual cows. The

feeding behaviour was measured with chewing sensors (MSR Electronics, Henggart, Switzerland) for 24 h twice per sampling period. Moreover, milk samples were collected and milking characteristics recorded with a Lactocorder (WMB AG, Balgach, Switzerland) twice per sampling period, during morning and evening milking. The milk samples from the evening and from the morning were mixed and divided into subsamples. A part of this milk (10 ml in two replicates) was used to measure milk coagulation with a Lactodynamograph (Foss Electric Denmark). Data were analysed using the MIXED procedure of SAS (version 9.1 Inst. Inc., Cary, NC). The statistical model included the experimental condition (R- or O-system) period (from A to E) and their interaction as fixed factors. Period was considered as repeated factor, with animals nested within treatment as subject. Differences with probability levels of $p < 0.05$ were considered significant.

III – Results and discussion

Although milk yield systems (average milk yield during the five monitored periods, R-group 6.33 kg/milking, O-group 6.28 kg/milking) and coagulation properties (data not shown), did not differ between the two alpine management; ingestion time was shorter in the R-group than in the O-group ($p < 0.01$) (Table 1).

Table 1. Effect of alpine grazing time (R-group vs. O-group) on feeding behaviour and milking characteristics

Time/Period	R-group ¹					O-group ²					SEM
	Barn ³		Trans ⁴		Alp ⁵	Barn ³		Trans ⁴		Alp ⁵	
	A	B	C	D	E	A	B	C	D	E	
Ingestion time, min	242	269	219 ^a	270 ^a	292	194	315	347 ^b	362 ^b	366	± 21.5
Rumination/ ingestion time ratio	1.55	1.64 ^b	1.42 ^b	1.25 ^b	1.13	1.89	1.19 ^a	0.92 ^a	0.83 ^a	1.09	± 0.10
Milk peak flow rate, kg/min	3.57 ^b	3.62 ^b	3.3	3.25 ^b	3.3 ^b	1.8 ^a	1.71 ^a	2.04	1.72 ^a	1.31 ^a	± 0.22
Average milking time, min	3.08 ^a	3.16 ^a	3.22 ^a	2.81 ^a	2.47 ^a	7.5 ^b	6.84 ^b	6.05 ^b	5.55 ^b	5.55 ^b	± 0.36
Average milk flow rate, kg/min	2.37 ^b	2.42 ^b	2.02	1.95 ^b	1.95 ^b	1.16 ^a	1.11 ^a	1.3	1.07 ^a	0.85 ^a	± 0.15

^{a-b} Within a row, least squares means without a common superscript differ in R- vs. O-group for the same sampling Time ($P < 0.01$).

¹ R-group: Cows managed with a restricted grazing time on pasture

² O-group: Cows managed with an open air grazing time on pasture

³ Winter feeding period in the barn with hay

⁴ Transition feeding period from hay to fresh grass

⁵ Summer grazing periods

Conversely the rumination-time/ingestion-time ratio was higher in R-group than in the O-group ($p < 0.01$). In both groups statistical differences were registered in the first and second period on the summer pasture, while in the last period of summer grazing (period E) the statistical evidence disappeared for both parameters, probably due to an adaptation to alpine conditions. Because forage quality was obviously high enough to fulfil the cows' requirements for milk production, the difference in the rumination/ingestion time ratio suggests that R-cows ate very fast, and when they were sheltered at the barn they spent more time ruminating. On the other hand, O-cows had more time to eat and thus the ratio of rumination/ingestion time was lower. Milk ejection and consequently

milking characteristics (like average milking time, peak and average milk flow rate) could be affected by stress factors, induced by different milking procedures. In our experiment, cows were milked outdoor in a mobile milking parlour in O-condition and, like in winter, in the barn in R-condition. But also milking routine may have had an effect. Peak milk flow rate, average milking time and average milk flow rate were higher for R- than O-cows ($p < 0.05$) even under winter conditions (Table 1), which means that this was not the result of grazing time allocation. No significant difference was found between the systems in terms of coagulation properties (data not shown in table).

IV – Conclusions

These results show that, if Aosta Red-Pied cows are fed with alpine forages of sufficient quality, they can adapt their feeding behaviour to the time allocated for grazing without compromising either milk production or milk coagulation properties. Milking characteristics were not directly affected by the type of farming management system.

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Mountain pastures and local products in Southern Albania. Between production and resource management issues

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Abstract. The paper aims to present changes and current dynamics of mountainous pastoral systems in Southern Albania (Korca region) and to identify origin-based quality products as a strategy for sustainable rural development. According to the historical data (available or reconstructed through interviews), rapid and unregulated changes in mountainous productive systems within the post-communism transition threaten local natural resources and cultural landscapes. Changes are primarily due to massive out-migration of population and the consequent brutal disruption of social and productive fabric as also to the collapse of the ancient value chains without establishing a proper institutional context for the empowerment of livestock sector and a balanced management of mountain pastures. Nevertheless, the rapid growth of urban markets and the increase in sales of milk and meat coming from mountainous territories –perceived by consumers as of distinct quality– create new perspectives for the studied region.

Keywords. Mountain pastures – Local products – Pastoral systems – Albania.

Alpages et produits locaux au sud de l'Albanie. Les problèmes de production et les perspectives de commercialisation

Résumé. Le papier vise à présenter les changements et les dynamiques actuelles des systèmes pastoraux de montagne en Albanie du Sud (région de Korça) et d'identifier les produits de qualités liées à l'origine comme une stratégie de développement rural durable. Selon les données historiques disponibles (ou reconstituées à travers des entretiens), des changements rapides et non réglementés dans les systèmes de production de montagne durant la transition postcommuniste menacent les ressources naturelles locales et les paysages culturels. Les changements sont principalement dus à une émigration massive de la population et l'interruption brutale consécutive du tissu social et productif mais aussi à l'effondrement des anciennes chaînes de valeur sans l'établissement d'un cadre institutionnel approprié pour l'autonomisation du secteur de l'élevage et une gestion équilibrée des alpages. Néanmoins, la croissance rapide des marchés urbains et l'augmentation des ventes de lait et de viande provenant de territoires montagneux, perçus par les consommateurs comme de qualité distincte, crée de nouvelles perspectives pour la région étudiée.

Mots-clés. Alpages – Produits locaux – Systèmes pastoraux – Albanie.

I – Introduction

The Albanian mountainous areas have territorial specificities and face particular economic and human context. At the same time, local products have strong link to their specific origin, especially those being processed like cheese. In fact, little technical change can be seen as a chance, as they still have a very rustic and authentic character that is appreciated by some consumers. The communist collectivization period during 1944-1991 followed by a long economic transition for these

areas creates nowadays a binding context of the local economic development. In these areas the livestock farming system is dominant and is considered by researchers as a key resource for an endogenous local development (Bernard *et al.*, 2014; Garnier, 2013). This new Albanian specific context has rarely been studied in depth and this paper tends to respond with a descriptive approach to the question of how the management of the mountain pastures and the resource use access affects the farming systems of the local breeders. We try to identify pressures and incentives that affect the local farming system both from the production and commercialization factors, and how the local actors react.

For this purpose, we have chosen to study a mountainous territory in the Korça region, which is one of the most developed centers in southeastern Albania. Vithkuq is a mountainous territory, with a specific knowledge and know-how in livestock farming systems. The recent data shows that the market demand for pastoral products, especially from small ruminants, has increased in recent years in the region of Korça (Bombaj *et al.*, 2015). Despite the desertification after the fall of communism (Lerin and Marku., 2010) data shows a sharp increase in the herd size but also new dynamics in the local production systems (Çili *et al.*, 2013) and issues on natural resources use. The demand for these local products partly explains the expansion of herds in the area and many farmers see the need to produce in large quantities to thrive economically. This situation has created an increasing demand for pastures that are managed in an unclear way, generating competition and conflicts among the farmers, including seasonal moving breeders from West Albania, for the best pastures during summer.

II– Materials and methods

1. Materials

The study area comprises a total of 13 villages with a surface of 243.6 km². Combining statistics and preparatory discussions, the selection of villages was done according to the number of families in each village, herd size, proximity and ties with the three dairies in the territory. In order to gather data that can inform the diverse farming systems, we have made interviews with respect to a balance between specialized farmers, intermediate farmers and subsistence farmers

2. Methods

Stage 1 – Quick characterization of the territory.

Stage 2 – In-depth interviews in the municipality. It was done with semi-structured interviews (formal and informal) and observations collected directly from actors/landscape and farms.

Stage 3 – Interviews outside the study area on the wholesale market and the retail market in Korça and stores details in Tirana.

Stage 4 – Analysis of the field results and discussion.

III – Results and discussion

1. The local farming system and pressures affecting it

In Albania according to (MAFCP, 2014) around 352,315 farm households still have a high level of land fragmentation (1.16 ha/farm with an average of 4.8 parcels). The agrarian reforms towards the market economy have pushed farmers to adapt their local farming systems. In the considered territory the average size of the farm is 1.22 ha. As the farm size is very small and the summer pas-

tures very rich, the family livestock farming is one of the main sources of family income for the local farmers. The dominant farming system is based on sheep farming. The pastoral dynamics of the municipality of Vithkuq in the recent years is as follows in the Table 1 below.

Table 1. Pastoral dynamics of the municipality of Vithkuq

Years	Total population	Herd size	Total milk production (tonnes)	Total meat production (tonnes)
2005	2,939	17,920	2,750	160,5
2014	1,660	18,549	2,520	249,7
Difference in %	-56%	+4%	-9%	+55

Source: Çili *et al.*, 2013; Matka, 2015; and author's calculation.

According to our surveys we can state that the local farming system is constituted by three different types of farms: (a) small subsistence farms; (b) intermediate farms producing market's surpluses; (c) specialized farms, whose production is mainly marketed. The local farming systems co-exist on the municipality's territory with farmers from other regions (transhumant).

The recent evolution of each type of farm in the territory can be summarized as follow:

- The small subsistence farms: 131 farms were identified, characterized by the self-consumption and with very occasional or no sale. This type of farm has 1-10 sheep/goats and / or 1-4 bovine animals. They don't have young labor force and don't do transhumance.
- The intermediate farms: 142 farms, characterized by a start of breeding specialization with fairly consistent sales. This type of farm has 11-99 sheep / goats and / or 5-9 bovine animals. They don't do transhumance but they tend to expand their activity if they have a young labor force.
- The specialized farms: 53 farms, they sale the majority of production. This type of farm has more than 100 sheep / goats or more than 10 bovine animals. They do transhumance and tend to expand their activity. The specialized farms tend to increase every year in the territory.

Some key elements have been identified as pressures on these farms. They can be grouped in 4 dimensions, and interact between each other and make the local farming system develop.

- First, the main technical changes at the farm level were the improvement of the breeds and the increased mechanization. The introduction of new breeds has led to controversial changes. Some "specialized" breeders are not able to manage their manure and throw it often in the rivers. Furthermore, as the arable land is very limited, some farmers lack fertilizing material for their crops and use large doses of chemical fertilizers to increase their crop production.
- Second, the policy changes since 1991 have led to a new context of property rights creating new possibilities for farmers to invest in their activities.
- Third, the local initiatives during the last fifteen years have given some new dynamics aiming for better production conditions for the local breeders.
- Fourth, market pressure: Although farmers have increased their milk and meat production, they do not really have a favorable bargaining power with the dairies where they sell their milk. The value chain of the dairy products is mostly informal and the transactions cannot be legally traced. The current dynamics of the value chain does not position the products in a niche market capable of engaging a virtuous circle for a good remuneration of the producers and for the reproduction of the natural resources.

2. The summer pastures: a crucial resource for the local farming system

After the collectivization period the local agro pastoral production systems have gradually evolved by adapting to the new economic context but the lack of a strategic public support has led to harm natural resource management. Recently the increased demand for the summer pastures by the dynamics of expansion of the local farmers and by farmers coming from other regions of Albania give new dynamics in terms of natural resource management issues. The herds of the transhumant breeders coming from the other regions are larger and more numerous to come in the recent years. Different types of mountain pastures properties were identified and the attribution of the summer pastures use rights causes some tensions with the local breeders because the pastures boundaries are not always clear. The access to summer pastures is one major factor that influences the farming systems of the local breeders. Their use is a major challenge for the management of both farming systems and the landscape.

This reorganization alters the operation of pastoral systems, with threats on local natural resources (concentrate overgrazing in some areas, abandonment of marginal areas and / or under-utilization of pastures in these areas, poor management of fertilizer and thus pollution of rivers around villages). The main issue is to identify the right levels and coordination mechanisms that can help local breeders to better organize to sell their milk and meat at a fair and reasonable price for their activity, while valorizing and respecting the proper use of the pastoral resource.

IV – Conclusions

Albanian context is changing, making the farms adapting fast. This induces recently big changes and challenges for the sustainable use of the natural resources. The local farming system in the considered study area is adapted to the new economic context. The specialization of the local breeders, especially for the meat production, is accompanied by an increased demand for the summer pastures. This resource is crucial both for the farming system, and the transhumant breeders coming from other regions of Albania. The management of this resource affects the local farming system and some conflicts generated by the summer pastures use rights are observed. Further research is needed to determine in what level the use rights decisions are taken and the role of the local breeders in the local management of use rights.

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Animal diet quality during the grazing season in two mountain low-input dairy systems

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Abstract. When animals graze swards at moderate or low stocking rate and hence have feeding choices to make within heterogeneous vegetation, the quality of their diet is difficult to assess. In such grazing conditions, the evaluation of the selected herbage digestibility through the analysis of the content of their faeces is a relevant alternative. The objective of this study was to examine the evolution of grazing animals' diet quality in two experimental grassland-based dairy systems (called "extensive" and "intensive"), using this indicator. About 800 faeces samples from cows and heifers have been collected by rectal sampling when animals were grazing during three periods (spring, summer, autumn) over 4 years in both systems. Each system was designed with 12 Holstein cows, 12 Montbéliarde and heifers for herd renewal, a short calving season at spring, a low (0.66 LU/ha), or moderate (1.09 LU/ha), stocking rate, no concentrate or a weak amount (4 kg/d during 200 days). A significant decrease in cows' diet digestibility (-4.9%) was observed in the "extensive" system in summer while a slight, regular but significant decrease was assessed in the "intensive" system (-2.2%). Significant difference of digestibility was found between breeds and between cows and heifers, within system. No positive relationship between digestibility and milk production was highlighted in the "intensive" system while significant correlations were found in summer and autumn in the "extensive" one, suggesting a limiting energy value of the diet at this period for this system.

Keywords. Dairy cow – Permanent grassland – Faeces – Organic matter digestibility – Milk production.

Qualité du régime alimentaire des animaux durant le pâturage dans deux systèmes laitiers bas intrants de montagne

Résumé. Lorsque les animaux pâturent avec un chargement modéré ou faible et, par conséquent, choisissent l'herbe dans une végétation hétérogène, la qualité de l'alimentation est difficile à évaluer. Dans ces conditions de pâturage, l'évaluation de la digestibilité du fourrage sélectionné par l'analyse des fèces est une alternative pertinente. Dans cette étude, l'objectif était d'examiner l'évolution de la qualité de l'alimentation des animaux pendant le pâturage dans deux systèmes d'élevage laitiers expérimentaux (qualifiés d' "extensif" et d' "intensif"), en utilisant cet indicateur. Durant 4 ans, environ 800 échantillons de fèces provenant de vaches et génisses au pâturage ont été collectés par prélèvements rectaux au cours de trois périodes (printemps, été, automne) dans chacun des systèmes. Chaque système, composé de 12 vaches Holstein, 12 Montbéliarde et des génisses de renouvellement, est caractérisé par une saison de vêlage courte au printemps, un chargement faible ou modéré et pas ou peu de concentré (4 kg/j pendant 200 jours). Une diminution marquée de la digestibilité des régimes (-4,9%) a été observée dans le système "extensif" entre le printemps et l'été, alors qu'une diminution faible et régulière a été observée dans le système "intensif" (-2,2%). Des différences importantes de digestibilité ont été observées entre races et entre vaches et génisses, dans chaque système. Aucune relation entre digestibilité et production laitière n'a été trouvée dans le système "intensif" alors que des corrélations significatives ont été observées en été et à l'automne dans le système "extensif", ce qui suggère une valeur énergétique limitée de l'alimentation à cette période pour ce système.

Mots-clés. Vache laitière – Prairie permanente – Fèces – Digestibilité de la matière organique – Production laitière.

I – Introduction

Grazing intensity determines the structural heterogeneity of grassland vegetation and consequently its quality for domestic herbivores. Grazing at high stocking rate allows maintaining homogeneous and leafy swards of high digestibility along the grazing season. By contrast, grazing at moderate or low stocking rate leads to the creation of a mosaic of short grazed patches that remain vegetative, and tall under-grazed patches composed of reproductive stems and dead leaves (Garcia *et al.*, 2003). In such extensive grazing conditions, the major difficulty to estimate the diet nutritive value may be the accurate collection of representative herbage samples of the diet actually consumed by the animal (Lukas *et al.*, 2005). Nutritive value of forage assessed with micro mower which cut the entirety of the sward does not match properly animal feeding selection. Furthermore, the technique of hand plucking of vegetation samples similar to those ingested by the animal seems to systematically underestimate diet digestibility especially when studying feed intake on multi-species swards (Mahler, 1991). Methods using oesophageal cannula are invasive for the animals, money and time-consuming, limiting therefore the number of samples. The estimation of herbage organic matter digestibility (OMD) from crude protein (CP) concentration in faecal samples using regression equations, offers opportunities to overcome these obstacles (Peyraud, 1998). In addition, these faecal methods, combined with near infrared reflectance spectroscopy (NIRS), allow analysing many samples.

In two experimental grassland-based dairy farming systems, with different levels of stocking rate, we used this faecal method as an indicator of the grazing management, allowing to give us the diet digestibility of grazing animals. Our aim was to examine the evolution of the quality of animals' diet according to the system, the grazing period, the type of animal, and the year. Moreover, we investigated the relationships between diet digestibility and milk production.

II – Materials and methods

1. Experimental design and animals

The experiment was conducted from 2011 to 2014 at an experimental farm of the INRA Herbiopôle Unit (French Massif-central, 45.3046N, 2.8378E, 1100 m) where two grassland-based dairy farming systems were used. The first one called "Bota" (for Biodiversity, organolepsy, task load, autonomy) aims to preserve the herbage territory, to supply societal goods as biodiversity and high quality local cheeses, to use very low inputs, and to minimize farm labor. It was designed with a 59.6 ha area composed of 12 permanent diversified grassland plots, a low stocking rate (0.66 LU/ha), a short calving season in spring, first calving at 3-year-old, no mineral fertilization, no concentrates given to cows and a long rotation duration at pasture (4 grazing cycles of 51 days in average). The second system, called "Pepi" (for Production, efficiency, planet, innovations), is oriented towards milk production and herbage quality while minimizing environmental impacts. It was built with 29.2 ha of 7 old temporary and productive grassland plots, a moderate stocking rate (1.09 LU/ha, which is slightly higher than average in the surrounding area), a short spring calving season, 2-year-old heifers, a sharp adjustment of mineral fertilization (40 kg of nitrogen /ha) and concentrates (4 kg/d at pasture), rotational grazing (5 grazing cycles of 41 days in average), and early cutting. Each system used 24 cows and heifers for herd renewal, equally distributed among Holstein and Montbéliarde breeds. The two groups of cows and heifers have been paired at the beginning of the experiment and put on each system. All the 24 cows of each system grazed always together. Two-year-old and 3-year-old heifers of Bota grazed almost all the grazing season a diversified summer pasture far from the farm buildings while 2-year-old heifers of Pepi grazed with cows or remain into the plot after the grazing of the cows.

2. Measurements, sampling and laboratorial analysis

Each year, at 3 periods along the grazing season, faeces from all the animals of each system were simultaneously collected by rectal sampling at the farm building. The 3 periods were chosen according to the state of the vegetation expected in Bota system: in spring when sward is expected to be mainly at vegetative phenological stage, in summer when sward heterogeneity is assumed to be at a maximum and at the beginning of autumn to account for cumulative grazing effects. Over the 4 years, they were positioned on average the June 1st (spring), July 12th (summer) and September 9th ('autumn'). A total of 792 faeces samples from cows and heifers were thus obtained (on average 33 faeces samples per period and per system). Once collected, samples were dried at 60°C for 72 hours and grinded at 1 mm size. Acid detergent fiber (**ADF**) and nitrogen (**N**) of fecal samples were predicted by NIRS using models characterized by the following statistics: for nitrogen, standard error of cross validation (**secv**) = 0.07; coefficient of determination in cross validation (r^2_{cv}) = 0.98, and for ADF, (**secv**) = 1.42, (r^2_{cv}) = 0.87. Chemical analyses for 80 samples were set up to validate the model.

Individual digestibility was calculated using the equation given by Peyraud *et al.* (unpublished):

$$\text{OMD} = 0.980 - 2.474/\text{CP} - 0.00276 \cdot \text{ADF} \quad (r^2 = 0.87, \text{rsd} = 0.0123, \text{CP expressed as \% of OM})$$

Individual milk production was measured at each milking, allowing us to calculate, at each period, the mean daily milk production during the week following the fecal collection.

3. Statistical analysis

Data of individual OMD were analysed using the mixed procedure of SAS (version 9.4; SAS Institute, 2013). The model took into account the effects of year, system, period, breed, type of animal (cow or heifer) and the interactions of year*system, year*period, system*period, system*type and year*system*period. The analysis of variance was followed by the multiple comparison test of Tukey–Kramer. Discrepancies with P values less than 0.05 were considered significant. The relationship between individual milk production and OMD within period and system was analyzed using the regression procedure of SAS. The coefficients of variation of individual digestibility from animals grazing on a pasture in a particular date were also calculated.

III – Results and discussion

On average, diet digestibility of Pepi and Bota animals (0.77 and 0.74 respectively) were closed to those given in the INRA reference tables corresponding to grazing on mountain permanent grasslands at vegetative and reproductive stage, respectively (Agabriel, 2007). The quality of animals' diet was similar in spring (P1) in the two systems (Fig. 1; $P = 0.076$) before being significantly different in summer and in autumn. It highly decreased from spring (P1) to summer (P2) (-4.9%; $P < 0.0001$) before being steady in autumn in Bota system while this decrease was very moderate and regular in Pepi along the grazing season (-0.4% between P1 and P2; -1.8% between P2 and P3, $P < 0.001$). This decrease in the quality of grass intake over the grazing season in extensive grazing system has already been shown by Farruggia *et al.* (2014). It reflects the increase of reproductive vegetation in Bota pastures along the grazing season due to the unbalance between herbage growth and animal intake. In Pepi, the relative stability of the diet digestibility from spring to summer clearly illustrated a good control of herbage quality by grazing management, as expected in the goals of this system. The concentrates distributed to Pepi cows can also influence the quality of the diet over the grazing season. Regarding the effect of breed, minor but significant differences were found between Holstein and Montbéliarde (0.75 vs. 0.76, respectively; $P < 0.0001$) suggesting that Montbéliarde were a little more selective than Holstein when grazing, or that they have a higher digestion ability. Small differences were also observed between cows and heifers in Bota ($P < 0.0001$) and in Pepi ($P < 0.001$), reflecting that heifers grazed lower quality pasture, due to the grazing management of the young animals in the two systems.

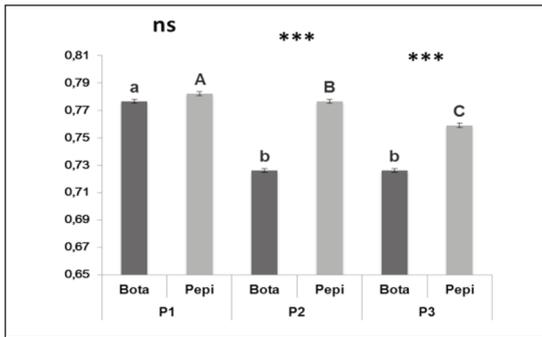


Fig. 1. Diet digestibility according to the dairy system (Bota or Pepi) and the grazing period (P1 to P3).

Letters in lowercase differ at $P < 0.05$ between period within system Bota while letters in uppercase differ at $P < 0.05$ between period within Pepi. For differences between systems: ns = non-significant; *** $P < 0.001$. Standard error is given.

The coefficient of variation of OMD varied from 0.2 to 3.6% in Bota and from 0.9 to 3.1% in Pepi. These quite low variations between animals could suggest that they selected similar range of patches within sward, which was unexpected in Bota heterogeneous pastures. Such results suggest also that the pasture digestibility could be evaluated in routine with this method by gathering feces from animals grazing within same pasture.

Finally, no significant relationship between individual diet digestibility and individual daily milk production was highlighted in Pepi whereas significant correlations were found in Bota system in summer ($r = 0.28$; $P < 0.04$) and in autumn ($r = 0.45$; $P < 0.0001$), suggesting a limiting energy value of the diet in these periods in this system.

IV – Conclusions

The forage OMD, estimated from fecal CP and ADF by NIRS associated with a predictive model, allows to characterize the quality of the animals' diet and to follow its evolution over the pasture season in mountain low-input systems. It is an operational technique, especially for dairy cows when they return to the milking parlour.

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Session 3
**Animal-Pasture interactions in mountain areas:
bottlenecks and opportunities in biodiversity
management and forage production**

Grazing and biodiversity: from selective foraging to wildlife habitats

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Abstract. Livestock grazing in low-intensity farming systems is a key aspect in the conservation of Europe's biodiversity, which reaches high levels of species richness in semi-natural grasslands. With the demise of traditional grazing systems, the design of viable low-intensity grazing systems for the future requires a good understanding of grazing impacts on biodiversity. Here, I review various scale-dependent aspects of selective grazing and how they may affect biodiversity. Insects such as butterflies are well-suited to elucidate small-scale impacts of grazing intensity. They highlight the importance of viewing grazing impacts in a framework of spatial heterogeneity and successional dynamics. In order to optimise these successional dynamics, grazing management may adopt techniques such as rotational grazing and strategic placement of mineral licks. However, we still lack a good evidence base on the effects of targeted grazing practices on biodiversity. The challenge to solve this gap can be met by a combination of creative field experiments that focus on the mechanisms of biodiversity responses and adaptive management that builds on a continuous feedback from sound monitoring.

Keywords. Grazing impact – Low intensity farming – Conservation – Butterflies – Rotational grazing.

Pâturage et biodiversité : du broutage sélectif à l'habitat de la faune sauvage

Résumé. Le pâturage du bétail dans les systèmes d'élevage à faible intensité est un aspect déterminant pour la conservation de la biodiversité en Europe, qui atteint de forts niveaux de richesse en espèces dans les prairies semi-naturelles. Avec la disparition des systèmes de pâturage traditionnels, la conception de systèmes de pâturage à faible intensité viables pour l'avenir requiert une bonne compréhension des impacts du pâturage sur la biodiversité. J'examine ici plusieurs aspects de pâturage sélectif dépendants de l'échelle ainsi que la manière selon laquelle ils peuvent affecter la biodiversité. Des insectes tels que les papillons sont appropriés pour élucider les impacts à petite échelle de l'intensité de pâturage. Ils mettent en lumière l'importance d'envisager les impacts du pâturage dans un cadre d'hétérogénéité spatiale et de dynamique de succession. En vue d'optimiser ces dynamiques de succession, la gestion du pâturage peut faire appel à des techniques telles que le pâturage rotationnel et l'emplacement stratégique de pierres à lécher. Toutefois, il nous manque encore une bonne base de preuves quant aux effets des pratiques de pâturage ciblé sur la biodiversité. Le défi lié à cette lacune peut être résolu par une combinaison d'expérimentations créatives aux champs focalisées sur les mécanismes de réponse de la biodiversité et de gestion adaptative, visant à tirer parti d'un feedback continu à partir d'un suivi robuste.

Mots-clés. Impact du pâturage – Élevage à faible intensité – Conservation – Papillons – Pâturage rotationnel.

I – Introduction

Low-intensity land use has played a major role in shaping Europe's biodiversity (Poschlod, 2015). A high proportion of plant and animals species are linked to the open landscapes that have developed over several millennia of the traditional land use systems preceding the era of industrial agriculture that relies on the inputs of chemical fertilisers (Bignal and McCracken, 1996). Grazing by various types of ungulate livestock has been an important driver determining the structure and composition of plant communities and the associated animal diversity that characterise these semi-

natural communities. It has even been argued that these landscapes and characteristic species closely resemble the natural herbivore-dominated communities from which they have been derived (Vera 2000; Bakker *et al.*, 2015).

At present, the conservation value of the species-rich communities from traditional land use systems has been recognised under the umbrella of High Nature Value (HNV) farming systems (Oppermann *et al.*, 2012). With the continuing pressure to increase agricultural productivity, HNV farming still faces a growing threat of marginalisation, leading to abandonment and, ultimately, loss of biodiversity (Balmer and Ehrhardt, 2000). Stimulating rewilding with the restoration of wild native herbivores has been suggested as an option to maintain the biodiversity of HNV farming systems (Merckx and Pereira, 2015), but with conflicting claims of land owners and challenging socio-economic problems for the affected rural communities, such initiatives have not yet proved successful on a large scale. With increasing concerns for the planetary boundaries of the earth system for human influence (Steffen *et al.*, 2015), a renewed emphasis on the beneficial ecosystems services and robust sustainability of low-intensity farming systems seems called for (Maes *et al.*, 2012; Rodríguez-Ortega *et al.*, 2014). In developing these efforts, it will be important to include biodiversity to the full extent, as the ecosystem service approach tends to focus on a minority of species that perform the core of ecosystem services, such as pollination, which fails to meet the requirements of rare species (see Kleijn *et al.*, 2011).

Integrating biodiversity aspects into the optimisation of grazing systems requires a good understanding of the impact of different land use types and intensities across species communities. Although significant steps have been made to deepen our understanding of biodiversity dynamics in agro-ecosystems (e.g., Tschardt *et al.*, 2012), this remains a challenge for low-intensity grazing systems, given their typically large spatial extent and high landscape complexity (WallisDeVries *et al.*, 1998; Plachter and Hampicke, 2010). In this paper, I will review some main aspects of grazing impact on biodiversity. I will especially focus on the role of spatial scale as both the grazing process and functional aspects of habitat quality are strongly scale-dependent (Fig. 1; see WallisDeVries, 2002). Also, in addressing conflicts between grazing impact and biodiversity, it is imperative to view the various management options at the proper spatial scale. In dealing with biodiversity, I will rely especially on examples from butterflies and other insects, as arthropods are well-suited to illustrate the impacts of grazing across a range of spatial scales (Van Klink *et al.*, 2015a). The case studies that are treated here derive not only from montane but also from lowland ecosystems, such as coastal salt marshes and heathlands, but as these also pertain to low-intensity grazing systems, the emerging insights should be considered equally applicable to montane and alpine ecosystems.

II – Spatial scales in grazing behaviour

The environment of free-ranging livestock can be viewed as mosaic of units at different spatial scales, ranging from the landscape level of a herd's home range (order of magnitude 1-100 km²) down to the dm² scale of individual bites. Evidently larger spatial scales should also be considered with respect to seasonal ranges, such as in mountainous environments, and viable populations or even species persistence of wild herbivores. The grazing process operates across this range of spatial scales (Fig. 1; Bailey *et al.*, 1998; Rook *et al.*, 2004).

Local depletion and foraging selectivity are the main motivations for short-term movements within a feeding bout between bite locations (head movements), between feeding stations (a single step) and between patches (series of steps) within a feeding site (WallisDeVries *et al.*, 1999), where animals graze for a longer period of several hours. At larger scales of time and space, decisions are made on the selection of plant communities, landscape types and seasonal ranges. These involve trade-offs between the energy gains of staying against the temporary costs of travel to other feed-

ing sites with more abundant resources. Here, other currencies besides energy and protein, such as water or minerals (particularly phosphorus and sodium; McNaughton, 1990; WallisDeVries and Schippers, 1994) may play a role in the selection process. Selection can occur at each scale level and may accumulate across scale levels.

Selectivity is also affected by social interactions between herd members leading to intraspecific competition, which increases with stocking rate (Lawrence and Wood-Gush, 1988) and is affected by social status (Hewitson *et al.*, 2007). In complex environments, the experience of herd members may also result in foraging decisions for the entire herd at higher spatial scales (Prins, 1996).

Foraging selectivity may differ as a result of variation in body size, morphology and digestive physiology between species (Hofmann, 1989; Cromsigt *et al.*, 2009) and breeds (Rook *et al.*, 2004). Variation in body composition and, hence, basal metabolic rate between species (Richmond *et al.*, 1977; Christopherson *et al.*, 1978; 1979) and breeds (Wright and Russel, 1984; Webster, 1985) may also lead to differences in foraging selectivity, as voluntary intake and growth rate are positively related to energy requirements (Ketelaars and Tolkamp, 1992). Thus, the higher energy requirements of dairy breeds compared to beef breeds (Thompson *et al.*, 1983; Solis *et al.*, 1988) and of early maturing than late maturing breeds (Mason, 1971) is likely to lead to a greater selectivity for patches with high intake rates of digestible dry matter, although well documented examples are rare (see Rook *et al.*, 2004). Thus, in a comparative study of two Aberdeen Angus genotypes, Cid *et al.* (1997) found that, at the end of the growing season, sward height structure was more heterogeneous in paddocks grazed by the more selective early maturing genotype, at a similar overall mean herbage mass. This greater patchiness may have subsequent impacts on biodiversity.

III – Spatial scales in wildlife habitats

Arthropods have been found to be generally more vulnerable to grazing intensity than plants (Van Klink *et al.*, 2015a), which warrants a focus on arthropods as biodiversity indicators in grazing systems. Amongst arthropods, butterflies are appropriate organisms to illustrate spatial scales of wildlife habitats from bite level to home range level (Fig. 1). Relevant spatial scales for plants are typically smaller and those for birds are mostly much larger (WallisDeVries, 2002). Moreover, the ecological relations of butterfly species in Europe have been comparatively well studied in comparison to other insect groups (Thomas, 2005). In order to understand habitat requirements for butterflies, as well as for other species, a resource-based perspective (Dennis *et al.*, 2003) has proved fruitful. Here, the habitat is defined as the full set of essential resources and conditions required by an organism to complete its life cycle. Thus, butterflies will need to find, amongst others, nectar plants, shelter and roosting sites as adults, food plants in a suitable microclimate for oviposition and larval development. As cold-blooded animals, they are sensitive to microclimatic conditions, especially during the larval stages. In temperate regions, this means warm and sheltered conditions at the microscale of decimetres in early stages to metres for late instars. This restricts many species to low-productive environments with low dead:green ratios of plant biomass in spring (WallisDeVries and Van Swaay, 2006). The distribution of all essential resources and conditions may show a complete spatial overlap in a single patch at a scale of <1 ha, but they may also be spatially disjunct. In that case, the daily mobility of the butterfly (x100 m in many species) will determine whether the distance between separate resources may be bridged to obtain a functionally adequate habitat (Vanreusel *et al.*, 2007).

The dispersal capacity of butterflies varies greatly between species. However, in many species that are considered habitat specialists in the modern anthropogenic landscape (WallisDeVries, 2014), dispersal is limited to a few kilometres. As the density of individuals is often low and yearly fluctuations in population size are large due to climatic variation and parasitoids, local populations can maintain themselves only when the size of a habitat patch is in the order of hectares (Schtickzelle

and Baguette, 2009). In the long run, this is insufficient for a viable population because of the extinction risk due to stochastic events. A network of patches is then required, all the more so because in the modern fragmented landscape individual patches are often much smaller than one hectare. Many butterflies thus typically require a metapopulation structure at a landscape scale for long-term population persistence (Schtickzelle and Baguette, 2009).

In the light of the overwhelming diversity of arthropod life histories, it is essential to distinguish species according to their life history traits (e.g. WallisDeVries, 2014) in order to understand contrasting responses between (groups of) species (see Van Klink *et al.*, 2013; WallisDeVries *et al.*, 2016).

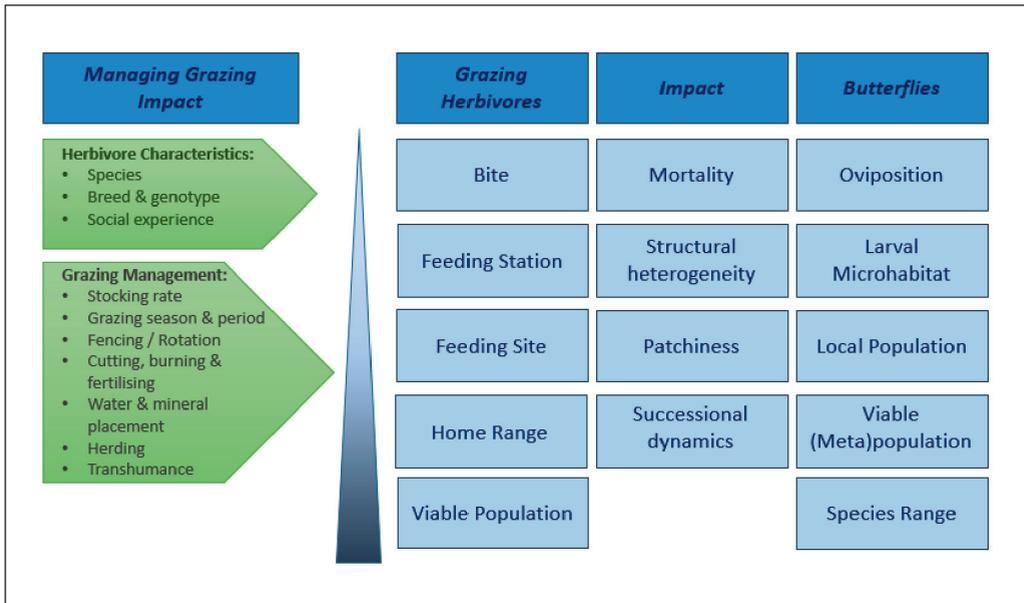


Fig. 1. Options to manage grazing impact in relation to spatial scales of grazing and its impact on butterflies and their habitat.

IV – Spatial scales of grazing impact

Four main types of impact of grazing ungulates on butterflies and other arthropods can be identified (Van Klink *et al.*, 2015a): (i) disturbance and unintentional predation, (ii) reduction of plant resource availability by defoliation or trampling, (iii) increase in resource availability for dung-dependent insects and (iv) changes in habitat quality through alterations of plant diversity, vegetation structure and abiotic conditions. The first two impacts are detrimental, but the third is beneficial and the fourth may be either detrimental or beneficial. Beneficial impacts may be expected when grazing (a) increases resource availability by suppressing competitors of hostplants or by enhancing plant regrowth for herbivore species and by increasing dung availability for coprophagous insects or (b) improves microclimatic conditions by affecting vegetation structure. These impacts vary with spatial scale (Fig. 1).

The level of the bite is the basic unit determining not only the impact on vegetation structure but also the direct impact on the least mobile stages in the butterfly life cycle. Van Noordwijk *et al.* (2012) provide rare evidence of mortality in overwintering *Melitaea cinxia* caterpillars due to grazing events. Although grazing during periods of insect activity is likely to cause less severe mortality, evidence

on substantial mortality due to cutting (Humbert *et al.*, 2009) suggests that this impact should not be underestimated. Furthermore, travel between feeding stations by grazing animals may cause disturbance and also increase dispersal activity in smaller animals, as has been documented in grasshoppers (Berggren, 2004). Trampling can not only directly kill arthropods, but also affect habitat conditions indirectly through soil compaction and the creation of bare ground (Van Klink *et al.*, 2015b). Whereas dung represents a crucial resource delivered by grazing livestock to dung beetles and other coprophagous insects, these insects may also suffer mortality through trampling at high stocking rates (see Van Klink *et al.*, 2015a).

Selective foraging has been supposed to maximise arthropod diversity through the creation of a patchy vegetation mosaic (Dumont *et al.*, 2012). Indeed Cherrill and Brown (1992) have shown that the grasshopper *Decticus verrucivorus* requires a combination of short and tall vegetation to find food, shelter and optimal thermoregulation. Grasshopper species richness has also been shown to increase with greater patchiness under cattle grazing (Jerrentrup *et al.*, 2014). Structural heterogeneity also appears a prerequisite for butterfly species such as *Melitaea cinxia* (WallisDeVries, 2006) and *Maculinea alcon* (WallisDeVries, 2004). However, this may apply especially to the larger and more mobile arthropods. For small and sedentary species, grazed mosaics may rather function as a patchwork of suitable and hostile habitats, following the principles of island biogeography (Cole *et al.*, 2010; Van Klink *et al.*, 2013). For such small species, horizontal patchiness can also result in large edge effects that may compromise the vertical architectural complexity which strongly determines the variation in arthropod niches (Tscharntke and Greiler, 1995). Indeed, Van Klink *et al.* (2013) did find a higher overall species richness of arthropods in tall, ungrazed salt-marsh vegetation than in homogeneous short vegetation grazed by sheep, but species richness was similar in tall vegetation and in patchy mosaics. Still, in heathland insects it has been shown by WallisDeVries *et al.* (2016) that an array of species depends on intensively grazed vegetation in dry heathland, particularly thermophilous species and species depending on prostrate plants with low competitive ability. In contrast, species requiring more humid microclimates and those associated with large tussock grasses or grazing-intolerant herbs were found mostly in lightly grazed wet heathland. Such species-specific responses to grazing intensity may be placed in a perspective of vegetation succession, with contrasts between species from early and late successional stages.

Another effect of selective grazing is an alteration of plant species composition in the vegetation. Grazing may both increase plant species diversity by preventing the encroachment of dominant grasses and shrubs as well as reduce it by overgrazing of palatable species (Olf and Ritchie, 1998). Here, differences between livestock species may affect the outcome. For example, the great ability of sheep forage selectively on herb species may reduce overall species richness (Schoier and Dumont, 2012) and flower abundance (Schoier *et al.*, 2013), with negative effects on various insect groups. Thus, sheep grazing has caused losses of populations of the rare butterfly *Euphydryas aurinia* in the United Kingdom and Ireland, due to overgrazing of its host plant *Succisa pratensis* (see WallisDeVries, 2002).

The less selective grazing behaviour of cattle rather tends to benefit plant species richness by suppressing dominant grasses (see Rook *et al.*, 2004). Horses tend to select for grasses and because of their ability to bite down close to the ground, they may create greater contrasts in patchiness than cattle (Nolte *et al.*, 2014). The higher daily activity of horses than cattle generates considerably greater trampling effects on the vegetation, with potentially negative effects on tall flowering plants and associated insects, but with particularly detrimental effects on nesting birds (Mandema *et al.*, 2013).

At larger spatial as well as temporal scales, grazing may lead to successional mosaics of grassland, scrub and woodland, with unpalatable or thorny shrubs acting as grazing refuges for tree recruitment (Olf *et al.*, 1999). In such woodland pastures, there is not only an impressive floristic diversity (WallisDeVries *et al.*, 1998) but also a high faunistic diversity, e.g. in butterflies (Bailey *et al.*, 1998). Overgrazing then may lead to a virtual disappearance of the structural heterogeneity of shrub and woodland edges and, hence, an impoverished arthropod diversity (Van Klink *et al.*, 2016).

V – Targeting grazing impact

Targeting grazing impact in order to optimise plant and animal diversity against the socio-economic requirements of maintaining viable livestock grazing systems is a complex puzzle. Fortunately, there are many options to manipulate grazing intensity and grazing patterns. This especially involves reducing grazing intensity of overgrazed or preferred sites on the one hand, and increasing the attractiveness and use of underutilised or avoided sites on the other hand (Bailey *et al.*, 1998).

A first series of measures to modify grazing impact consists of selecting appropriate species, breeds and, especially in complex environments, individuals with social and local experience (see section II; Rook *et al.*, 2004). Although traditional breeds do not offer biodiversity benefits *per se* (Wallis-DeVries *et al.*, 2007), their often lower metabolic requirements may render them more prone to graze less digestible tall and tussock grasses or exploit less accessible terrain. Besides the choice of grazing animal, combinations of livestock species may also influence resource exploitation. Thus, goats can be more successful in controlling shrub encroachment than sheep (Osoro *et al.*, 2013). Mixed grazing by sheep and cattle also may lead to an enhanced arthropod abundance and, hence, greater breeding abundance of meadow pipits *Anthus pratensis* than sheep grazing alone (Dennis *et al.*, 2008). The benefits of mixed grazing on insect diversity appear to be greater at low plant diversity than at high plant diversity, especially through its impact on structural heterogeneity (Zhu *et al.*, 2012).

Manipulating stocking rate is an obvious and effective measure to modify grazing intensity. In production-oriented grazing systems, extensification may provide rapid biodiversity benefits to insect communities (WallisDeVries *et al.*, 2007) that may extend over longer time periods, although benefits may be lost with further extensification (Jerrentrup *et al.*, 2014), due to the encroachment of competitive plants.

Differentiation in grazing intensity at small to moderate spatial scales (size order 0.1-1 ha) may be achieved by rotational grazing. This may result in increased flower abundance and higher densities and species richness of butterflies and other pollinators (Farruggia *et al.*, 2012; Scohier and Dumont, 2013). However, there is an, as yet uninvestigated, risk that subsequent grazing may turn the temporarily ungrazed refuges to 'ecological traps' when these are not only used for foraging but also for reproduction. Van Klink *et al.*, (2016) emphasize the value of edges between grazed and ungrazed areas for arthropod diversity; at high grazing intensity, creating such grazing refuges by fencing may be an easy alternative to a reduction in stocking rate. When space is less limiting, rotation with extended grazing intervals over a greater number of paddocks may be considered. Morris *et al.* (2005) reported on a case study where such a complex rotation system was successfully applied on chalk grassland. In any case, such rotational grazing systems do show promise to reconcile objectives for livestock production and biodiversity to a considerable extent (Farruggia *et al.*, 2012).

At larger spatial scales, selective foraging in heterogeneous environments may result in overgrazing of vulnerable patches and undergrazing of areas where grazing is desired, e.g. to suppress dominant grasses or shrubs. Probo *et al.* (2014) investigated a rotational grazing in alpine mountains, with a rotation over 6 paddocks of c. 100 ha each that were grazed by cattle in 3-week periods. In the rotational system, cattle were indeed showing a less aggregated grazing pattern and exploited steeper slopes to a greater extent than in a continuous grazing system. Another option for grazing less attractive vegetation is by enclosing livestock in temporary night camps or by placement of mineral supplements. In such areas, pressure grazing on dominant dwarfshrub vegetation resulted not only in a greater cover of bare ground, but also a higher cover and pastoral value of the herbaceous vegetation as well as an increased dung beetle diversity (Tocco *et al.*, 2013). Probo *et al.* (2013) also experimented with the placement of mineral supplements and again found that the increased use by cattle reduced shrub cover and increased forage pastoral value in shrub-encroached alpine pastures. Manipulating access to water may be used in a similar way as mineral supplement placement to manipulate livestock distribution (Ganskopp, 2001).

Further options to increase the attractiveness of grazing areas are by prescribed burning, cutting and fertilising (Bailey *et al.*, 1998). However, with all these options, negative effects on biodiversity should be taken into consideration. Thus, burning may be detrimental to reptiles (Lyet *et al.*, 2009) and insects (Swengel, 2001), although superficial burning in late winter may prove beneficial (e.g. Panzer, 2002). Small-scale application of such measures can therefore be recommended for all these measures.

Grazing patterns over truly large spatial scales, exceeding the landscape scale (>10-100 km²), are currently rare in European livestock grazing systems. Transhumance systems, as described by Ruiz and Ruiz (1986) in Spain or by Poschlod and WallisDeVries (2002) in Germany are no longer functioning, although they are thought to have played a major role in the dispersal of plant seeds and they are likely to have contributed to further aspects of landscape heterogeneity and biological diversity. Thus, Dolek and Geyer (2002) describe the challenges and the potential of a shepherded grazing system with sheep (and goats) as a practical low-intensity land use type to maintain biodiversity in calcareous grasslands of Bavaria. With ongoing abandonment of marginal lands for high-intensity agriculture, there may be new potential to reinstate such large-scale grazing systems in a modern of sustainable land use (Cubbage *et al.*, 2012).

VI – Conclusion

Over recent decades, considerable progress has been made to elucidate the impacts of low-intensity grazing on biodiversity. Taking into account spatial-dependent processes in grazing systems is a crucial step in this development. With a growing emphasis to understand the mechanisms behind the emerging patterns, we are getting better equipped to optimise grazing management in relation to the conservation, and even restoration, of biological diversity. Trait-based approaches have become an important tool of the equipment.

However, in the face of the variation and complexity of low-intensity grazing systems, the evidence base on the effects of targeted grazing practices on biodiversity is still weak. Also, many studies that rely on counts of the mobile stages of adult arthropods cannot reliably distinguish between short-term concentration effects and long-term population responses (Scheper, 2015). The challenge to solve this knowledge gap can be met by a combination of (a) research involving creative field experiments that focus on the mechanisms of biodiversity responses and (b) practical implementation of adaptive management that builds on a continuous feedback from sound monitoring. Finally, we still face the major challenge to adequately incorporate the biodiversity benefits of low-intensity grazing systems in the larger framework of sustainable land use (Maes *et al.*, 2012; Siepel *et al.*, 2013; Fraser *et al.*, 2014).

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Flower-foraging insects and their pollen loads in mountain permanent grasslands

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Abstract. Semi natural grasslands are considered as a vital habitat for wild pollinators, which in return contribute to preserve the floristic diversity of this environment. To study the interactions between pollinators and plants, flower-foraging insects were caught from beginning of May to end of June along walking transects in 6 mountain permanent grasslands in Cantal (France). We developed and test in parallel a method based on DNA barcoding analysis, allowing a quick identification of the insect and its pollen load at the same time. We collected thus 394 flower visitor insects, most of them belonging to Diptera (72%) of which comprised 32% Empididae and 20% Syrphidae, and 20 % belonging to Hymenoptera of which 80% were wild native and domestic bees. Three families of flowers (Asteraceae, Apiaceae and Ranunculaceae) comprised two thirds of the total flowering species from which the insects were collected. DNA barcoding of these insects showed that 87% of the collected insects were carrying pollen and 45% were carrying two genders of plants or more. Results suggest the important role of the Diptera as wild pollinators at this period in such mountain environment. Moreover, our results have demonstrated that the DNA barcoding is a powerful tool to study flower-foraging insects and their pollens loads which will be very soon operational.

Keywords. Mountain grasslands – Flower-foraging insects – Pollination – Interactions plants-insects – DNA barcoding.

Insectes butineurs et transport de pollen dans les prairies permanents de montagne

Résumé. La pollinisation des plantes prairiales est un processus biologique essentiel qui assure le maintien de la diversité floristique des prairies permanentes. Pour étudier ces interactions plantes-insectes, nous avons capturé les insectes butinant les fleurs sur des transects dans 6 prairies permanentes du Cantal, contrastées du point de vue floristique. Nous avons développé et testé en parallèle une méthode d'analyse basée sur le barcoding, permettant la détermination simultanée de l'insecte et de son cortège de pollens. Nous avons ainsi piégé 394 insectes butineurs, très majoritairement des Diptères (72%) dont 32% d'Empididae et 20% de Syrphidées, ainsi que 20% d'Hyménoptères dont 80% d'abeilles domestiques et sauvages. Les Astéracées, Apiacées et Renonculacées comptabilisent les 2/3 des visites. L'analyse des barcodes ADN des pollens a montré qu'une forte proportion des insectes capturés (87%) transportait du pollen et 45% transportaient deux à six genres botaniques différents. Les résultats mettent en évidence le rôle important des Diptères dans les prairies de montagne en tant que pollinisateurs potentiels importants à cette période de l'année. Notre étude a par ailleurs démontré que le barcoding est un outil pertinent et puissant qui sera très bientôt opérationnel.

Mots-clés. Prairies permanentes de montagne – Insectes butineurs – Pollinisation – Interactions plantes – Code barre ADN.

I – Introduction

In the mountain regions, permanent grasslands constitute the main agricultural area and the primary food supply for domestic ruminants. They represent therefore a crucial issue for these territories. The preservation of their plants diversity is bound to the stability of agricultural management but also to the pollination, natural process allowing reproduction and long-term maintenance of plants. Pollinating insects, carrying pollen from flower to flower, mainly in search of their food, are active pollen vectors and consequently important actors of the reproduction of grassland dicotyledons. However, the role and the importance of many flower-foraging insects in pollen transport are still poorly understood in grassland context especially in mountain areas. Most studies on pollination process focus indeed on crops and/or highlight the role of the grasslands as a source of vital pollinators for entomogames neighboring crops in mixed farming breeding (Rollin *et al.*, 2013). Grasslands are paradoxically poorly studied in terms of intrinsic pollination. Increase our knowledge on transport pollen by insects in grasslands is an important scientific goal that would help us to better define the issue of pollination in these types of areas. In that context, the current development of DNA analysis (DNA barcoding) presents an opportunity to assess the plant-pollinator webs. In this study, we set up field observations in mountain grasslands to explore the flower-foraging insect networks and we tested in parallel the DNA barcoding method as an alternative tool to enhance our knowledge on those interactions.

II – Materials and methods

The study was implemented in the INRA experimental farm in Marcenat (Cantal, France – 45.3046N, 2.8378E, alt 1000m), located on a mountain grassy volcanic plateau. The site is characterized by a high mean annual precipitation (1205 mm, 1989-2009) and a cold mean annual temperature (7.5°C) even in summer (July: 15.4°C, August: 15.5°C). Six semi natural grasslands were sampled displaying two management regimes (mown and grazed) and three management intensities (low, medium and high level) along a floristic richness gradient. Flower-foraging insects, collecting actively pollen and/or nectar, were caught along a walking 100m-transect under clement weather conditions. Time spent per transect was 15 min gross (chronometer stopped each time an insect was caught). Three sampling periods of 2 or 3 days of trapping were done: between 7 May and 12 May (P1, 2 days), between 28 May and 2 June (P2, 3d) and between 17 and 22 June (P3, 3d). In total, 48 transect observations were done (6 plots x 8 days). Order of transects varied according the day of trapping, so that each grassland were observed in the morning, at midday or in the afternoon during a period.

Most of the insects were caught directly in a sterile vial to reduce contamination for further DNA analysis and were brought back to the laboratory. Only a few fearful insects were first caught in a clean net and then transferred directly in a sterile vial. Pollen was removed from the insect body by adding ethanol in the vial containing the insect and shaking it firmly. The insect was then removed from the vial and pinned for visual identification.

To identify insects and their pollen loads using DNA barcoding, the alcohol solution containing the pollen extracted from the insect was filtered while the 2 front legs of the insects were taken. Finally, the filter was placed in the microtube with the 2 respective legs and 30 µL of a buffer solution. Once DNA was extracted and amplified with PCR, pollen and insect were analyzed simultaneously using a small region of the Cytochrome Oxidase Subunit 1 (COI) (Hebert *et al.*, 2003) for insects and the ribosomal ITS region which includes ITS2 (Keller *et al.*, 2014) for pollens. Only the insects and their pollen of the two first collecting periods were analysed by barcoding.

III – Results and discussion

Over the three periods, we observed and caught a total of 394 flower-foraging insects (76 in P1, 160 in P2 and 158 in P3). Abundance was higher in plots with high level of botanical diversity: average of 11 and 12 individuals trapped per transect in cut and grazed plots respectively against 6 individuals in plots cut or grazed with low level of diversity. We identified 11% of the individuals to family level, 37% to genus level and 37% to species level. Fifteen percent remained undetermined, mainly small individuals (< 7mm), and were morphotyped. Diptera represented 72% of the total catches far ahead from Hymenoptera (20%), Lepidoptera (5%) and Coleoptera (3%). Five families of Diptera counted 62% of the total catches (Empididae, Syrphidae, Scathophagidae, Sphaeroceridae, Indetermined<7mm). Empididae was the most abundant family among the total catches (23%) as among Diptera (32%), followed by the Syrphidae (14% of total catches and 20% of the Diptera). Small undetermined flies represented 21% of the Diptera. Apidae (*Apis* and *Bombus*) and Halictidae families counted each for 7% of the total catches following by the Andrenidae family (3%). All these insects were foraging on 36 plants species belonging to 16 botanical families. Most of them were found on Asteraceae (118 visits: 30%) such as *Taraxacum* (71 visits), Ranunculaceae (18%) such as *Ranunculus acris* and *Ranunculus bulbosus*, and Apiaceae (15%) such as *Conopodium majus*. These three families encompassed 63% of the total flowering species from which the insects and mainly Diptera (207 individuals) were collected. Caprifoliaceae family, represented by a single genus (*Knautia*) counted 37 visits (9%), mainly of wild bees, Syrphidae and Lepidopterae.

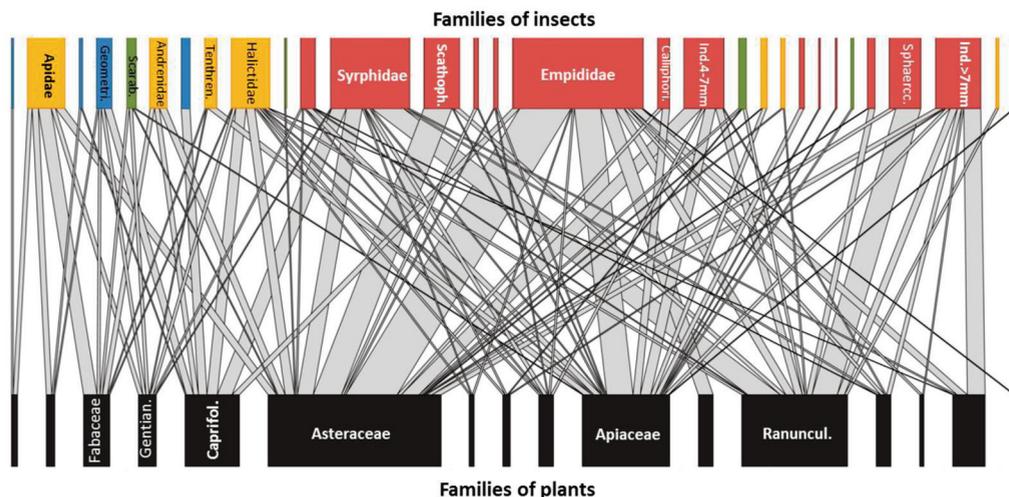


Fig. 1. Flower-forager insects network obtained from visual surveys. Rectangles represent insect families (above) and plants (below). Their widths are proportional to the sum of interactions involving them. Colours of the rectangles differ according to the insect orders.

The flower-forager network (Fig. 1) highlights that Diptera foraged 13 of the 16 plant families foraged by insects. Only the Fabaceae, the Orobanchaceae (*Rhinantus* sp.) and the Lamiaceae were not visited by flies. Empididae (Diptera) were the insect group with the largest foraging range by foraging 11 different families, mostly Asteraceae and Apiaceae. Moreover, they were the only insects to forage little flowers such as *Veronica* sp., *Viola lutea* and *Cruciata laevipes*. The Syrphidae visited also several plant families (10), mostly the Asteraceae, the Caprifoliaceae and the Ranunculaceae. Likewise, almost all of the Scathophagidae individuals were found on Asteraceae and

most of the Sphaeroceridae on Ranunculaceae. Regarding the domestic and wild bees, Apidae foraged five plant families with a preference for Fabaceae. Halictidae visited ten plant families mainly Caprifoliaceae and Asteraceae, while the Andrenidae were found only on three families. Wasps (Ichneumonidae) and sawflies (Tenthredinidae) were found nearly exclusively on Apiaceae. Although they were not abundant in our catches, the three families of Coleoptera and the four families of Lepidoptera visited a large range of families of plants (8 and 5 families of plants respectively). Our study allows pointing out that Diptera are key-flower-foraging insects at the beginning of the grazing season in our mountain grasslands. These results confirm the observations of Orford *et al.* (2015) who have recently underlined the role of these “forgotten” insects in pollination process. Like Lefebvre *et al.* (2014) in alpine meadows, we have shown that Empididae were important flower visitors. We have also observed that some small Empididae are only forager insects of three small flowers, which suggests the importance of these species in pollen dispersion for tiny blossoms. Finally, we have underlined the role of the “dung flies” (Scathophagidae) who constituted 9% of our captures of Diptera. Their reputation of effective carrier of pollen because of their plentiful pilosity has been already demonstrated by Skevington and Dang (2002). Our results corroborate the hypothesis of Pouvreau (2004) who suggests that Diptera may play an important role in pollination in regions with harsh climatic conditions such mountain areas in which pollinators like Apoidea are inactive a long period of the year. Those results allow also alerting about the very little number of taxonomists who are able to identify species from this key order beyond Syrphidea.

Regarding our DNA barcoding results, pollen was detected and identified on the body of 82% of the insects caught. The key result is that 42% of these individuals transported a mixed pollen load, composed from two different plant genera up to six genera (2% of individuals). Moreover, we have also highlighted that 3% of the insects transport pollens from non-grassland plants such as *Betula sp.*, *Quercus sp.* and *Salix sp.* However, our identifications of the insect species were less successful. We identified only 27% of the insects, most of them being Diptera (84%). Twenty four percent were not identified while the PCR produced enough reads to identify them. This result means that the individuals were not still referenced in the international databases. The barcoding of every insect is indeed in progress and represents a challenging goal in view of the huge insect species number. Another 106 individuals remained nevertheless undetermined, most of them being Hymenoptera and very small flies (< 4mm), for which the PCR produced no reads or not enough reads. PCR issue due to non-universal primers seems the main reason of Hymenoptera identification failure. Concerning the small flies, the difficulties of identification can be due to the very little quantity of DNA material we have obtained with the two tiny legs. Nevertheless, we have proved the powerfulness of the DNA barcoding for pollination study applications but we have also shown that the technique needs to be improved to be fully operational. In an immediate future, DNA barcoding will be a new tool in the taxonomists toolbox supplementing their knowledge as well as being an innovative device for non-experts who need to make identification for ecological studies (<http://www.barcodeoflife.org>).

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Wild herbaceous legumes for pasture restoration in the Sierra Nevada Natural Park: forage and seed yields

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Abstract. This study evaluates the forage and seed yield of 16 wild annual legume species which were grown in two different forest sites in the Sierra Nevada Natural Park (Granada, SE Spain). Because “Sopotújar”, an abandoned tree nursery, had been used as a sheepfold in recent years, its soil fertility was very high. “Lanjarón” was a pine plantation (*Pinus pinaster*) with low soil fertility. Rainfall during the growing cycle reached only 53% and 66% of the mean historical rainfall levels for Sopotújar and Lanjarón, respectively. Nevertheless, productivity was found to be high in Sopotújar, with yields of up to 7850 kg ha⁻¹, while Lanjarón recorded yields of only up to 487 kg ha⁻¹. *Vicia monantha* had the highest forage productivity levels in both sites. *Vicia disperma*, *Lathyrus clymenum*, *L. cicera* (only in Lanjarón), *Medicago truncatula* (only in Sopotújar) and *M.rigidula* (only in Lanjarón) were the most productive species. In Lanjarón, weather and soil conditions resulted in very poor fructification levels (almost inexistent). In Sopotújar, *Vicia monantha* had the highest seed yield (1234 kg ha⁻¹), followed by *Vicia lutea* and *L. clymenum* (460 and 457 kg ha⁻¹, respectively). Our results indicate that *V. monantha*, *V. disperma*, *L. cicera*, *L. clymenum*, *M. rigidula* and *M. truncatula* are the species best adapted to the environmental conditions of our experiment. More research needs to be carried out to confirm our findings and to develop new seed and soil management systems to improve forage and seed yields.

Keywords. Mediterranean rangeland – *Vicia* – *Lathyrus* – *Trifolium* – *Medicago*.

Légumineuses herbacées sauvages pour la restauration des pâturages dans le Parc Naturel de Sierra Nevada: production de fourrage et de semences

Résumé. Ce travail évalue la production de fourrage et de semences de 16 espèces légumineuses annuelles qui ont été cultivées dans deux domaines forestiers du Parc Naturel de Sierra Nevada (Grenade, Espagne). Le site “Sopotújar” était une pépinière forestière abandonnée, utilisé comme une bergerie au cours des dernières années, avec un niveau de fertilisation du sol élevé. Le site “Lanjarón” était une plantation de *Pinus pinaster*, avec une faible fertilité des sols. La pluviométrie pendant notre étude fut seulement 53% et 66% de la moyenne pluviométrique historique (Sopotújar et Lanjarón, respectivement). Cependant, une productivité élevée a été trouvée à Sopotújar (jusqu’à 7850 kg ha⁻¹); au contraire, Lanjarón n’atteignit que 487 kg ha⁻¹. *Vicia monantha* eut la productivité fourragère la plus élevée pour les deux sites. *Vicia disperma*, *Lathyrus clymenum*, *L. cicera* (seulement à Lanjarón), *Medicago truncatula* (uniquement à Sopotújar) et *M. rigidula* (seulement à Lanjarón) étaient aussi entre les espèces les plus productives. À Lanjarón, la production de semences fut presque nulle, à cause des conditions climatiques et du sol. À Sopotújar, *V. monantha* eut le rendement le plus élevé des semences (1234 kg ha⁻¹), suivie par *Vicia lutea* et *L. clymenum* (460 et 457 kg ha⁻¹, respectivement). Nos résultats indiquent que *V. monantha*, *V. disperma*, *L. cicera*, *L. clymenum*, *M. truncatula* et *M. rigidula* sont les espèces les plus adaptées aux conditions environnementales de cette étude. D’autres expériences sont nécessaires pour confirmer nos résultats, ainsi que pour trouver d’autres modes de gestion du sol et des semences pour augmenter la production.

Mots-clés. Pâturage méditerranéen – *Vicia* – *Lathyrus* – *Trifolium* – *Medicago*.

I – Introduction

Pasture restoration is considered to be one of the keys to mitigating the impact of climate change (Lal, 2003). Annual self-reseeding legumes have great potential for improving and restoring pastureland in semiarid areas given their good fodder quality, mainly due to their high protein content, low establishment requirements, their N fixation capacity and, thus, their ability to satisfy the nutritional needs of other plants (Porqueddu and González, 2006). However, their use in pasture improvement and restoration programs in natural areas should be restricted to autochthonous species and ecotypes, for which seeds that have been collected and/or produced in those areas are required. This study therefore evaluates the forage and seed yields of 16 wild legume species whose seeds were harvested in the field and grown in two different mountain forest sites in the Sierra Nevada Natural Park (Granada, SE Spain).

II – Materials and methods

The trials were carried out at two sites in the Sierra Nevada National Park: (1) Lanjarón (Cortijo Quemado), which used to be a pine plantation (*Pinus pinaster*), and (2) Soportújar (Vivero de la Sombra), an abandoned tree nursery, which had been used as a sheepfold in recent years. Table 1 summarizes the main characteristics of each site.

Table 1. Characteristics of the two study sites. N.D.: non detectable

	Lanjarón	Soportújar
UTM coordinates	30 S 455850 4088670	30 S 463814 4088725
Altitude (m.a.s.l.)	1320	1352
Rainfall (mm) [†]	281 (428) [†]	366 (685) [†]
Soil parameters		
– Texture	Sandy loam	Sandy loam
– ECC (meq /100 g ⁻¹)	11.13	14.78
– pH (1/2.5,v/v)	6.5	5.9
– Organic Matter (%)	2.7	3.7
– Total N (%)	0.162	0.202
– Total P (p.p.m.)	N.D.	34
– Total K (p.p.m.)	154	550

[†] Rainfall during growing cycle and, in brackets, historical average for the sites.

Seeds were collected in the field (fallows, slopes, shoulders of roads, grasslands, etc.) during late spring and early summer 2013 and were sown in October. The following species were sown, with the seeding rate given in brackets: *Medicago* L. spp. (3 g m⁻²), *Medicago polymorpha* L. (3 g m⁻²), *M. rigidula* L. (All). (4 g m⁻²), *M. orbicularis* (L.) Barta (4 g m⁻²), *Lens nigricans* (M. Bieb.) Godr. (6 g m⁻²), *Trifolium cherleri* L. (3 g m⁻²), *T. glomeratum* L. (1.5 g m⁻²), *Lathyrus cicera* L. (15 g m⁻²), *L. clymenum* L. (12 g m⁻²), *L. sphaericus* Retz. (10 g m⁻²), *L. tingitanus* L. (15 g m⁻²), *Vicia amphicarpa* L. (9 g m⁻²), *Vicia disperma* DC (10 g m⁻²), *V. monantha* Retz. (9 g m⁻²), *V. lutea* L. (12 g m⁻²) and *V. sativa* L. (12 g m⁻²). *Medicago* spp. is mainly composed of *M. truncatula* and also of *M. polymorpha*, and *M. rigidula*.

The experimental design used was a randomized block with four replicates per species. Each replicate consisted of a 2 x 1.5 m plot. Prior to the establishment of the plots, the entire experimental area (in both sites) was ploughed to create a suitable seedbed. Each plot was then fertilized with a pelletized organic amendment composed of a mixture of turf and sheep manure (81.7% organic

matter, 2.6% total organic nitrogen, 2% P₂O₅ and 3.9% K₂O₅). The seeds were sown by hand in furrows 25-cm apart and were slightly covered with soil.

Forage yield was estimated in mid-May 2014 by hand-clipping plant forage in 4 randomly selected 25 x 25 cm quadrats in each plot. Samples were oven dried at 60° C to constant weight (48 h) to determine dry weight and dry matter (DM). Averaged data were extrapolated to one hectare. Seed yield was estimated (only in Soportújar) using the same procedure as that for forage yields. The seeds were manually extracted from each sample and weighed. In Lanjarón, spring drought together with poor soil quality led to very poor fructification (almost zero). However, in Soportújar, thanks to better soil conditions and higher precipitation rates, fruits grew and matured, thus enabling seed yield to be estimated. Forage yield data were analysed using the GLM procedure of SPSS. The Levene and Shapiro-Wilk tests were used to check homoscedasticity and normality, respectively, in order to ensure that the model's assumptions were met. No data transformation was needed. In each site, one way ANOVA and the LSD *post hoc* test were used to determine differences among species. Seed yield data were analysed using the non-parametric Kruskal-Wallis test, as homoscedasticity and normality were not accomplished, and also by using the pair-wise comparison *post-hoc* test.

III – Results and discussion

Forage yield in Lanjarón was low, ranging from 45.9 to 487 kg DM ha⁻¹. The most productive species, with over 300 kg DM ha⁻¹, were *V. monantha*, *L. cicera*, *V. disperma* and *M. rigidula*, while the least productive species, with up to 110 kg DM ha⁻¹, were *V. lutea*, *Medicago* spp., *V. sativa*, *T. cherleri* and *M. polymorpha* (Fig.1). These low values are probably due to the higher water requirements of *V. sativa*, *M. polymorpha*, *M. truncatula* and *V. lutea* and/or to higher levels of hard-seedness which might have led to low germination and consequently low establishment of *T. Cherleri* and *V. lutea* plants (Ramos *et al.*, unpublished). Similar results were obtained by Robles *et al.* (2015) in an analogous experiment carried out in the same area in 2009/2010, although the better rainfall conditions favoured slightly higher productivity for most species.

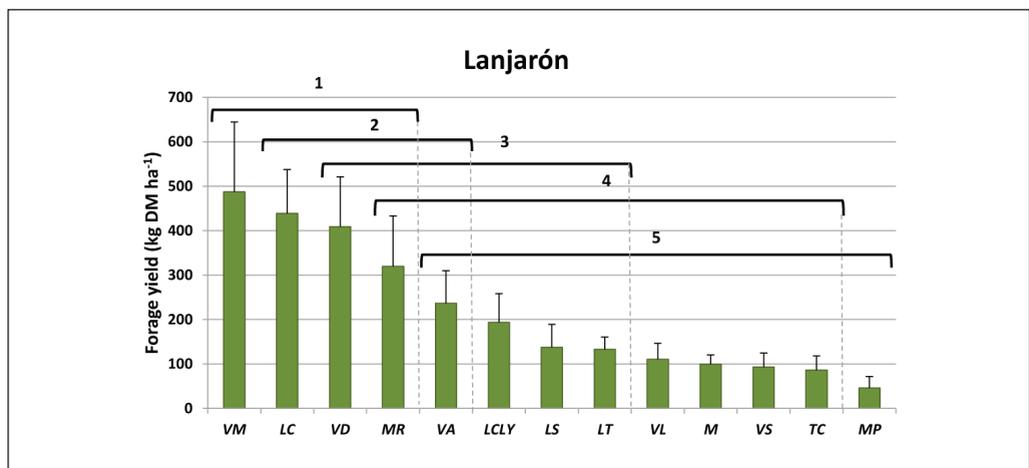


Fig. 1. Forage yield (kg DM ha⁻¹) in Lanjarón. VM: *Vicia monantha*, LC: *Lathyrus cicera*, VD: *Vicia disperma*, MR: *Medicago rigidula*, VA: *Vicia amphicarpa*, LCLY: *Lathyrus clymenum*, LS: *Lathyrus sphaericus*, LT: *Lathyrus tingitanus*, VL: *Vicia lutea*, M: *Medicago* spp., VS: *Vicia sativa*, TC: *Trifolium cherleri*, MP: *Medicago polymorpha*. The numbers above the horizontal brackets indicate significant differences among treatments (F = 3.158, d.f. = 12, p = 0.004; LSD test, p<0.05).

As a whole, forage yields in Soportújar, ranging from 265 to 7570 kg DM ha⁻¹, (Fig. 2), were notably higher than in Lanjarón, probably due to improved soil fertility, especially with regard to phosphorus (Porqueddu and González, 2006), and higher rainfall levels (see Table 1). *V. monantha* yielded the highest forage values (7570 kg DM ha⁻¹), followed by *V. disperma* (3622 kg DM ha⁻¹), *L. clymenum* (2796 kg DM ha⁻¹), *Medicago* spp. (2576 kg DM ha⁻¹) and *L. tingitanus* (2320 kg DM ha⁻¹) (Fig. 2). The lowest values were recorded by *M. orbicularis*, *L. nigricans*, *T. cherleri*, *T. glomeratum* and *L. sphaericus*, ranging from 265 to 665 kg DM ha⁻¹, probably due to the higher hardseedness levels of these species which might have led to low germination and consequently low establishment (Ramos *et al.*, unpublished).

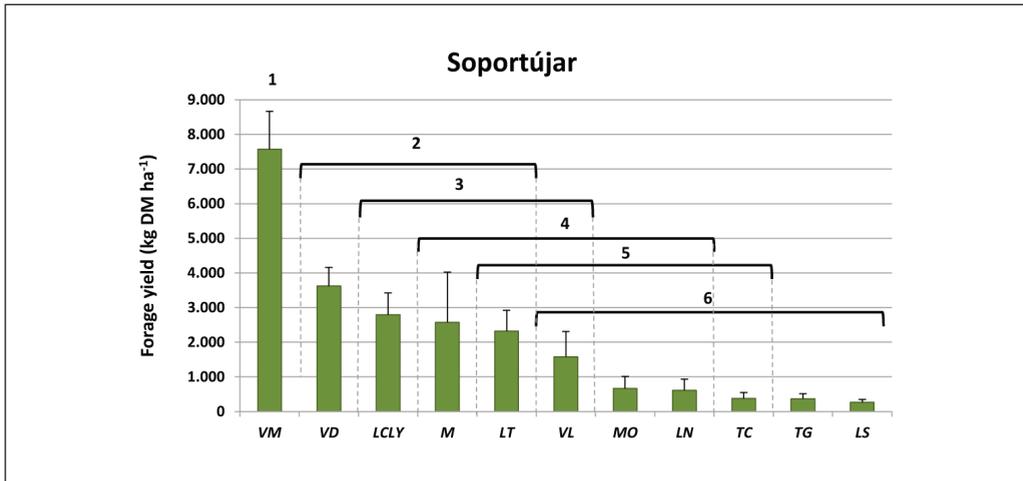


Fig. 2. Forage yield (kg DM ha⁻¹) in Soportújar. VM: *Vicia monantha*, VD: *Vicia disperma*, LCLY: *Lathyrus clymenum*, M: *Medicago* spp., LT: *Lathyrus tingitanus*, VL: *Vicia lutea*, MO: *Medicago orbicularis*, LN: *Lens nigricans*, TC: *Trifolium cherleri*, TG: *Trifolium glomeratum*, LS: *Lathyrus sphaericus*. The numbers above the horizontal brackets indicate significant differences among treatments (F = 3.158, d.f. = 12, p = 0.004; LSD test, p < 0.05).

In Soportújar, seed yield was consistent with forage yield, as the most productive species in terms of forage yielded more seeds (*V. monantha*: 1234 kg seeds ha⁻¹), while the least productive species produced the poorest seed yields (*L. sphaericus*: 66.7; *T. glomeratum*: 49.1; *T. cherleri*: 21.6 kg seeds ha⁻¹). Only *V. lutea*, which had a medium forage yield but the second highest seed yield (460 kg seeds ha⁻¹), showed a different pattern.

IV – Conclusions

On the basis of our findings, we would recommend *V. monantha*, *V. disperma*, *L. cicera*, *L. clymenum*, *M. rigidula* and *Medicago* spp. (predominantly *M. truncatula*) as the best species for the restoration and improvement of pastures, as they appear to be better adapted to the pedoclimatic conditions of the Sierra Nevada Natural Park. As soil fertility and rainfall may determine forage and seed yields, fertilization and irrigation could be necessary in order to increase seed and forage yields.

Despite these promising results, further research is required in order to increase productivity, especially with regard to species with very low yields.

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Immediate effects of prescribed burning on C-related topsoil properties in Central Pyrenees

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Abstract. Prescribed burning, i.e. the deliberate use of fire under specific conditions, is a management tool for recovering pasturelands affected by shrub encroachment. The objective of this work is to determine the immediate effects of prescribed burning on topsoil properties related to C cycle in soils covered with dense scrubs (*Echinospartum horridum*) in Tella (Huesca, Central Pyrenees, Spain). Soils were sampled in triplicate immediately before and after burning at 0-1 cm, 1-2 cm and 2-3 cm depths. We analysed the content of total oxidizable C (TOC); the content and mineralization rates of labile and recalcitrant C pools C, as inferred from incubation assays (141 days); microbial biomass C (MBC); and the β -D-glucosidase (GL) activity. All studied soil properties were significantly affected by fire, varying in terms of intensity and affected depth. Fire produced a significant decrease in TOC (-41% on average), similarly affecting the upper 3 cm of soil. The content of labile C decreased considerably (-87% on average) at depths up to 3 cm, but its mineralization rate increased (+ 150% on average). The MBC was particularly affected at 0-1 cm (-53%), while GL activity showed significant decreases throughout the upper 3 cm (-49% on average). These results show a strong impact on the studied soil properties just after burning. Monitoring the evolution of these soils is necessary to assess their resilience in the short and medium terms, and check the sustainability of controlled burning for pasture management in the Pyrenees.

Keywords. Pastureland – Controlled fire – Soil organic matter – Soil biological activity – Carbon mineralization.

Effets immédiats du brûlage dirigé sur des propriétés du sol superficiel liées au C dans les Pyrénées Centrales

Résumé. Le brûlage dirigé est un outil de gestion permettant le rétablissement des pâturages touchés par l'embroussaillage. L'objectif de ce travail est de déterminer les effets immédiats du brûlage dirigé sur les propriétés du sol superficiel liées au cycle du C dans des sols couverts par le genêt hérissé (*Echinospartum horridum*) à Tella (Huesca, Espagne). Les sols ont été échantillonnés en triple avant et après un brûlage sur 0-1 cm, 1-2 cm et 2-3 cm de profondeur. Nous avons analysé la teneur en C oxydable total sur sol (COT); la teneur et le taux de minéralisation du C labile et récalcitrant, déduit à partir de tests d'incubation (141 jours); le C issu de la biomasse microbienne (CBM); l'activité des β -D-glucosidase (GL). Toutes les propriétés du sol étudiées ont été significativement affectées par le feu, variant en termes d'intensité et de profondeur affectée. Le feu a produit une diminution significative du COT (-41% en moyenne) et identique dans les premiers 3 cm de sol. Le contenu de C labile a considérablement diminué (-87% en moyenne) jusqu'à 3 cm, mais son taux de minéralisation a augmenté (+ 150% en moyenne). Le CBM a été particulièrement touché sur 0-1 cm (-53%), tandis que l'activité des GL a montré des diminutions significatives sur les premiers 3 cm de sol (-49% en moyenne). Ces résultats montrent un fort impact du brûlage sur les propriétés des sols étudiés. Le suivi de l'évolution de ces sols est nécessaire afin d'évaluer leur capacité de résilience dans les court et moyen termes et de vérifier la viabilité du brûlage dirigé pour la gestion des pâturages dans les Pyrénées.

Mots-clés. Pâturages – Feu contrôlé – Matière organique du sol – Activité biologique du sol – Minéralisation du carbone.

I – Introduction

Pastureland area in the Central Pyrenees has greatly declined in recent decades in favour of thorny shrubs as “erizón” (*Echinopartum horridum*), mainly due to the abandonment of traditional practices of forestry and livestock farming related to rural exodus. The effects of shrub encroachment include alteration of the nutrients and water cycles in soil, increased fire risk and loss of biodiversity and livestock resources (Montané *et al.*, 2010). Prescribed burning is a useful tool for recovering pasturelands degraded by shrub encroachment (Fernandes *et al.*, 2013). These controlled fires are characterised by lower temperatures (normally not exceeding 400 °C) and being of lesser intensity and severity than wildfires. Although there is extensive information on the environmental effects of controlled fire under Mediterranean climate, very few studies have investigated controlled burning of scrubland in humid environments and aimed at pasture improvement (San Emeterio *et al.*, 2014). The general objective of this work is to investigate the immediate effects of prescribed burning on the quality and biochemical stability of soil organic matter (SOM) in soils covered by scrubs in the central Pyrenees (NE Spain). Specific aims include: (1) to quantify the variation in the SOM as a result of burning, (2) to evaluate the biochemical stability of SOM before and after burning through mineralization assays in laboratory, and (3) to assess the impact of fire on soil biological characteristics related to C cycle (microbial biomass C and β -D-glucosidase activity).

II – Materials and methods

The study area is located within a large pastureland area in the municipality of Tella-Sin (Huesca, Spain) in the central Pyrenees, at 1875 m a.s.l. The mean annual rainfall is 1700 mm and the mean annual temperature is 5°C. Large limestone outcrops alternate with areas of thin soils (classified as Eutric Epileptic Cambisols (IUSS, 2014) sufficient to support pastures of great quality, dominated by *Bromus* and *Festuca*. In April 2015, a controlled burning was performed in an experimental area of 12.5 ha, south-exposed, with an average altitude of 1820 m a.s.l. and slope ranging from 10 to 40 %. The highest temperatures recorded during fire were 397°C and 121°C at 1 cm and 2 cm depth, respectively, decreasing back to temperatures of 25°C 96 minutes since the start of burning. We collected soil samples from the Ah horizon in triplicate immediately before and after burning at 0-1, 1-2 and 2-3 cm depth. We analysed the following soil properties: total oxidizable C (TOC) and total N; microbial biomass C (MBC) (Vance *et al.*, 1987); mineralization of soil organic C during incubation assays and β -D-glucosidase (GL) activity (Eivazi and Tabatabai, 1988). The amounts of C-CO₂ emitted during the incubation were fitted to a double exponential decay model (labile and recalcitrant pools) using XLSTAT (version 2015, Addinsoft SRL, Paris). From this model, the content of potentially mineralizable C (PMC) and mean residence time (MRT) of the labile fraction were obtained. To determine the impact of fire at different soil depths, we compared, for each soil layer, the values of the soils properties studied before and after burning using Mann-Whitney U tests.

III – Results and discussion

All the soil properties studied were significantly affected by fire at varying intensities and depths (Table 1). The TOC and the C/N ratio significantly decreased after burning, affecting similarly the first three cm of soil. In general, it is considered that the combustion of the organic matter starts to be significant at around 200-250 °C, leading to total disappearance at about 500°C (Certini, 2005). In our experiment, temperature reached nearly 400°C at 1 cm depth, which would explain the sharp decline in the organic matter content. Fire affected the MBC at 0-1 cm depth (-53%), although a decreasing trend can also be seen at 1-2 cm depth, while the GL activity decreased significantly at depths up to 3 cm (-49% on average). It is generally accepted that the most immediate effect of fire on soil microorganisms is a reduction in their biomass, leading to complete sterilization of the up-

per 2-3 cm of soil in extreme cases (Knicker, 2007). It has been suggested that high soil moisture might also intensify the heat transfer in soil and thereby increase microbial mortality (Certini, 2005). In our study, the combination of relatively high temperatures at 1 cm depth and high soil water content before burning contribute to explain the decrease in the MBC. The impact of fire on GL activity can be explained by both the thermal denaturation of the enzyme due to high soil temperature and the inactivation of enzymes associated with soil colloids (Knicker, 2007). Burning decreased the C-CO₂ efflux (-50% on average), affecting similarly the upper three cm of soil (Fig. 1). The labile PMC content decreased considerably (-87% on average) up to 3 cm, and its mean residence time (MRT) decreased (-48% on average). Severe fire is known to cause important losses of most labile forms and accumulation of refractory organic materials, resulting in decreased respiratory rates of burned soils relative to unburned soils (González-Pérez *et al.*, 2004), which seems to be the case here.

Table 1. Mean values of soil properties at different depths immediately before and after the prescribed fire

	0-1 cm		1-2 cm		2-3 cm	
	Unburned	Burned	Unburned	Burned	Unburned	Burned
SWC, %	100 ± 32 a	74.5 ± 29 a	108 ± 46 a	78.6 ± 36 a	84.2 ± 39 a	59.0 ± 14 a
TOC, g/kg	248 ± 36 a	139 ± 21 b	209 ± 24 a	130 ± 33 b	174 ± 33 a	104 ± 13 b
C/N ratio	12.7 ± 1.84 a	9.3 ± 0.9 b	12.1 ± 1.76 a	10.1 ± 0.48 b	12.1 ± 1.42 a	9.7 ± 0.1 b
MBC, g/kg	15.9 ± 2.3 a	7.4 ± 4.7 b	13.1 ± 5.5 a	8.6 ± 2.2 a	8.9 ± 1.9 a	8.0 ± 3.2 a
GL, μmol PNP g/h	32.2 ± 4.9 a	13.9 ± 4.6 b	24.5 ± 4.2 a	15.3 ± 8.5 a	20.6 ± 5.2 a	9.5 ± 1.2 b
C-CO ₂ efflux, mg/kg/ day	81.7 ± 14 a	43.3 ± 6.6 b	60.7 ± 11.2 a	37.9 ± 2.1 b	52.5 ± 11.5 a	23.4 ± 6.7 b
Labile PMC, g/kg	9.36 ± 3.2 a	2.46 ± 0.5 b	11.5 ± 7.0 a	2.32 ± 0.5 b	28.6 ± 24.5 a	1.6 ± 0.4 b
MRT of the labile PMC, days	61.3 ± 10 a	32.2 ± 7.1 a	106 ± 59 a	65.2 ± 24 a	195 ± 143 a	49.1 ± 16 a

SWC, soil water content; TOC, total organic C; MBC, microbial biomass carbon; GL, β-D-glucosidase activity; PMC, potentially mineralizable C; MRT, mean residence time. Values followed by different letters indicate significant differences between unburned and burned samples (Mann-Whitney U tests, $P < 0.05$).

IV – Conclusions

Our results showed a strong immediate impact of prescribed fire on the soil properties studied. These effects were greater than expected for a controlled burning. Monitoring the evolution of these soils with time will allow us to assess their resilience after prescribed burning, and to check the sustainability of this technique for managing mountain pastures in the Pyrenees.

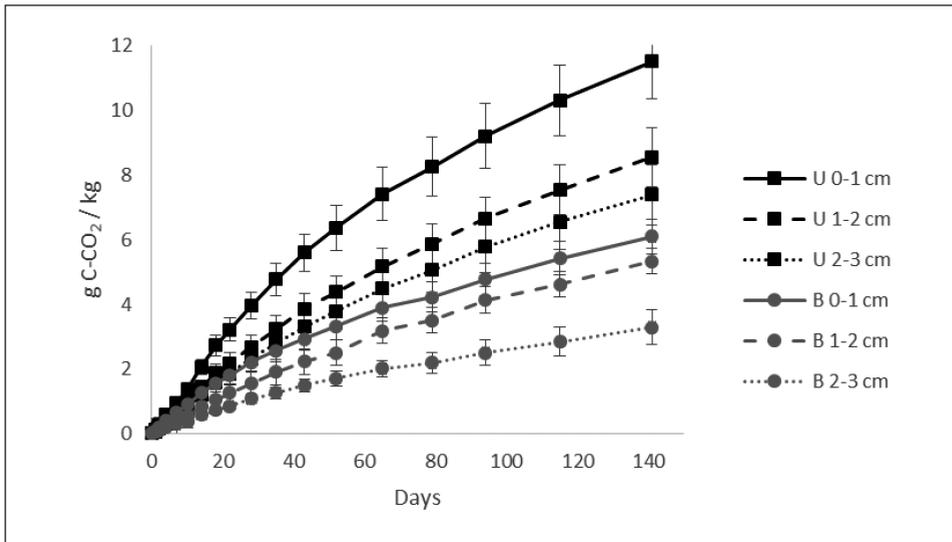


Fig. 1. Accumulated soil organic carbon (g C-CO₂ / kg) mineralized after 141 days of incubation. U, unburned soil; B, burned soil.

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To what extent are mountain permanent grasslands different from lowland ones? Results from a study conducted in France

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Abstract. To evaluate differences between mountain and lowland permanent grasslands we used the results of a study conducted in various mountainous regions (Pyrenees, Massif Central, Jura, and Vosges) and in lowlands from semi-continental, oceanic and coastal regions of France. A set of 190 permanent grasslands (47 in mountain areas > 600 m) was selected in 78 farms and surveyed for two years in 2009 and 2010. From the botanical composition, 19 types of permanent grasslands were defined (respectively 5, 6, 5 and 3 different types for mountain, semi-continental, oceanic and coastal areas). Mineral and organic N fertilization and grazing intensity are in the same range between mountain and lowland grasslands. Except for one type dominated by conservative grasses, biomass production is comparable in mountain permanent grasslands than in lowlands ones. Similar conclusion can be drawn for forage quality. In contrast, botanical composition differs strongly with higher species richness and proportions of legumes and forbs in the mountain grasslands. It can be concluded that forage production services provided by mountain permanent grasslands are in the range than that of lowlands ones, but that environmental services provided by botanical diversity are of higher value in mountain permanent grasslands.

Keywords. Production – Forage quality – Biodiversity – Permanent grasslands.

Dans quelle mesure les prairies permanentes de montagne sont différentes de celles de plaines ? Résultats d'une étude conduite en France

Résumé. Pour étudier les différences entre les prairies permanentes de montagne et de plaine, nous avons utilisé les résultats d'une étude réalisée sur 190 prairies situées dans 78 élevages répartis dans les principales régions herbagères de France, et pour 47 d'entre elles dans les massifs des Pyrénées, du Massif Central, du Jura et des Vosges. A partir de l'étude de leur composition botanique, 19 types de prairies ont été définis, 5 en montagne (> 600 m), 6 en zone semi-continentale, 5 en zone océanique et 3 en zone littorale atlantique. Les niveaux de fertilisation azotée comme l'intensité de pâturage sont comparables entre les prairies de montagne et de plaine. A l'exception d'un type de prairie dominée par les graminées de type conservatif, la production de biomasse est également similaire entre les prairies de montagne et celles de plaines. Il en est de même pour la qualité du fourrage. En revanche, la composition botanique des prairies de montagne est très différente, avec un nombre d'espèces, une proportion de légumineuses et de plantes diverses significativement plus élevées. En conclusion, les prairies permanentes de montagne produisent des services fourragers comparables à ceux prairies permanente de plaine, mais des services environnementaux liés à leur diversité botanique supérieurs.

Mots-clés. Production – Qualité du fourrage – Biodiversité – Prairies permanentes.

I – Introduction

The environmental utility (biodiversity, water quality, soil erosion, landscape aesthetics, etc.) of permanent grasslands is largely recognized. In addition, their economic utility as a cheap food resource in ruminant production systems may be considerable. A way to promote the conservation and the use of permanent grasslands in livestock farming systems is to provide evidence about the joint interest of grasslands, in terms of production and environment. Mountain permanent grasslands are often thought to provide higher ecosystem services in relation to their botanical diversity than lowland permanent grasslands. They are also thought to be less productive and in some cases of lower nutritive value. However, studies of botanical and agronomical characteristics of permanent grasslands over a wide range of agro-climatic conditions are rare. In this paper, to evaluate differences between mountain and lowlands permanent grasslands we used the results of a study conducted at the French national level in various mountainous regions (Pyrenees, Massif Central, Jura, Vosges) as well as in lowlands from semi-continental, oceanic and Atlantic coastal regions.

II – Materials and methods

A set of 190 permanent grasslands was selected from 1500 listed by a survey conducted in 2008 on 78 farms (in which permanent grasslands represented more than 50% of forage area) distributed in the main lowland and mountain grassland areas of France except the Alps and the Mediterranean area. Within this set, 47 plots were located at more than 600 meters a.s.l. in four mountainous massifs: Pyrenees, Massif Central, Jura and Vosges. The whole set of grasslands was studied during 2 years (2009-10) considering the seasonal dynamic of forage characteristics and botanical/functional composition. Management practices were characterized by interviewing farmers, in particular to estimate mineral and organic N fertilization (kg/ha) and livestock grazing intensity (days.LU/ha/year).

Botanical composition was determined in spring 2009 on each grassland in a homogeneous plant community (vegetation structure and floristic composition) of c. 1 ha. The list of species was compiled from eight randomly located sampling areas (0.25 m²) and completed by an overview of the global plant community in order to note the presence of other species in the sampled area (Michaud *et al.*, 2011).

The seasonal dynamic of forage production and nutritive value was assessed during 2009 and 2010 on the dominant homogeneous plant community of each grassland. In three areas of that plot (1.5 × 3 m), samples were taken on four occasions each year: two samples in spring (one at the beginning of spring and one at the end of spring), one in summer and one in autumn. At each measurement, two samples were collected and frozen. On the first sample the proportions of grasses, legumes and forbs were estimated visually, according to volume, and on a sub-sample of 40 tillers grasses the proportion of functional types were determined according Cruz *et al.* (2010). The second sample was dried to determine the dry matter content, and thus to estimate the biomass production of each grassland was calculated for all cutting dates. The nutritive value of the herbage (organic matter digestibility and crude protein content) was estimated using NIRS (Michaud *et al.*, 2015).

From the botanical composition (species abundance and dominance, functional types of grasses), 19 types of permanent grasslands were defined, respectively 5, 6, 5 and 3 different types for mountain, semi-continental, oceanic and coastal areas (Launay *et al.*, 2011). For this study, we focussed on differences between mountain and lowland permanent grasslands using one-way analysis of variance and analysing relationships between grasslands characteristics and altitude.

III – Results and discussion

The N fertilisation was not different between mountain and lowland grasslands (Table 1). Lowland grasslands tended to be more heavily grazed. Indeed, in mountain livestock systems, permanent grasslands are the almost only forage resource and have to ensure conserved forage for winter. In contrast, botanical composition differed strongly between mountain and lowland permanent grasslands. Mountain grasslands were characterized by a significantly higher species richness linked with higher proportions of legumes, forbs and conservative grasses [Type C grasses in the classification by Cruz *et al.* (2010)]. Despite strong differences in botanical composition, biomass production and mean quality of forage was not significantly different between mountain and lowland grasslands (Table 1). Digestibility was significantly higher in lowland grasslands at the beginning of spring (and also at the end, data not shown), but at the whole growing season level, the higher proportion of legumes and forbs may compensate the lower digestibility of grasses in mountain grasslands (Michaud *et al.*, 2015).

Table 1. Comparison of mountain and lowland grasslands in the set of 190 plots across France

	Mountain	Lowland	P value
N fertilisation (kg/ha)	52.8 ± 62.8	47.8 ± 55.5	ns
Grazing days (LU.days/ha)	194 ± 217	268 ± 214	0.085
Number of species	31.6 ± 11.5	21.6 ± 6.71	< 0.001
Legumes [†] (%)	11.2 ± 8.78	6.48 ± 8.09	0.001
Forbs [†] (%)	14.0 ± 13.0	5.96 ± 7.60	< 0.001
Conservative grasses [†] (%)	16.7 ± 19.5	5.81 ± 8.67	< 0.001
Biomass production ^{††} (t/ha)	7.29 ± 2.67	7.07 ± 2.42	ns
OM digestibility beginning of spring (%)	75.9 ± 3.36	77.9 ± 3.96	0.018
Mean OM digestibility ^{†††} (%)	68.2 ± 2.31	68.2 ± 3.42	ns
Mean crude protein content ^{†††} (g/kg DM)	122 ± 13.1	119 ± 19.2	ns

[†]: End of spring determinations. ^{††}: Sum of spring, summer and autumn cuts. ^{†††}: Mean weighed by biomass production at each cut.

On the set of grasslands we studied, there was a clear positive relationship between altitude and species richness of the grassland (Fig. 1). In this range of species richness that is moderate (most of the grasslands contained between 10 and 40 species) there was no positive nor negative relationship between species richness and biomass production (Fig. 1) or forage quality (data not shown). This suggests that botanical diversity is not opposite to biomass production and forage quality [cf. Huyghe *et al.* (2008) for a review], and that mountain grasslands can combine a good level of forage production with the provision of environmental services related to botanical diversity. What is questioning in this study is the relatively low production level of lowland grasslands. It can be hypothesised that due to the fact that in lowlands permanent grasslands is not the unique forage resource in the farm, farmers adopt a less intensive management in accordance with the moderate N fertilisation rates we estimated from farmers interviews.

This overall comparison must not hide the differences between and within grassland types that was established in the French classification of permanent grasslands (Launay *et al.*, 2011; Baumont *et al.*, 2012). Figure 2 illustrates these variations for biomass production. Within mountainous grassland types, the first corresponds to an extensive pasture dominated by grasses adapted to medium to poor fertility environment (*Agrostis* sp., *Festuca rubra*), and shows lower production. The grasslands of Atlantic coast were also characterized by a low production.

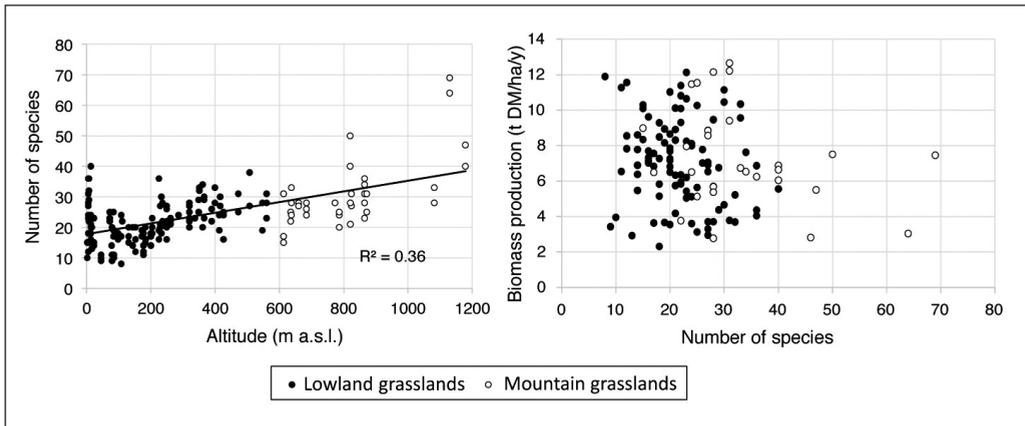


Fig. 1. Relationships between altitude, number of species and biomass production in mountain and lowland permanent grasslands.

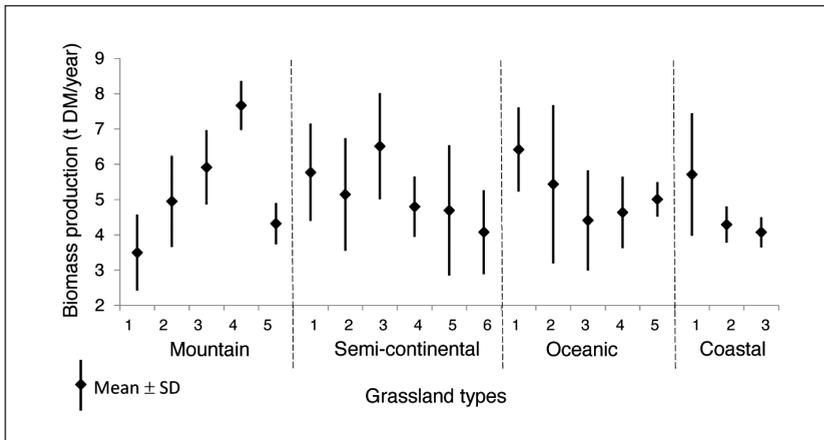


Fig. 2. Variation in biomass production between the 19 grassland types categorized from the set of 190 grasslands (Data from Launay *et al.*, 2011).

IV – Conclusions

Forage production services provided by mountain permanent grasslands are in the range than that of lowlands ones, but that environmental services provided by botanical diversity are of higher value in mountain permanent grasslands. Well managed mountain permanent grasslands can combine a satisfactory ruminant production level with environmental services.

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How to optimize the carrying capacity of Jura summer pastures?

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Abstract. Swiss summer pastures management is constrained by an official carrying capacity limit for benefiting from governmental subsidies. The grazing duration and number of animals are set accordingly either to long-term practices or to pastoral plans established by means of vegetation mapping. This paper presents results issued from three case studies in the Jura mountain area. It confirms that botanical surveys lead to correct annual DM yield assessment. They give however no information about the grass growth dynamics. Our measurements show that the distribution of production during the season may vary significantly from one year to another. Moreover, the impact of climate change reinforces the need to adapt pasture management. Finally, the discussion focuses on the short-term adjustment of the stocking rate to the grass production potential.

Keywords. Mountain pastures – Botanical survey – DM yield – Grass intake – Milk production.

Comment optimiser le chargement animal des pâturages d'estivage du Jura ?

Résumé. En Suisse, la gestion des pâturages d'estivage est réglementée par une limite de chargement animal, de façon à pouvoir bénéficier de subventions gouvernementales. La durée de pâturage et le nombre d'animaux sont fixés en considérant les pratiques à long terme ou sur la base d'un plan de gestion établi au moyen d'une cartographie de la végétation. Cet article présente les résultats issus de trois études de cas dans la région d'estivage du Jura. Il confirme que les relevés botaniques conduisent à une évaluation correcte du rendement annuel en matière sèche. Ces relevés ne donnent en revanche aucune information sur la dynamique de croissance de l'herbe. Nos mesures montrent que la répartition de la production en cours de saison peut varier considérablement d'une année à l'autre. En outre, l'impact du changement climatique renforce la nécessité d'adapter la gestion des pâturages. Enfin, la discussion se concentre sur l'ajustement de la charge instantanée au potentiel de production d'herbe.

Mots-clés. Pâturages de montagne – Relevés botaniques – Rendement – Ingestion – Production laitière.

I – Introduction

In the Swiss southern Jura foothill, a transdisciplinary project aims at prospecting on how dairy farmers can improve their forage autonomy taking into account the climate change. In this lowland region, dairy production concerns either industrial milk with silage or PDO cheeses with hay based foraging. Cows' productivity and grassland utilisation intensity are rather high. This may lead to an imbalance between the forage potential and the herd's requirement. Recent drought events negatively affected grassland productivity. Consequently, forage maize surface has expanded up to 900 m elevation. Above this altitude, summer pastures benefit from a favourable relief and are less encroached in comparison with sloping Alp regions. They draw more and more attention, as they complete forage shortage. In particular, the mosaic patchiness of wood-pastures may buffer impacts of drought (Gavazov *et al.*, 2013).

Summer pastures management is subject to legal constraints that limit the amount of concentrate (no more than 1 kg concentrate per day and per Livestock Unit LU) and the carrying capacity (grazing du-

ration and number of animals). In cases of significant structural changes, any modification of the carrying capacity requires the establishment of a pastoral plan including an actual map of vegetation. On this basis, the annual production is estimated and used to calculate the carrying capacity. Pastoral plans do not take into account temporal and spatial variability of grass growth. The objectives of this study are to illustrate the range of variation and to discuss the possibilities of adaptive management.

II – Materials and methods

The **study area** is located in the Jura Mountains ('Combe des Amburnex' 46°32' latitude north and 6°13' longitude east) at about 1300 m elevation. The climate is harsh and rainy, with mean annual air temperature of 5.9 °C and mean annual precipitation of 1920 mm. The soils are characterised by the karst, with an upper decalcified layer (pH of about 5) and high organic matter content (up to 10%). The texture and the depth of the soils are highly variable, depending on the local topography. The vegetation is dominated by *Festuca rubra* and *Agrostis capillaris*. Three summer pastures (P1, P2 and P3) situated in this valley have been observed between 2012 and 2014.

Experimental plots (one per vegetation unit) were fenced on representative paddocks of the pastures. DM production and grass growth were measured using a design inspired by Corrall and Fenlon (1977) and simplified for marginal areas. Two plots of 6.5 m² were mown and weighted alternatively every two weeks during the whole vegetation period. Botanical composition and pastoral value (PV) were determined according to the method of Daget and Poissonet (1971).

Grass height was measured in each paddock of the pastures P2 and P3 in 2014 with a plate pasture meter. Grass cover (available biomass) was then calculated using an average grass density of 240 kg DM ha⁻¹ cm⁻¹.

III – Results and discussion

1. Soil depth and grass growth

In 2012, two experimental plots were located on pasture P1 on shallow (20 cm) and deep soil (60 cm) with diverse botanical richness (31 vs. 21 plant species). The pastoral value (PV) reached 27.9 on shallow soil and 46.0 on the deep one. Accordingly, annual DM yield reached 890 and 2,960 kg DM ha⁻¹, respectively. Grass growth dynamic was similar for both situations (Fig. 1), but means from May to September differed from 5.2 on shallow to 16.9 kg DM ha⁻¹ day⁻¹ on deep soil.

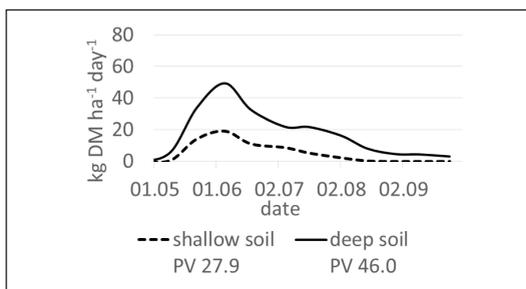


Fig. 1. Grass growth related to soil depth (P1, 2012).

Figure 1 illustrates the huge **spatial variability** encountered in the study area. As expected, with increasing soil depth, the botanical diversity decreased and the pasture yield increased. Accordingly, the pastoral plan of P1 (Brühlmann *et al.*, 1997) indicates the following yield ranges established by means of a vegetation mapping : 600-1,000 kg DM ha⁻¹ year⁻¹ on shallow soil and 2,600-3,100 kg DM ha⁻¹ year⁻¹ on deep soil. The whole pasture P1 (102 ha) potential yield was assessed to 1,600 kg DM ha⁻¹ year⁻¹ and is grazed from 29th May until 3rd October (127 days) by 80 LU suckler cows. With a theoretical grass intake of 15 kg day⁻¹ LU⁻¹, herd requirement reaches 1,594 kg DM ha⁻¹ and fits to grass supply.

2. Climate and grass growth

In the study area, drought exerts less impact on highland than lowland pastures (Meisser *et al.*, 2014). On summer pastures, evapotranspiration is lower and vegetation is more resistant to drought. Inter-annual climate variability is a great source of variation that influences production and grazing management. Especially late spring snow melting and severe summer drought affect pastures DM productivity. Figure 2 illustrates the **temporal variability** of pasture P2 production in the years 2014 (late and humid) and 2015 (early and dry).

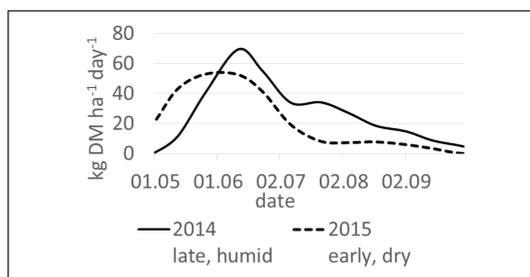


Fig. 2. Grass growth related to climate (P2, 2014-15).

Even if the mean grass growth rate from May to September was similar in both years (23.5 and 20.0 kg DM ha⁻¹ day⁻¹ in 2014 and 2015, respectively), grazing management was hardly constrained in 2015. Climate conditions influenced grassland with over yielding in spring and growth stop in summer. This unusual distribution of the DM production imposed changes such as an earlier leaving of herds in September.

3. Grazing management and grass utilisation

In 2014, two neighbour dairy summer pastures (P2 and P3) characterised by similar natural conditions and grazing systems (rotation on 6 paddocks) were investigated. Herders provided information on pasture and herd management, as well as milk production. Table 1 shows important differences between both pastures in terms of grazing intensity. The ratio surface per cow almost varies from single to double. The cows feeding requirement (concentrate and hay) as well as the milk production per cow were the highest for P3.

Table 1. Key numbers of two dairy pastures (P2 and P3, Wettstein and Lincio, 2014)

Pasture	Duration [days]	Surface [ha]	Dairy cows [nb]	Surface per cow [ha cow ⁻¹]	Milk [kg cow ⁻¹ day ⁻¹]	Concentrate [kg cow ⁻¹ day ⁻¹]	Hay [kg cow ⁻¹ day ⁻¹]
P2	111	42.5	28	1.5	16.6	0.9	0.0
P3	100	58.0	75	0.8	18.8	1.6	3.4

These data allowed calculating the hypothetical grass quantity grazed by cows. Figure 3 compares grass supply and intake and shows some unbalance. At the beginning of season, excess production and low intake led to biomass accumulation. This trend appears clearly in Figure 4, which illustrates the evolution of the grass cover issued from grass height measurement.

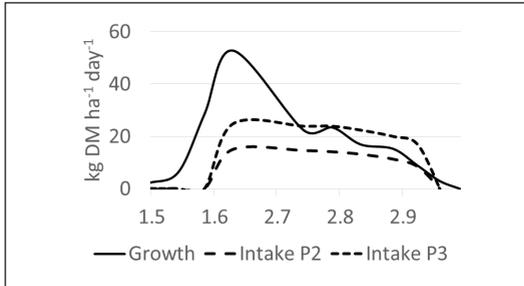


Fig. 3. Grass growth and intake (P2 and P3, 2014).

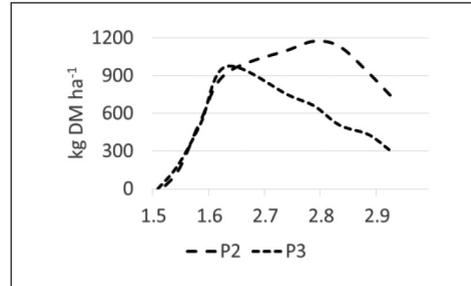


Fig. 4. Grass cover (P2 and P3, 2014).

This case study revealed that carrying capacity and grazing management widely differ in the same area. Anyway, an earlier begin of grazing and a regulation of the stocking rate by variation of the herd size should contribute to improve the pastures efficiency (Mosimann, 2007). In mid-September, dairy cows left both summer pastures and heifers were set on P2 in a way to clean residual grass before winter.

IV – Conclusions

Pastoral value (Daget and Poissonet, 1971) is suitable to link botanical composition and foraging potential of grassland, but the specific indexes of plants remain key factors (D’Ottavio *et al.*, 2009; Lombardi *et al.*, 2011). The method has been adapted to the Jura context, integrating specificities of wood pastures. It forms the basis for the calculation of carrying capacity in pastoral plans (Barbezat and Boquet, 2008). Although the annual DM yield estimation is good, it remains difficult to predict its temporal distribution. Grass growth measurement helps to understand the broad variation observed year after year by herders. Moreover, it facilitates the search for improvement factors, such as an adjustment of the herd size over the time. Regular assessment of the grass cover leads to constructive discussions on grazing management. However, agronomical recommendations must respect the political will to preserve mountain landscape and biodiversity. Optimisation of rangelands pastures carrying capacity should not compromise their long-term sustainability.

Acknowledgments

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Grassland odorscape: a new tool to explore the ecosystemic services

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Abstract. Plants, insects and microorganisms are the protagonists of the ecosystem services provided by permanent grasslands. All of them emit volatile organic compounds (VOCs) to communicate. The result is a chemical landscape, also called odorscape. To explore this pool of information and enhance our understanding on the process behind the ecosystem services, we trapped volatile compounds on two mountain permanent pastures chosen for their contrasting grazing and fertilisation management. Measurements were made in July over two periods of three consecutive days using solid-phase microextraction (SPME) fibers fixed on sticks. The VOCs adsorbed on the fibers were then analyzed by gas-chromatography-mass spectrometry (GC-MS). We also recorded floristic composition, trapped the pollinator insects and took pictures of the canopy to quantify grassland colors using image analysis. We obtained rich and complex VOC profiles. They contained a total of 67 peaks corresponding to VOCs belonging to various chemical families. Nevertheless, the differences between the two grasslands chemical signatures were less marked than expected, considering their differences in floristic species richness (83 vs. 65 species). Certain compounds however, were specific to one of the two pastures and others were positively (e.g. benzaldehyde) or negatively (e.g. α -pinene) correlated to the presence of pollinators. Measuring the odorscape constitutes a promising tool to better understand a range of services provided by grasslands.

Keywords. Grassland – Chemical landscape – Volatile organic compounds – Volatilome – Biodiversity.

Le paysage odorant des prairies : un nouvel outil pour explorer les services écosystémiques

Résumé. Les plantes, les insectes et les microorganismes des prairies émettent des composés organiques volatils (COV) pour communiquer. Il en résulte un paysage chimique aussi appelé paysage odorant que nous avons voulu explorer pour mieux comprendre les processus à l'origine des services écosystémiques rendus par l'écosystème prairial. Nous avons ainsi capté les COV dans deux prairies permanentes pâturées, contrastées du point de vue de l'intensité de leur conduite et de leur niveau de fertilisation. Les mesures ont été faites en juillet à 2 périodes de 3 jours consécutifs en utilisant des fibres SPME (Micro-Extraction en Phase Solide) fixées sur des piquets. Les COV ont été analysés par chromatographie en phase gazeuse couplée à la spectrophotométrie de masse (GC-MS). Des relevés botaniques et des piégeages des insectes pollinisateurs ont été effectués. L'analyse d'image à partir de photos a été utilisée pour quantifier les couleurs présentes dans les parcelles. Nous avons obtenu des profils riches en COV, contenant un total de 67 pics correspondant à des familles chimiques variées. La différence entre les profils des deux prairies a été moins importante que prévue compte tenu de leur composition botanique contrastée. Nous avons néanmoins mis en évidence des COV spécifiques aux prairies et montré que certains COV étaient corrélés positivement (ex. benzaldéhyde) ou négativement (ex. α -pinène) avec les insectes pollinisateurs. La mesure du paysage chimique des prairies s'avère un outil prometteur pour rendre compte des services écosystémiques.

Mots-clés. Prairies – Paysage chimique – Composés organiques volatils – Volatilome – Biodiversité.

I – Introduction

Permanent grasslands shelter a diversity of microbes, plants and animals, all of which emit volatile organic compounds (VOCs) into the atmosphere. The role of plant VOCs is to attract pollinating insects, but also to communicate with other plants when they undergo heat or drought stresses, or to attract the predators of herbivore insects when they are attacked. COVs from insects and microorganisms are either by-product of their metabolism or signal molecules. The resulting chemical landscape, also called odorscape, likely contains a high amount of information on the biotic status of the grasslands and on the ecosystemic services they provide. While most of the studies conducted up to now focused on the interaction between a given plant and a given insect isolated in closed chambers, Leppik and Frerot (2014) have characterized the chemical landscape of maize crop *in situ* using solid phase micro extraction fibers (SPME) located in the field. In a recent study (Cornu *et al.*, 2015), we applied this technique to permanent grasslands in order to (1) check its feasibility in such a heterogeneous ecosystem and (2) to explore pasture odorscape as an innovative tool to assess and enhance the possible ecological roles and environmental services it offers. Accordingly, VOC measurements were implemented in two mountain semi natural grasslands displaying contrasting diversities of flowering plants.

II – Materials and methods

The experiment was conducted at the INRA farm of Marcenat located in an upland area of central France on volcanic soils (Cantal, France – 45.3046N, 2.8378E; altitude 1070-1190m). The region is characterized by a low annual mean temperature of 7.4°C (2002-2013), and a high mean annual precipitation of 1167mm.yr⁻¹. Two plots, close to each other (1.3 km) were chosen for their contrasting floristic diversity and management: “Montagne”, a large 8.98 ha pasture that had received no fertilizer in the last 20 years and had always been grazed at a low stocking rate, resulting in a high botanical diversity, and “La Prade”, a 1 ha pasture, flat and wet in places, well fertilized (30 NU.ha⁻¹.yr⁻¹ and 40 m3.ha⁻¹.yr⁻¹ of slurry) and grazed at a higher stocking rate, inducing moderate botanical diversity.

Measurements were made in July in two periods of 3 days: P1 (1, 3 and 4 July) while cows were grazing and P2 (16, 17 and 18 July) when cows had been turned out of the pastures. On each pasture, three 10 × 12 m areas, representative of the different plant communities were excluded from grazing. These enclosures were removed just after the third day of measurement in each period. Sward structure measurements, VOC trapping and insect counts were performed on the same three consecutive days in each of the six enclosures, in both periods. Botanical analyses were performed at the end of P1. All the species and their abundances were determined in three 1 m² quadrats distributed along the diagonal of each enclosure. Species present in the enclosure but not in the quadrat were also identified. Flowering intensity was estimated during the 2 periods based on the relative abundance of dicotyledonous flowering stems using a stick at 50 locations over each enclosure (first contact). In addition, in P1, eight pictures of the canopy were taken vertically in each enclosure and the average number and percentage of blue-red pixels, known to be attractive for pollinators, were quantified using the imageJ software (Schneider *et al.*, 2012) to quantify. Insects were trapped using pan traps (Westphal *et al.*, 2008) except for bumblebees which were netted. Flies were discarded, wild bees were sorted, identified and counted, and the remaining hymenoptera were counted as “others”.

The SPME fibers were cleaned and conditioned by heating in a gas chromatograph injector before using. They were fixed on a metal stake in the middle of the enclosure, at the maximum canopy height, at the same place in P2 as in P1. Each day of measurement, the 6 fibers were installed between 08:30 and 10:00 and removed in the same order between 16:30 and 18:00. VOCs were then analyzed by gas chromatography coupled to mass spectrometry (GC/MS). Peak area information was extracted from the raw GC-MS data and expressed as a percentage of the total chromatogram area.

Data were analysed using Statistica Software (Statsoft, Maisons-Alfort, France). The effects of the day of measurement and of the enclosure were tested separately by means of univariate ANOVAs. A two-way ANOVA was performed to test the effect of the grassland (G), the period (Per) and their interaction (G × Per). The variables for which the grassland and the period had the most significant effects were subjected to a principal component analysis (PCA). Correlations between VOCs and insects were tested using parametric statistical analysis and the highlighted relationships were checked using non-parametric Spearman rank correlations.

III – Results and discussion

During P1, temperature was close to the average for July (15–17°C with a maximum at 25°C) but quite rainy while in P2, weather was hot (18–22°C and a maximum at 29°C) with no precipitation. Montagne had a higher average number of species per square meter than La Prade (30 vs. 19) and forbs were twice as abundant (average 51% vs. 24% respectively). Flowering intensity was much greater on Montagne over the two periods compared with La Prade (P1: 26 vs. 5%; P2: 15 vs. 4% respectively), as was the abundance of the ‘blue-red’ color of the canopy (0.9 vs. 0.4% of pixels). Regarding the chemical signatures, a total of 67 VOC were detected over the six enclosures and the two periods: 10 hydrocarbons, 8 alcohols, 10 aldehydes, 8 ketones, 7 acids, esters, lactones or anhydrides, and 24 unidentified compounds (UI). Among these were 13 benzene compounds and 11 terpenoids. These compounds were recovered on both plots, except UI-21 found only in Montagne. Compared with a maize field, our grasslands emitted a greater number of compounds, belonging to a wider range of chemical families. Four major VOCs together represented 40% of the total peak area: UI-7, propan-2-one, 1-ethoxy-2-propanol and butyrolactone. Propan-2-one may have an abiotic origin as well as a microbial, plant or animal origin (Sharkey, 1996). It is also known as a signal molecule toward insects (Davis *et al.*, 2013). The compounds originating from ruminants that could have been expected, such as volatile fatty acids from C2 to C7, sulfur compounds, phenolic compounds and indole derivatives were not found. Only benzyl alcohol and benzoic acid were recovered, and these compounds could also have originated from plants. The range of the number of compounds trapped in the enclosures was similar on Montagne (60 to 67) and on La Prade (63 to 66). However, the two-way ANOVA showed that six compounds were significantly more abundant on Montagne than on La Prade: terpinene, UI-3 and UI-14 ($p < 0.01$) propan-2-one, UI-21 and 2-phenylethyl acetate ($p < 0.05$). Only benzoic acid was significantly more abundant on La Prade than on Montagne ($p < 0.05$). Therefore, although the two plots have contrasted botanical compositions, these differences did not induce broad variations in their VOCs profiles as expected. By contrast, a marked and significant effect of the period was observed: 19 compounds had a higher relative abundance in P1 than in P2 including terpenes, 1-ethoxy-2-propanol, Δ -hexenol, Δ -hexenyl acetate, and 2-phenylethyl acetate while 12 VOCs were more abundant in P2 than in P1, among which most ketones, the aldehydes and 1-butanol. These differences observed between P2 and P1 were probably due to the effects of temperature and humidity changes between P1 and P2 associated with those of plant maturation and cow grazing. Among the compounds that were more abundant in P1 when cows were grazing beside the enclosures, compounds such as longifolene and bisabolene probably reflected the higher percentage of dicotyledonous flowering plants in P1 compared with P2.

The PCA performed with the peaks most significantly influenced by the grassland (terpinene, UI-14 and benzoic acid), the period (1-butanol and Δ -bisabolene) or both (UI-3) discriminates well the two periods on the PC 1 while the two plots tend to be separated along the PC 2 (Fig. 1). PC 1 clearly separates P1 from P2, mainly because of β -bisabolene and UI-14 which have higher relative abundances in P1. Together, the two first PC explained 68% of the variance.

Significant correlations ($p < 0.05$) between VOCs and insect counts were found. There was a negative correlation between the number of wild bee species and limonene ($R = -0.39$) and between the number of “other hymenoptera” and α -pinene ($R = -0.35$), Δ -hexenyl acetate ($R = -0.41$) and limonene ($R = -0.46$). Butyrolactone, already cited as a constituent of insect pheromones, correlated with the number of pollinators and the number of bee species. Lastly, a negative correlation was observed between limonene and the number of wild bee species, which could reflect the vegetative stage of the plants, limonene being emitted by leaves and stems rather than by flowers. However, the trapping conditions were probably less efficient than in maize crops, where the headspace may be protected against wind, retained and to some extent concentrated by the height of the plants. In the future, we need to improve our method to reduce the variability between measurements.

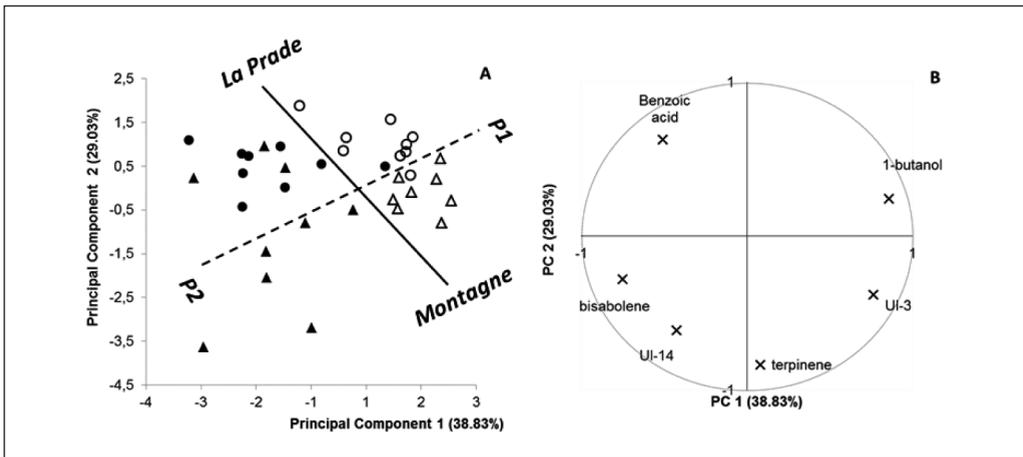


Fig. 1. Representation of Montagne and La Prade grasslands at both periods on the 1 × 2 plane of the PCA. **A:** Observations (2 grasslands × 3 enclosures × 3 repetitions × 2 periods) and **B:** Variables included in the PCA. P1: filled symbols, P2: empty symbols, Montagne : triangles, La Prade : circles.

IV – Conclusions

Our study has demonstrated that SPME-GC-MS method is able to provide grassland VOC profiles. The correlations found between wild pollinators and certain VOCs, even if they need to be confirmed, provide clues to finding “semiochemicals” linking grasslands to the insects they host. These first encouraging results open the way to new knowledge to assess and enhance grassland value in terms of ecological services. In the future, microbial activity in soil, pollinating attractiveness and relationships between grasslands odorscape and milk sensorial quality would be an interesting track to explore with this innovative tool.

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Targeted and untargeted alkaloid characterisation of pasture herbs and milk from eastern Italian Alps using high resolution mass spectrometry

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Abstract. Alkaloids, widely present in herbs, have attracted the attention of phytochemists for over 150 years due to their potential value as medicinal agents or their toxic principles. In this work we developed a method for targeted and untargeted alkaloid investigation that automatically combines SPE-on line sample purification with UHPLC/ESI/High Resolution Mass Spectrometry (Q-Orbitap) detection. Thirty-five alkaloids were quantified in comparison with analytical standards, 48 were putatively identified and confirmed using the chromatographic retention time and the fragmentation profile obtained analysing the extracts of plants already well-documented in the literature, and further 200 using an in-house database built from literature information on exact mass and isotopic pattern. Besides, the alkaloid profile of 67 single herbage plants, characteristic of the local alpine flora, and that of 48 herbal mix samples representative of the exact daily intake of 8 cows grazing in three consecutive days on two distinct alpine pastures in north-eastern Italy, was described. Moreover, also the corresponding 48 milks produced by those cows were analysed. Among the quantified alkaloids, the most abundant were Lycopsamine and Gramine (42 and 31% of pasture samples, and 52 and 44% of milks, respectively; contents from 0.4 to 80 $\mu\text{g kg}^{-1}$ in herb, and 0.04-0.4 $\mu\text{g L}^{-1}$ in milk). The untargeted analysis found over 120 different alkaloids in herbal mixes and roughly 40 in milks.

Keywords. Alkaloids – Pasture plants – Orbitrap.

Caractérisation ciblée et non ciblée des alcaloïdes présents chez des plantes herbacées de pâturages et des échantillons de lait de vaches à l'aide de la spectrométrie de masse à haute résolution, dans les Alpes orientales italiennes

Résumé. Les alcaloïdes, très répandus dans les herbes, ont attiré l'attention des phytochimistes depuis plus de 150 ans, du fait de leur potentiel comme agents médicinaux ou de leurs propriétés toxiques. Ce travail a développé une méthode pour la détection ciblée et générale d'alcaloïdes, qui combine automatiquement la purification de l'échantillon par voie de SPE online avec UHPLC / ESI / High Resolution Mass Spectrometry (Q-Orbitap). Trente-cinq alcaloïdes ont été quantifiés par rapport aux normes analytiques pures. Quarante-huit alcaloïdes ont été confirmés en utilisant le temps de rétention chromatographique et le profil de fragmentation, en analysant les extraits d'herbes déjà bien documentées dans la littérature, et 200 autres alcaloïdes ont été provisoirement identifiés en utilisant une base de données construite à partir d'information de la littérature concernant les masses exactes et des motifs isotopiques. D'abord, le profil de composition de 67 plantes herbacées distinctes qui composent la flore alpine locale a été établi. Ensuite, 48 échantillons de mélange à base de plantes représentatives de l'ingestion quotidienne de la vache, recueillies à partir de deux alpages dans le nord-est de l'Italie, et 48 échantillons de lait produits par les vaches au pâturage sur ces alpages, ont été analysés. En ce qui concerne le contenu des 35 alcaloïdes quantifiés, lycopsamine et gramine étaient les plus répandues (42 et 31% des échantillons de pâturage, et 52 et 44% des laits, respectivement) avec une distribution de concentration dans les herbes de 0,4 à 80 $\mu\text{g kg}^{-1}$ et dans le lait de 0.04-0.4 $\mu\text{g L}^{-1}$. Plus de 120 alcaloïdes différents ont été détectés avec une analyse non ciblée dans les mélanges à base de plantes et à peu près 40 dans les laits.

Mots-clés. Alcaloïdes – Plantes de pâturages – Orbitrap.

I – Introduction

Alkaloids are an extremely varied group of natural, nitrogen-containing and basic organic compounds. Currently over ten thousand alkaloids have been isolated from various natural sources, especially in plants. Despite this, their physiological function in herbs is not yet fully understood. Usually considered simply waste products of plant metabolic processes (Hartmann, 2007), the highly differentiated chemical structure suggests that they play various specific biological roles, from plant protection against pathogen and herbivore attacks (Rasmann and Agrawal, 2008) to scavenger activity (Larson and Marley, 1894). Alkaloids have been classified into three principal classes depending on precursors and final molecular structures: atypical (non-heterocyclic compounds, sometimes called 'proto-alkaloids' or biological amines), typical (heterocyclic compounds further classified into: pyrrole, pyrrolidine, tropane, pyrrolizidine, piperidine, quinoline, isoquinoline, aporphine, quinolizidine, indole, indolizidine, pyridine, imidazole, and purine groups), and pseudo-alkaloids (basic compounds, not deriving from amino acids). Acting very quickly on specific areas of the nervous system, alkaloids can often manifest a marked physiological action on humans and animals. Some of them are responsible for the beneficial effects of traditional medicines, such as Corynoline, an isoquinoline alkaloid belonging to *Papaveraceae* family and used in traditional Chinese Pharmacopoeia (Liu *et al.*, 2016), or pterogynine and pterogynidine, isolated from *Pterogyne nitens* and tested for their effect on a human infiltrating ductal carcinoma cell line (ZR-7531) (Duarte *et al.*, 2010). However, some alkaloids may instead have the harmful effects of poisons. Pyrrolizidine (PA), found primarily in the plant families of Boraginaceae, Compositae and Leguminosae, is the most studied alkaloid group due to increased awareness of its potential risk and the European Food Safety Authority (EFSA) has published a scientific opinion on PAs in food and feed (Mudge *et al.*, 2015). In particular, 1,2-dehydro pyrrolizidine ester alkaloids are toxic for humans and livestock and globally many episodes of PA intoxication have been reported involving humans as well as ruminants (Wiedenfeld and Edgar, 2011). Furthermore, some studies have investigated and confirmed the potential transfer of PAs present in herbs to milk, although in much lower concentrations and supposedly not dangerous for health (Hoogenbooma *et al.*, 2011; Rouge *et al.*, 2013). The objective of the study was the characterisation of the alkaloid profile of herbs and milks produced by cows grazing on alpine pastures in order to evaluate the extent of the transfer of these nitrogen compounds from the grass to the milk as possible markers of the floristic composition ingested.

II – Materials and methods

1. Reagents and solutions

LC-MS grade acetonitrile (ACN), LC-MS grade methanol (MeOH), MS grade formic acid (FA, 98%), LC-MS grade ammonium acetate were purchased from Fluka (St. Louis, MO, USA) and ammonia solution 25% was purchased from Merk Millipore (Darmstadt, Germany). For mass calibration a standard mix of n-butylamine, caffeine, MRFA and Ultramark 1621 (Pierce® ESI Positive Ion Calibration Solution, Rockford, IL, USA) were used. Deionized water was produced with an Arium®-Pro Lab Water System (Sartorius AG, Goettingen, Germany).

Analytical standards were purchased from PhytoLab GmbH & Co. KG (Vestenbergsgreuth, Germany), and Harmaline, Strychnine from Sigma (St. Louis, MO, USA). The standards were dissolved in a 50% aqueous methanol solution to reach a final concentration of about 3 mg L⁻¹ of each individual alkaloid, and used for calibration in the range 0.05 – 3000 µg L⁻¹.

2. Plant and milk sampling and sample extract preparation

Two pastures with different vegetation types (Bovolenta *et al.*, 2014) were grazed, at the same phenological stage, by a herd of Simmental dairy cows. During 3 days for each pasture, samples of

herbage consumed by 8 previously selected cows were collected using the hand-plucking technique. For herb samples, an homogeneous aliquot of 2.5 g herb sample was added to 20 mL of extraction solution (H₂O/MeOH/FA; 44.5:44.5:1 v/v/v) in polyethylene 50 mL falcon tubes (Sartorius AG, Goettingen, Germany), sonicated for 10 minutes (LBS1 6Lt, FALC Instruments, Treviglio BG, Italy), and left under vertical shaking for 12 hours at 20 rpm (Rotoshake 24/16, Gerhardt GmbH & Co. KG, Königswinter, Germany). The mixtures were once again sonicated for 10 minutes, and the methanolic extract was separated after centrifugation (10 minutes at 4100 rpm; IEC CL31 Multispeed, Thermo Scientific, Sunnyvale, CA, USA). Finally, the extract was filtered with a 0.45 µm cellulose filter cartridge (Sartorius AG, Goettingen, Germany) and diluted 2 times with an ammonia solution (pH = 10) before analysis.

During the milking (twice a day for 3 days) individual milk samples were collected from selected cows. For milk samples, a homogeneous aliquot of 5 g was added to 2 mL of extraction solution (H₂O/MeOH/FA; 40:40:20 v/v/v) in polyethylene 50 mL falcon tubes and sonicated for 15 minutes. Then 1 mL hexane was added and the samples were shaken for 10 minutes. After centrifugation (10 minutes at 4100 rpm) the hexane phase was removed and the water layer was filtered with a 0.45 µm PVDF filter cartridge (Sartorius AG, Goettingen, Germany), and diluted 2 times with water.

3. Method

On-line purification was performed with a SolEx HRP spe cartridge, loading the sample with ammonia: methanol (96:4 v/v; pH = 9) at 1 ml min⁻¹, during chromatographic separation with a Raptor Bipheny analytical column, managing gradient elution in 32 minutes from 30% to 100% of organic solvent (eluent A: water/0,1% formic acid/5mM ammonium acetate; B: methanol:acetonitrile (95:5 v/v)/0,1% formic acid/5mM ammonium acetate). The mass spectrometer was operated with a heat source in positive ion mode using the following parameters: sheath gas flow rate set at 30 arbitrary units; aux gas flow rate at 10 arbitrary units; spray voltage at 3.5 kV; capillary temperature at 330 °C; aux gas heater temperature at 300 °C; Mass spectra were acquired in full MS-data dependent MS/MS analysis (full MS—dd MS/MS) at a mass resolving power of 140,000.

III – Results and discussion

A group of 35 alkaloids were quantified with reference to pure analytical standards. The method was linear up to concentrations of 1000/3000 µg L⁻¹ with R² always > 0.99, and the limits of quantification ranged between 0.15 and 37 µg kg⁻¹ for herbs and 0.01-3 µg L⁻¹ for milk. Accuracy, expressed as the average of relative errors, was less than 10% for 71% of compounds, and precision (as RSD%) was generally < 10% throughout the quantitation range. For other 48 alkaloids, whose analytical standards were not commercially available, the presence was confirmed using the chromatographic retention time and the fragmentation profile as defined analysing the extract of plants of already well-documented composition (*Arnica montana*, *Lobelia inflata*, *Gelsemium sempervirens*, *Ranunculus montanus*, *Senecio vulgaris*, *Datura stramonium*, *Hyoscyamus niger*, and *Solanum nigrum*). Besides, more than 200 other alkaloids were tentatively identified using an extensive in-house database with exact masses and molecular formulas (isotopic patterns) found in literature.

Overall, the 67 plant extracts contained 146 different alkaloids (or their isomers): 4 were identified by comparison with the analytical standards, 8 comparing the retention time and fragmentation profile, and 154 tentatively identified using the in-house database. The most frequently present alkaloids were Allosedamide, Piperidine and 8-ethylnorlobelol (belonging to the piperidine group); 5-methoxyvascine (quinazoline); one isomer of Nicotinic acid (pyridine); Europine/Heliotrine N-oxide (pyrrolizidine); Fluoxetine (protoalkaloid), and Quinidine (quinoline). The plants with the largest number of detected alkaloids were *Carex sempervirens*, *Biscutella laevigata* and *Leontodon hispidus*, having over 50 different alkaloids, or their isomers.

For the herbal mixes, target analysis allowed to detect 3 alkaloids (Lycopsamine in 42% of samples; Gramine, 31%; and Veratramine, 8%) with concentrations ranging from 0.4 to 8.5, 3.7-65, and 40-350 $\mu\text{g kg}^{-1}$, respectively. The untargeted analysis showed the presence of 120 other different alkaloids. The most frequent were Nicotinic acid, Venoterpine, Fluoxetine, 8-ethylnorlobelol, Ephedrine/Feruginine, Bellendine, 2-Pyrrolidineacetic methyl ester, 5-methoxyvascicolol, Gentiobetaine, Onetine, Piperidine, 5-methoxyvascine, Gelsemine, and Yohimbine, or the corresponding isomers.

As regards milk samples, the target analysis allowed to quantify 3 alkaloids (Lycopsamine in 52% of samples; Gramine, 44%; and Senkirkin, 8%) with concentrations ranging from 0.04 to 0.1, 3.7-65, and 0.4-17 $\mu\text{g kg}^{-1}$, respectively, while the untargeted analysis detected 40 other alkaloids, being 8-ethylnorlobelol, 2-Pyrrolidineacetic methyl ester, (-)-Coclaurine/Chavicine/Piperine, 5-methoxyvascicolol, Valerine, 3-acetyltopine, and one isomer of 8,10-diethyllobelidol the most frequently present.

The results showed for herbal mixes and milks very differentiated and complex alkaloid profiling. Reasonably, the assessment of transfer mechanisms of alkaloids from herbs to milk must then take into account also factors such as their bacterial or enzymatic degradation, the metabolic waste disposal, and the reduced assimilation during digestive processes.

IV – Conclusions

The proposed analytical method allowed to define a wide and detailed database regarding alkaloid composition, and represented a useful tool for the compositional description of a large selection of herbs sampled in mountain pastures. Moreover, the first findings on the presence of the same alkaloids in both the herbal mixes consumed daily by cows, and the corresponding produced milks, suggest interesting perspectives of feed traceability.

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Habitat selection of dairy-sheep in Atlantic mountain grasslands

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Abstract. Understanding the implications of habitat selection by dairy sheep for diet quality is essential for an appropriate management of grasslands and dairy production. Here we test whether ewes select grassland patches with high plant diversity or with species of high nutritional quality (i.e. low carbon/nitrogen ratio –C/N ratio–) to meet their physiological needs. We also discuss whether non-lactating and lactating ewes behave alike. Our study was conducted in the Aralar Natural Park (Northern Spain) during the lactating period (2015, May-June). The geographical locations of 40 ewes from 3 different flocks were recorded every 30 minutes using GPS (Global Position System) devices: 7 lactating and 6-7 non-lactating in each flock. Floristic composition was measured and the most abundant plant species were collected to quantify N and C content. Dense and transition pastures were selected by ewes, regardless of their physiological state. The preference order of habitats differed among flocks. The positive correlation between selection index and plant diversity indicated that sheep selected the most diverse habitats, and not the higher N content ones to graze.

Keywords. Ewes – GPS – Physiological state – Plant diversity – Plant nutritional quality.

Sélection des habitats par les ovins laitiers dans les pâturages des montagnes atlantiques

Résumé. Il est essentiel de comprendre les implications, pour la qualité du régime, de la sélection d'habitat par les ovins laitiers, en vue d'une gestion appropriée des pâturages et de la production laitière. Cet article examine si les brebis sélectionnent des portions de pâturage à forte diversité végétale ou à espèces de haute qualité nutritionnelle (c.a.d. à faible rapport carbone/azote – ratio C/N) pour leurs besoins physiologiques. Nous analysons aussi si les brebis en lactation et non-lactation se comportent de la même façon. Notre étude a été menée dans le Parc Naturel d'Aralar (Nord de l'Espagne) durant la période de lactation (2015, mai-juin). Les localisations géographiques de 40 brebis de 3 troupeaux différents ont été enregistrées toutes les 30 minutes par appareil GPS (Global Position System): 7 brebis en lactation et 6-7 brebis en non-lactation dans chaque troupeau. La composition floristique a été mesurée et les espèces végétales les plus abondantes ont été collectées pour quantifier la teneur en N et C. Des pâturages denses et en transition ont été sélectionnés par les brebis, indépendamment de leur état physiologique. L'ordre de préférence des habitats différait selon les troupeaux. La corrélation positive entre indice de sélection et diversité végétale indiquait que les ovins sélectionnent pour paître les habitats plus divers, et non ceux à plus forte teneur en N.

Mots-clés. Brebis – GPS – État physiologique – Diversité végétale – Qualité nutritionnelle des plantes.

I – Introduction

Grazing by seasonal livestock maintains a mosaic landscape with high spatial heterogeneity in Atlantic mountains. These grasslands have high economical and cultural importance, as they provide high-quality food resources that determine the production and quality of traditional dairy products such as milk and cheese.

Habitat preference is influenced by abiotic and biotic factors that operate at differing spatial scales (Bailey *et al.*, 1996). When selecting habitat, herbivores try to reach an equilibrium between the benefit of satisfying their nutritional requirements and the cost of seeking it (Stephens and Krebs, 1986) and these nutritional requirements depend on the morpho-physiological characteristics of the animal (Provenza, 1995). Recent works agreed that lactating ewes tend to select plant species with higher protein content than dry ewes (Allegretti *et al.*, 2012) and also, that plant diversity is a key factor to stimulate food intake (Feng *et al.*, 2016).

Understanding the implications of habitat selection by dairy sheep for diet quality is essential for an appropriate management of grasslands and dairy production. This study investigates whether ewes and, in particular, lactating ewes, selected habitats with abundant high nutritional quality species (low C/N ratio) or with high plants diversity. To test this hypothesis, habitat selection by lactating (L) and non-lactating (NL) ewes were first analyzed, and then whether N content (as nutritive quality indicator) and plant diversity could explain the observed selection pattern.

II – Materials and methods

The study was conducted in Atlantic Mountain grasslands located in the Aralar Natural Park (42°59'48"N, 2°06'51"W), Basque Country, Northern Spain. The extensive grazing system of the park from May to November supports about 18,000 dairy sheep, and also beef cattle and horses.

1. Experimental flock

3 flocks of dairy-sheep (*Ovis aries*) of the latxa breed were selected for the study: flock A (485 ewes), B (360 ewes) and C (270 ewes). Ewes are milked twice a day (morning and evening) and finish the lactating period in the park (May-June) after a short transhumance.

2. Vegetation sampling

A vegetation map was created using photointerpretation and verifying defined five habitats *in situ*: H1, stony pasture; H2, transition pasture (transition community between stony and dense pastures); H3, dense pasture; H4, scrubland and H5, other habitats including nitrophylic communities and small areas with scattered trees. H5 was excluded from the analysis, as ewes mainly use nitrophylic communities as resting areas.

Species composition of the grazing areas was measured using 300 random points (100 in each grazing area). Cover percentage of plant species was estimated by direct observation using 50 x 50 cm quadrats and the most abundant species (adding up to 21) were collected for posterior analysis of C and N content.

3. Habitat selection

Habitat selection by 40 ewes from selected flocks was assessed by using GPS (Global Position System) collars to record their spatial location during the lactating period (2015, May-June). In each flock, the GPS devices were divided into two groups: 7 collars in L ewes and 6-7 in NL ones. The location of ewes was registered every 30 minutes (Spot 3, GlobalStar). The original dataset was filtered removing position errors based on previous work, thus keeping 5350 locations. These records were used to define the grazing area of L and NL ewes of each flock with the minimum convex polygon function (Mohr, 1947) and overlaid with DEM (digital elevation model) layers later to exclude natural barriers.

Habitat selection was determined with Selectivity index (W_i), calculated as follows: $(W_i = \frac{o_i}{p_i})$

where o_i is the used proportion of habitat type i and p_i is the proportion of area covered by habitat type i in the grazing area. Then, Chi-square tests were used to test for statistical significance (Krebs, 1989).

Shannon diversity index (H') was calculated as follows: ($H' = -\sum_{i=1}^s p_i \ln p_i$), where, p_i : the proportion of species i (abundance divided by the total species found in a given quadrat). Combining species composition and nutritional variables (C and N content and C/N ratio), community weighted means were computed for 300 sampling points. Finally, Spearman rank correlations were used to explore relationships between nutritional and diversity variables and selection indices at habitat level.

III – Results and discussion

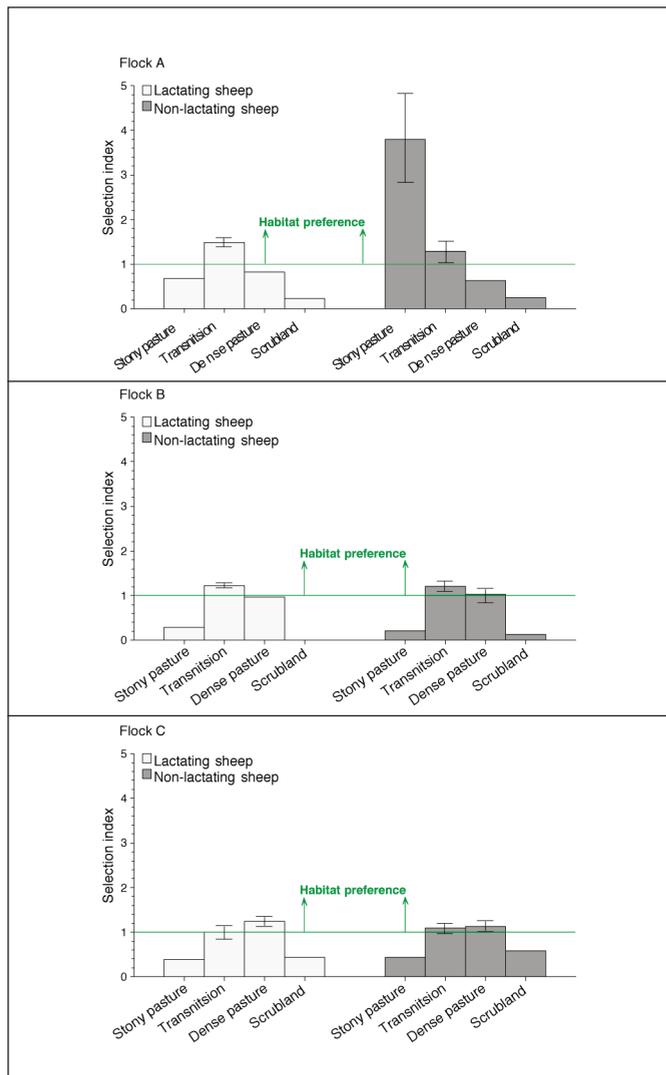


Fig. 1. Selection indices of each habitat and the habitat preference limit for lactating and non-lactating ewes in the three flocks.

Ewes of the three flocks mainly used dense and transition pastures. The sum of the use of both habitat ranges from 0.781 to 0.968 of the total use.

The selection indices (Fig. 1) indicated that ewes of flocks A and B selected positively transition pasture, whereas dense pasture was selected by the ewes of the flock C. L and NL ewes selected the same habitats in the three flocks, with the exception of the NL ewes of flock A. These NL ewes showed a clear preference for the stony pasture. This might be due to the fact that in the first week of May flock A was divided in L and NL ewes and the last ones did not return to shed. Probably, they used the stony pasture to take refuge during the study period. Scrubland was avoided by L and NL ewes of the three flocks (Fig. 1). Chi-square test was significant ($P \leq 0.001$) in all cases, so null hypothesis of random habitat selection was rejected for the three flocks.

These results suggest that ewes clearly preferred to graze in transition and dense pasture and that the flock determines the pattern of habitat selection rather than the physiological state of the animals.

Spearman correlation between N content and the selection index was not significant, but positive correlation was observed with the Shannon diversity index ($\rho = 0.608$; $P = 0.002$). This means that ewes selected the most diverse habitats to graze. Slight differences have been found in the N content among habitats (19.77-20.22%). However, species into the habitats differ more in N content, suggesting that selection for plant quality might occur at fine scale into the habitat (feeding station scale).

Feng *et al.* (2016) demonstrated that plant diversity increases the food intake, modifying the nutrient balance, toxin dilution and taste modulation (Wang *et al.*, 2010). Selection of high diversity patches in our study agrees with this hypothesis. Lastly, the social behaviour of ewes could explain the similar habitat selection between physiological states. Recent investigations have reported that group effect overcomes the individual diet requirement at least at habitat level (Sibbald *et al.*, 2008).

IV – Conclusions

Ewes, whatever the physiological state, preferred transition and dense pastures to graze. Habitat plant diversity, and not nutritional quality, drove the habitat selection by ewes.

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Response of vegetation to exclusion and grazing in Mediterranean high-mountain wet pastures (Sierra Nevada, Granada, Spain)

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Abstract. This study aims to determine the effect of medium-term livestock enclosure on two types of high-mountain wet pastures in the Sierra Nevada National Park: (1) "borreguil", with a predominance of *Carex nigra* and *Nardus stricta*, and (2) fescue pasture (FP), with a predominance of *Festuca iberica*. In February 2008, for each type of pasture, 5 plots were excluded to grazing, and 5 non-excluded plots were set up. The vegetation was assessed in July of 2008 and 2014. In this study, we analyse changes in the biomass production, plant cover, species richness, diversity and species composition after 6 years (2008 vs. 2014) of non-grazed plots as compared to grazed plots. In both types of pasture, biomass production showed significant differences between treatments and between years. In 2014, biomass was ten-fold higher in non-grazed plots and five-fold higher in grazed plots as compared to 2008 levels; with FP proving to be more productive than borreguil pastures. We also detected a slight downward trend in plant cover, richness and diversity in non-grazed plots, while these parameters appeared to increase in grazed plots, although a statistically significant change was only observed in FP plant cover. With regard to floristic composition, exclusions appeared to adversely affect small graminoids (only in borreguil pastures), *F.iberica* and legumes; on the other hand, exclusions had a positive effect on grasses, particularly *N. stricta*, in FP.

Keywords. *Festuca iberica* – *Nardus stricta* – Biomass production – Species richness – Diversity.

Réponse de la végétation à l'exclusion et au pâturage en estives humides méditerranéennes (Sierra Nevada, Grenade, Espagne)

Résumé. L'objectif de cette étude est de déterminer l'effet à moyen terme de l'exclusion au bétail sur deux types d'estives dans le parc national de Sierra Nevada: (1) "borreguil", dominé par *Carex nigra* et *Nardus stricta*, et (2) FP, pelouse dominé par *Festuca iberica*. Dans chaque type d'estive, 5 parcelles ont été exclues au pâturage, et 5 parcelles ont été pâturées. La végétation a été évaluée en Juillet 2008 et 2014. Nous analysons l'évolution de la production de biomasse, la couverture végétale, la richesse d'espèces, la diversité et la composition des espèces après 6 ans (2008 vs. 2014), en comparant les parcelles non pâturées par rapport aux pâturées. Dans les deux types d'estives, la production de biomasse a montré des différences significatives entre les traitements et entre les années. En 2014 elle était dix fois plus élevée qu'en 2008 dans les exclusions, et cinq fois plus élevée dans les parcelles pâturées. Aussi, FP s'est montré plus productive que borreguil. Nous avons détecté une légère tendance à la diminution de la couverture végétale, la richesse et la diversité dans les parcelles non pâturées, ces paramètres semblent augmenter dans les parcelles pâturées, malgré le fait que des différences significatives n'ont été observées que dans le couvert végétal de la FP. Concernant à la composition floristique, l'exclusion paraît affecter négativement les petites graminoides (uniquement dans les pâturages borreguil), *F. iberica* et légumineuses; d'autre part, les exclusions ont eu un effet positif sur les graminées, en particulier *N. stricta* dans les pelouses FP.

Mots-clés. *Festuca iberica* – *Nardus stricta* – Production de biomasse – Richesse des espèces – Diversité.

I – Introduction

High-mountain wet pastures are of great importance for livestock feeding during the summer months in the semiarid Mediterranean region. Some of these plant communities, which belong to the *Nardion* alliance, have been designated priority habitats in the 92/43/ECC directive (Bedia and Busqué, 2013).

The Sierra Nevada, a national park, is the highest mountain range in the southern Iberian Peninsula. Transhumance (sheep, goat and cattle herds) has traditionally been practised in these mountains. The abandonment of traditional practices has negatively affected the survival of wet pastures. In order to implement management plans in these pastures, it is necessary to know the characteristics (floristic composition, structure and fodder yield) of these grassland.

This study therefore aims to determine the effect of medium term livestock enclosure on two types of high-mountain wet pastures in the Sierra Nevada National Park: (1) “borreguil”, with a predominance of *Carex nigra* (L.) Reichard and *Nardus stricta* L.; and (2) pasture with a predominance of *Festuca iberica* (Hack.) K. Richt. We compared the changes in biomass, plant cover, species richness and diversity as well as species composition after 6 years (2008 as compared to 2014) in grazed and non-grazed areas.

II – Materials and methods

This study was conducted in the Sierra Nevada National Park (Aldeire, province of Granada, SE Spain) (37° 24' N and 3° 4' W at 2000-2150 m a.s.l.). The site has a typical mountain Mediterranean climate, with hot dry summers and snow in autumn and winter. During the survey, annual rainfall was 485 (2008), 681 (2009), 740 (2010), 301 (2011), 482 (2012), 507 (2013) and 518 mm (2014). The lithological substratum is siliceous. The sampling site was in a grazing area of approximately 550 ha. Two flocks of Segureña sheep (a total of 620 in 2008 and 550 in 2014), herded by shepherds, grazed the area from late May until late September. Approximately 50 to 70 heads of shepherdless cattle also erratically grazed there after the snow melted.

Two types of mountain pastures were evaluated: 1) “borreguil”, with a predominance of *C. nigra* and *N. stricta*, develops after the snow melts, which frequently occurs in swamped soils, and 2) fescue pastures (FP), with a predominance of *F. iberica* and very low *N. stricta* cover, develop in drier, nonswamp soils.

1. Experimental design and sampling

Five blocks were randomly located in each type of pasture. Each block comprised two plots (each 3x3 m) in: i) a permanent enclosure (non-grazed plot); and ii) an unfenced area (grazed plot) located next to the enclosure. The enclosures were set up in March 2008. Samplings were carried out at the end of July in two sampling years (2008 and 2014). Biomass was determined by cutting and collecting all above-ground biomass in eight 25 cm x 25 cm quadrats per subplot. This material was oven-dried at 60°C. Composition and plant cover were estimated using the point-intercept method. Two 2-m-long transects were performed in fixed crossed lines. Every 4 cm, a thin stick was vertically placed in the vegetation, and all species in contact with the recording stick were sampled. The data obtained from this procedure enabled us to determine: (i) plant cover, with frequent overlapping resulting in values of over 100% (see Tables 1 and 2), (ii) richness, with the number of species per plot, (iii) biodiversity, quantified by the Shannon index, using the natural logarithm (\log_2), and (iv) floristic composition, with only the dominant and more interesting pastoral species and functional groups (grasses, legumes and tall and small graminoids) being shown. Graminoids include only species belonging to the *Cyperaceae* family.

2. Statistical analyses

Data were analyzed using the two-way repeated measure ANOVA procedure of the SPSS general linear model (GLM) to estimate the overall significance of the effect of the treatment. In this model, “year” (2008 and 2014) is regarded as a within-subject (repeated) factor, treatment (non-grazed and grazed) as a between-subject factor, with the block factor as the random effect. The factors examined in the model were treatment, year and their interaction. Mauchly’s test indicated that the model accomplished the assumption of sphericity. Tukey’s HSD post hoc test was used for multiple comparisons. Some data were transformed using the Log N for biomass and arcsin for plant cover.

III – Results and discussion

Biomass production showed significant differences between treatments and between years in the borreguil and FP plots. In 2014, biomass was ten-fold higher in non-grazed plots and five-fold higher in grazed plots than in 2008 (Tables 1 and 2). After exclusions were set up in March 2008 (see Materials and methods), their effect on non-grazed plots in 2008 was moderate, and biomass was lower than in 2014, although rainfall was similar in both years. The differences between the years in the grazed plots could be related to lower grazing pressure in 2014. In this regard, Bedia and Busque (2013) point out that grazing utilization is a factor that alters productivity in pastures dominated by *N. stricta*. Biomass production in “Borreguil” grassland in 2014 is similar to that found by these authors in *Nardus* grasslands in northern Spain.

Table 1. Biomass production (Biomass), vegetal cover, richness and diversity in two types of pasture in the high mountain areas of the Sierra Nevada for two different years and two treatments

Pasture type	Year	Treatment	Biomass (g DM ha ⁻¹ year ⁻¹)	Plant cover [†] (%)	Richness (# sp)	Diversity (bits)
Borreguil	2008	Non-grazed	44.6 ± 5.5	219 ± 16.6	15.2 ± 1.4	2.8 ± 0.2
		Grazed	21.6 ± 4.8	182 ± 19.0	10.6 ± 1.8	2.2 ± 0.3
	2014	Non-grazed	539 ± 52.2	198 ± 8.3	11.8 ± 1.5	2.3 ± 0.3
		Grazed	114 ± 16.0	215 ± 5.4	14.6 ± 2.0	2.7 ± 0.2
Fescue pasture	2008	Non-grazed	82.9 ± 21.7	269 ± 18.0	11.8 ± 0.9	2.7 ± 0.1
		Grazed	31.9 ± 3.4	204 ± 7.2	10.4 ± 1.1	2.5 ± 0.1
	2014	Non-grazed	986 ± 220.3	207 ± 11.7	10.2 ± 1.3	2.5 ± 0.2
		Grazed	150 ± 19.8	229 ± 7.2	9.6 ± 1.1	2.5 ± 0.2

[†] Vegetal cover data are all over 100 as more than one species overlapped in each sampling point.

Table 2. ANOVA table for biomass production (Biomass), plant cover, species richness and diversity in two types of pasture (F = F values, P = p-values in the Anova analysis)

Type of pasture	Source	Biomass [†]	Plant cover	Richness	Diversity
Borreguil	Treatment (F, P)	37.8, <0.001	0.7, 0.438	0.18, 0.682	0.02, 0.884
	Year (F, P)	597.8, <0.001	0.2, 0.704	0.08, 0.779	0.00, 0.978
	Treatment [†] Year (F, P)	20.6, 0.002	3.3, 0.106	12.85, 0.007	10.35, 0.012
Fescue pasture	Treatment (F, P)	43.62, <0.001	6.22, 0.037	0.53, 0.489	0.17, 0.688
	Year (F, P)	137.32, <0.001	1.60, 0.242	2.88, 0.128	0.75, 0.413
	Treatment [†] Year (F, P)	7.50, 0.026	9.39, 0.016	0.32, 0.587	0.53, 0.486

[†] Data were log-transformed for the purposes of the analysis. Significant differences are marked in bold.

After 6 years of exclusion, in both types of grassland, we observed a slight downward trend in plant cover, richness and diversity in non-grazed plots, while these parameters appeared to increase in grazed plots, although statistically significant changes were only found in plant cover for FP (Tables 1 and 2). Nonetheless, this trend is reflected by significant interactions (“Treatment x Year”) in “borreguil” pastureland for richness and diversity and, in FP, for plant cover. Regarding plant composition (richness and diversity), Sternberg *et al.* (2000) found that, in Mediterranean grassland, grazing altered the competitive interactions among species through livestock feeding preferences and shortfalls caused by biomass removal and trampling. This could enable the establishment of less competitive species, thus leading to an increase in species richness.

In “borreguil” pastureland, no significant differences were found between treatment and year for any of the species sampled (Table 3). Only tall graminoids increased in the second year (Table 3, $F = 8.96$, $p = 0.017$). In addition, significant or almost significant “Treatment x Year” interactions were found in *F. iberica* ($F = 13.03$, $P = 0.007$), small graminoids and legumes ($F = 13.03$ and 2.36 , $P = 0.051$ and 0.057 , respectively), indicating that exclusions seem to have a negative impact on their specific contributions (Table 3).

Dominant species in FP exhibited an opposite trend: *N. stricta* increased after 6 years of exclusion, whereas *F. iberica* decreased, as indicated by the “Treatment x Year” interaction ($F = 13.17$ and 7.58 , $P = 0.007$ and 0.025 , respectively; Table 3). Grasses were significantly higher in the non-grazed plots ($F = 9.85$, $P = 0.013$); on the other hand, legumes were higher in the grazed plots ($F = 7.17$, $P = 0.028$). The latter showed significant differences between years (higher in 2008, $F = 10.21$, $P = 0.013$) and in the interaction ($F = 28.24$, $P = 0.001$), indicating the negative effect of exclusions.

Table 3. Botanical composition of “borreguil” pastureland and FP for two different years and two grazing treatments. Mean values (%) \pm s.e and ANOVA table. S.gram.: small graminoids (*Carex caryophylla* Latour., *C. echinata* Murray, *C. nevadensis* Boiss. & Reut.). T. gram.: tall graminoids (*Carex camposii* Boiss & Reut., *C. paniculata* L.). CN: *C. nigra*. NS: *N. stricta*

	Borreguil				Festuca Pasture			
	2008		2014		2008		2014	
	N-grazed	Grazed	N-grazed	Grazed	N-grazed	Grazed	N-grazed	Grazed
Grasses	77.4 \pm 10.5	68.4 \pm 12	75.8 \pm 13.2	69.6 \pm 19.9	127.4 \pm 6.9	104.60 \pm 5.2	116.40 \pm 2	106.4 \pm 2.2
S. gram.	9.4 \pm 3.0	10.0 \pm 7.6	2.4 \pm 1.47	16.6 \pm 5.2	1.4 \pm 1.4	4.0 \pm 4.0	0.6 \pm 0.6	8.0 \pm 8.0
T. gram.	11.4 \pm 6.8	3.0 \pm 1.4	21 \pm 11.6	5.2 \pm 2.4	10.4 \pm 6.5	3.4 \pm 2.0	34.2 \pm 20.1	3.4 \pm 3.4
Legumes	20.0 \pm 5.2	13.4 \pm 6.1	5.6 \pm 5.1	14.2 \pm 3.9	63.6 \pm 13.9	41.8 \pm 7.7	1.6 \pm 0.9	62 \pm 8.5
AN	0.2 \pm 0.2	0.6 \pm 0.6	0	0	9.6 \pm 9.6	2 \pm 1.38	5.4 \pm 5.4	8.4 \pm 8.4
AO	2.6 \pm 1.3	0.2 \pm 0.2	2.4 \pm 1.6	0.4 \pm 0.2	1.6 \pm 0.8	2 \pm 1.05	17.2 \pm 8.6	3.6 \pm 2.01
CN	71.6 \pm 7.4	69.6 \pm 6.8	63.2 \pm 3.7	75.4 \pm 10.0	5.6 \pm 5.6	2.2 \pm 2.2	0.4 \pm 0.4	0
FI	12.2 \pm 2.2	6.6 \pm 2.3	4.4 \pm 3	15.8 \pm 4.9	80.4 \pm 8.3	64 \pm 8.1	39.8 \pm 7.6	72.4 \pm 8.9
NS	59,6 \pm 11,5	56,8 \pm 13,4	68,6 \pm 17,1	50,4 \pm 20,0	33,4 \pm 10,2	33,8 \pm 11, 2	50,8 \pm 14,2	19,8 \pm 9,4

IV – Conclusions

Biomass production is the parameter which best reflects the effect of the factors studied (treatment and year): higher in the excluded plots and in 2014. Moreover, FP was more productive than “borreguil” pastureland. A slight downward trend can also be observed in plant cover, richness and diversity in non-grazed plots. Regarding floristic composition, the exclusions appear to have a negative effect on small graminoids (only in “borreguil” pastures), *F. iberica* and legumes; on the other

hand, exclosures favour grasses, particularly *N. stricta* in FP. Nevertheless, our results indicate that, after 6 years of pasture exclusion, few differences between grazed and non grazed plots were found, except in relation to biomass production.

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Transhumance of dairy cows on alpine summer pastures: relationships between milk production, pasture management, and insect biodiversity

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Abstract. In the Alps, centuries of coexistence of human activities and harsh climatic and topographic conditions generated the alpine summer pastures agroecosystems, rich in biodiversity and cultural values. The maintenance of species-rich summer pastures and their ecosystem services is linked to the low-intensity livestock grazing. In this study, the interactions between dairy livestock category/productivity, weed encroachment and butterfly biodiversity in 21 summer farms, 16 with lactating cows and 5 with heifers were assessed in the Trento province (Eastern Italian Alps). During transhumance, a seasonal movement of livestock to upland mountain pastures, data on milk production from May to October and Body Condition Score (BCS) at the beginning and at the end of the summer season for 799 lactating cows of different breeds (classified as local, dual purpose or specialised) were collected. A subjective index from 1 (good conditions) to 4 (bad conditions) to different pastures sections based on the level of weed encroachment was assigned. Three plots per summer farm were surveyed three times for data on butterfly diversity. The interaction between month and breed on milk yield and BCS was analysed. Relationships between butterfly biodiversity, weed encroachment and other traits were investigated. Local and dual-purpose breeds performed better during the transhumance than specialized breeds. The category/productivity of livestock and stocking rate were non-related with pasture conditions index and lower stocking rates favoured butterflies species abundance. The ability of local and dual purpose breeds to adapt to summer pastures conditions should be used to devise grazing management programmes to maximize the trade-off between pasture productivity and biodiversity.

Keywords. Highland pastures – Summer farms – Dairy cows – Grassland management – Insect biodiversity.

La transhumance des vaches laitières en pâturages alpins d'été: relations entre la production de lait, la gestion des pâturages et la biodiversité des insectes

Résumé. Les agroécosystèmes des alpages offrent plusieurs services écosystémiques, qui ont été préservés grâce à l'usage de la transhumance. Le changement de cette pratique met en danger la conservation de ces écosystèmes. On a évalué les interactions entre les catégories et la productivité de bétail laitier, l'invasion des mauvaises herbes et la biodiversité des papillons dans 21 fermes d'été dans les Alpes orientales, dont 16 logeaient des vaches laitières et 5 des génisses. Les données sur la production de lait ont été recueillies de Mai à Octobre, tandis que celles sur le Body Condition Score (BCS) de Juin à Septembre pour 799 vaches laitières de races différentes. Un score subjectif de 1 (bonnes conditions) à 4 (mauvaises conditions) a été attribué par différents secteurs des pâturages selon le niveau d'invasion des mauvaises herbes. Trois parcelles par alpage ont fait l'objet d'une enquête trois fois pour observer les papillons. Nous avons analysé l'interaction entre le mois et la race sur le rendement du lait et sur le BCS, et aussi les relations entre la biodiversité des papillons, l'invasion des mauvaises herbes et d'autres traits. Les races locales se sont révélées plus appropriées pour la transhumance. Les caractéristiques de gestion de bétail et le chargement ne sont pas liés aux conditions de pâturage, tandis qu'un chargement léger semble bénéficier aux papillons. La capacité des races locales à mieux s'adapter devraient être utilisée pour concevoir des programmes visant à améliorer le compromis entre la productivité du pâturage et la biodiversité.

Mots-clés. Pâturages alpins – Fermes d'été – Vaches laitières – Gestion des pâturages – Biodiversité des insectes.

I – Introduction

For centuries mountain farmers have practiced transhumance of livestock in summer farms, which are temporary farms used in summer to incorporate the highland forage into the total amount of resources of permanent farms (Mack *et al.*, 2013; Sturaro *et al.*, 2013b). The extensive livestock systems in mountainous areas maintain semi-natural grasslands, which can be classified as High Natural Value Farmland that delivers provisioning and non-provisioning ecosystem services (ES) (Rodríguez-Ortega *et al.*, 2014; Strohbach *et al.*, 2015). In the last decades, the mountain livestock systems experienced an abandonment process in marginal areas and an intensification trend in more productive areas (MacDonald *et al.*, 2000; Strijker, 2005; Bernués *et al.*, 2011), which deeply affected traditional summer farms management. In several cases lactating cows are no more moved to summer farms. On the other hand, highly specialized breeds are moved to highland pastures, requiring high levels of feed supplement to sustain their productivity (Sturaro *et al.*, 2013a). This paper presents a synthesis of the results of a project aimed at analysing the overall sustainability of summer farms in the Trento province (Zendri, 2015; Jerrentrup *et al.*, 2016). We assessed the impact of transhumance on body condition score, which is an indicator of the amount of metabolizable energy stored in body reserves on a live animal (Edmonson *et al.*, 1989), and milk production of different cattle breeds reared on summer farms in mixed herds. The effects of different intensities of pasture management on weed encroachment and butterfly diversity were also investigated.

II – Materials and methods

The study was conducted in the Trento Province (north eastern Italian Alps) in 21 summer farms (1680 ± 307 m a.s.l.), where multi-breed cattle herds grazed during the summer season (mid-June to September) of 2012. Ownership of summer farms is mainly public (usually district councils), and each summer farm normally hosts cattle from several permanent farms. As a consequence, usually the summer farms herds are composed by mixed breeds. Heifers grazed in five summer farms (1756 ± 366 m a.s.l.), and lactating cows in the other sixteen farms (1657 ± 295 m a.s.l.). Data on herd composition and milk yield were obtained from Provincial veterinary services and official recordings, whereas data on pasture area, pasture subdivision into sections and stocking rate were obtained through an on farm survey. A two steps analysis was performed. First, the effects of transhumance on 799 cows of two specialized dairy breeds (90 Holstein Friesian, 314 Brown Swiss) and of two dual-purpose groups (241 Simmental, and 154 classified as “local breeds”, mainly Grey Alpine and Rendena) on cows’ performance were analysed. Body condition score (BCS) was determined by two trained operators in summer farms, in July and September, using a five-classes scoring (from 1, emaciated, to 5 obese) as stated by Edmonson *et al.* (1989) for dairy breeds. Milk yield was recorded in May (in permanent farms before transhumance), June, July and September (in summer farms) and October (in the permanent farms after transhumance). In August official milk recording activity is interrupted. The BCS and milk yield data were analyzed (MIXED procedure, SAS, Institute Inc., Cary, NC) with a model including the fixed effects of breed, month (and their interactions), class of parity (2 classes) and class of days in milk (5 classes) of cows, and the individual nested within summer farms as random effect. At summer farm level, the differences in weed encroachment and butterfly biodiversity of pastures were examined. The different pasture sections were subjectively scored from 1 (good quality) to 4 (bad conditions) according to the level of weed encroachment. Data on butterfly diversity (Hesperioidea and Papilionidea) were collected three times during the summer season in a subsample of 15 summer farms. For each summer farm, three plots were selected: one next to the farm building (max. 50 m), and two at almost 300 m from the farm building following random directions. A mixed model was used to analyse the effects of distance from farm, animal category (lactating cows vs. heifers) and their interaction on butterfly species richness (Jerrentrup *et al.*, 2016). The correlation among management data (stocking rate and feed supplement), weed encroachment index and mean butterfly species richness were tested.

III – Results and discussion

Milk yield was affected by the interaction between the breed and the month of control (Fig. 1). In May and June milk production differed between breeds, with Holstein Friesian having the highest milk yield, Brown Swiss and Simmental the intermediate and local breeds the lowest ($P < 0.001$). However, Simmental had the greatest milk yield in July ($P < 0.05$), whereas the differences among breeds in the other months were non significant. The greater yield loss observed in specialised breeds when compared to the dual-purpose and local breeds agrees with the results obtained by Horn *et al.* (2014). Monthly average milk yields of all the breeds decreased during the summer season, despite of supplementary feeding, and recovered partially after returning to the permanent farms. This decrease could partially be explained by the advancing stage of lactation (average days in milk at the beginning of transhumance was 205 ± 105), and indicates that transhumance is a stressful challenge for dairy cattle, moved from a constant resource availability and shelter to outdoors grazing, where feeding involves long walks on steep slopes and a variable diet quality.

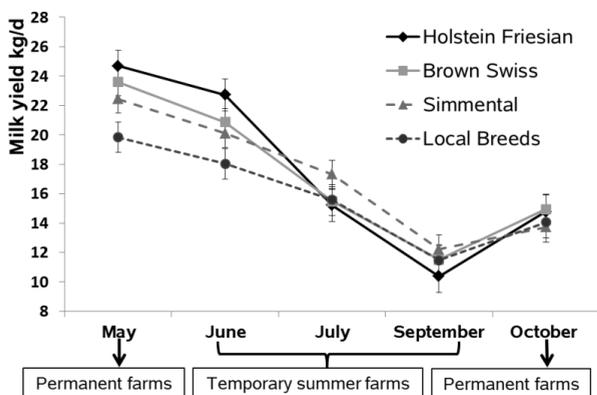


Fig. 1. Monthly milk yield of different cow breeds (Zendri, 2015).

The BCS confirmed the expected differences among breeds (average values: from 2.54 for Holstein Friesian to 3.01 for Local Breeds; $P < 0.001$). Differences between early (July) and late (September) summer season were, however, modest and not significant for all breeds.

The stocking rates were lower in summer farms with grazing heifers (0.86 ± 0.53 LU/ha) than in those with lactating cows (1.10 ± 0.56 LU/ha). Supplementary feeding was provided in all the summer farms housing cows with a daily average of 4.0 kg of concentrates/cow (SD = 1.2). Farms with grazing heifers tended to have greater weed encroachment than those with lactating cows (3.17 ± 0.51 vs. 2.83 ± 0.38 weed index per summer farm, respectively (one way ANOVA: $P < 0.10$). Stocking rate, amount of feed supplement and weed encroachment were not correlated ($P > 0.05$), which suggests a disruption of the traditional link between herd average needs and intensity of pasture management.

Sampled butterfly species were 70% sedentary and 30% mobile (Jerrentrup *et al.*, 2016). Low mobility makes sedentary butterflies more sensitive to changes in their habitats (Curtis *et al.*, 2015). Butterfly species richness was affected by the interaction between the distance to the farm and the type of grazing animals ($P < 0.05$). Butterfly species richness was greater far than near the farm building for farms with lactating cows (close: 9.6 ± 3.3 ; far: 18 ± 7.6 species abundance per summer farm; $P < 0.05$), whereas no differences were observed for farms with heifers (close: 10.4 ± 5.8 ;

far: 14 ± 3.4 species abundance per summer farm). Near the farm, species richness was lower for grazing cows than for grazing heifers ($P < 0.05$) most likely due to the adverse impact of an intense trampling and grazing on flower abundance and on the vegetation structure. This was not observed in summer farms with heifers.

IV – Conclusions

The traditional link between pasture management and cow's productivity has weakened in summer farms. The transhumance of specialized breeds, despite supplementary feeding, causes a strong reduction of milk yields, without improving significantly pasture conditions. A sustainable management of summer farms should focus on local or dual purpose breeds, more adaptable to the transhumance conditions. Summer pastures managed with moderate stocking rates of herds composed of local breeds would ensure a positive effect on butterfly biodiversity, without decreasing the milk yield, since local breeds adapt better to summer grazing than specialized breeds.

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Adaptation of an ecological and pastoral diagnosis to the Albanian context: Challenges and lessons learned

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Abstract. The European Life+ Program “Mil’Ouv” (standing for MILieux OUverts/open landscapes) has developed an innovative method of diagnosis to allow an efficient management of pastoral resources that is both environmentally sustainable and economically profitable. Indeed, in France, lots of diagnosis methods are already in use by technicians and extension services. However, most of the time, these methods are either too general or too specific and do not combine ecological and pastoral dimensions. Thus, the diagnosis proposed by Mil’Ouv is based on a multiscale analysis crossing the two perspectives. Each diagnosis is therefore carried out by a naturalist, a livestock specialist and the breeder him/herself. This method was designed in and for the Mediterranean part of France. There was a practical and analytical issue of extending and adapting it to another context. With a research-action program BiodivBalkans, it was decided to adapt this method to the Albanian situation, which was, in a way, the farthest from the reference model. From this adaptation process, three main results can be highlighted: (1) strengthening of arguments and examples to launch a “pastoral debate” in Albania (ignored until today) (2) recognition of the local knowledges of the Albanian breeders as an unavoidable element for a sustainable pastoral management (3) identification of eco-pastoral elements to be included in the Code of Practice of a Protected Geographical Indication (PGI) on a kid goat meat from a local breed.

Keywords. Pastoralism – Open landscape – Albania – France.

De la France à l’Albanie, adaptation d’un diagnostic éco-pastoral

Résumé. Le programme européen Life+ Mil’Ouv (pour MILieux OUverts) a développé et mis en œuvre une méthode innovante de diagnostic dont l’objectif est double : une gestion plus durable et plus efficace de l’environnement et des ressources naturelles. En France, de nombreuses méthodes de diagnostic existent, pratiquées sur le terrain par les techniciens et services de vulgarisation. Cependant ces méthodes sont souvent soit englobantes, soit très spécifiques et ne combinent pas les dimensions écologique et pastorale. Ainsi, Mil’Ouv a proposé un diagnostic éco-pastoral original, fondé sur une analyse multi-scalaire et un trio aux compétences complémentaires: naturaliste, spécialiste de l’élevage (pastoraliste), et éleveur lui/elle-même. Cette méthode a été conçue dans et pour la France méditerranéenne, par conséquent son extension et son adaptation à un autre contexte ont nécessité certaines adaptations d’ordre analytique et technique. Avec le programme de recherche-action BiodivBalkans, cette méthode a subi une série d’arrangements pour être adaptée à la situation albanaise, éloignée du modèle de référence. Trois principaux résultats sont attendus de cette adaptation: (1) la consolidation des arguments et des exemples pour lancer un «débat pastoral» en Albanie (jusqu’à présent inexistant) (2) la reconnaissance des savoirs locaux des éleveurs albanais en tant qu’éléments incontournables pour la gestion pastorale (3) l’identification des éléments éco-pastoraux pouvant être inclus dans le cahier des charges d’une IG sur la viande de cabri d’une race locale.

Mots-clés. Pastoralisme – Milieux ouverts – Albanie – France.

I – Introduction

The European Life + program “Mil’Ouv”¹ aims to improve pastoral breeding of natural resources as well as to maintain agro-pastoral habitats (especially “open landscapes”) in Mediterranean regions. Based on a sample of 130 farms, the program has designed a method to carry on-site diagnosis, called “eco-pastoral diagnosis”. The aim is to improve the management of pastoral resources in a way that is both sustainable from an environmental point of view and more efficient from an economic perspective.

In France, the testing zone was located in the southern area of the Massif Central, in the territory of the Unesco Site called “Causses and Cévennes - cultural landscape of the Mediterranean agro-pastoralism”. In 2015, this eco-pastoral diagnosis was tested and transferred in Albania through the CIHEAM-MAIM BiodivBalkans program² (a major project implemented by the Mediterranean Agronomic Institute of Montpellier on agro-sylvo-pastoral issues in the Mediterranean). For Mil’Ouv project it was the opportunity to test the application of the method in another Euro-Mediterranean territory; for BiodivBalkans to (1) give more arguments to the pastoral advocacy in Albania and (2) to introduce, in the Geographical Indication building process for the Hasi kid goat meat, fundamental environmental-pastoral requirements.

II – Mil’Ouv, an innovative method of eco-pastoral diagnosis

The original Mil’Ouv method stems from two main observations: (1) the decline of pastoral activities in France and in other Mediterranean and European regions is causing landscape closure, a phenomenon that entails degradation of opened landscapes biodiversity and increases fire risk (Lepart *et al.*, 2007); (2) breeders that are facing landscape closure and encroachment (i.e. decreasing forage resource) try to overcome this trend and ask for innovative and participatory devices to find solutions (Buffin *et al.*, 2014).

Therefore, the eco-pastoral diagnosis developed by Mil’Ouv program combines complementary skills of two technicians (a naturalist and a pastoral specialist), and the collaboration of the breeder. Only he will be able to know the state, availability and access of natural resources at farm scale. In that line, the idea is to co-construct strategies and propositions to optimize the use of resources and the sustainable management of pastoral areas. The second originality of the method is precisely to integrate several scales of analysis (farm, management unit, topo-facies). It enables to become more specific of environmental stakes and propose appropriate adaptation of pastoral practices (grazing periods/grazing paths, enclosure creation, etc.).

The method develops the following steps: (1) a global understanding of the farm functioning, based on a detailed interview with the breeder; (2) a field diagnosis to understand the interactions between pastoral practices and vegetation dynamics at different scales; (3) a monitoring phase, to assist breeders in their management choices and evaluate the impact of changing breeding practices, both on the environment and on the farming system.

III – Adaptation for the Albanian context

Albania is, in a way, one of the most distant cases possibly found from the French context in terms of institutions and production organization, as well as resources status and evolution. The trans-

¹ <http://www.cenlr.org/valoriser/projets/milouv>

² The BiodivBalkans program (2012-2016) is financed by the FFEM (*French Global Environment Facility*) and implemented by MADA (*Mountain Area Development Agency*) and the CIHEAM-MAIM.

ferring process of this eco-pastoral diagnosis required several adjustments to make it fully operational in Albania. The challenge was to expand its scope without losing its major principles and originality. Three major adjustments have been done to fit to the Albanian context. Once modified, the method has been tested on-adjusted during a collective one-week mission on the Hasi area in Albania (Garnier *et al.*, 2016).

1. Territory and diagnostic

The original diagnostic practiced in France by Mil'Ouv integrates three levels of analysis: farm level, management unit level and homogenous ecological plots level (“*topo-facies*”). In the original method, the territorial level was implicit, due to the important knowledge accumulation available to specify the area from ecological, geographical and historical perspectives.

In Albania, where livestock farming systems are both highly diversified and based on the use of natural resources (Bernard *et al.*, 2014a) the analysis of agrarian landscapes and landscape ecology is necessary. However, there is a low level of information available on local pastoral situations. The first adaptation was to make explicit the macro pastoral-ecosystem which is going to be considered during the “eco-pastoral diagnosis”, thanks to a preliminary identification and description of the local livestock farming system related to particular landscapes (“pastoral massifs”).

2. Farm scale and collective pastures

In France, farm level is often the most appropriate and most frequent scale of diagnosis. It constitutes the largest unit where ownership and management rights are overlapping. However, in Albania, a large part of grazing areas is collective. Property and management rights do not always overlap (Bernard *et al.*, 2014b). To that regard, it was important to extend the analysis to a higher level - but still the smallest unit of common land management. In north-eastern Albania, the ‘*lagja*’ constitutes this unit: it is a village quarter assigned to a lineage (family and relatives) with a common grazing sector (De Rapper, 1998; Bardhoshi N, 2008). In the adaptation of the method to Albania, the ‘*lagja*’ is an extra level of analysis (Fig. 1). Thus individual goals can be taken in account at farm scale and collective goals at ‘*lagja*’ or territory scale.

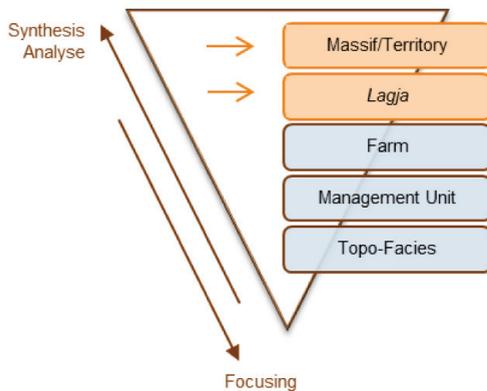


Fig. 1. Integration of two levels of analysis into the diagnosis methodology.

3. From 'open areas' to all type of grazing lands

In agro-sylvo-pastoral territories and especially in Albania, not only the herbaceous layer but also bushes, shrubs and forests are used as grazing resources. On the Hasi karstic plateau, heathlands and oak forests are of paramount importance both in terms of space, and as part of goats diet (Garner, 2014).

The eco-pastoral diagnosis as it has been designed for France focuses on the evolution of pastoral open landscapes. This choice made sense because these types of landscapes show major conservation issues across European Union, due to the decline of pastoralism and landscape closure (Blondel, 2006). However in the Albanian situation and regarding the overall objective of the method, it was suitable to extend the diagnosis from open landscapes to other grazing areas, including forest and scrublands. The aim was to cover all areas presenting pastoral and ecological interests and challenges.

IV – Conclusions

The adaptation of this eco-pastoral method has revealed its usefulness in the Albanian context. First, it allowed the program mentioned and its stakeholders to inform the environmental-pastoral issues in a systematic perspective in the frame of a GI building process. Moreover, this diagnosis made the breeders realize and able to demonstrate how their practices and interests are closely linked to the environmental state of grazing areas. The diagnosis also highlighted the fundamental interest to integrate local practitioner knowledge in comprehensive and collaborative ecological-pastoral strategies.

From the national point of view, this experiment should be continued, deepened and institutionalized. Agro-sylvo-pastoral systems are a major challenge (although unknown!) in Albania: most of the meat (with high quality standards) consumed by the population is produced in these High Nature Value breeding systems (Oppermann *et al.*, 2012). Livestock improvement strategies ignoring this fact, whatever their success could be, will miss the opportunity to combine rural and sustainable local development with provision of high quality products, agrobiodiversity conservation and landscape ecology protection. A lot of reasons not to do so!

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GPS based tools for extensively reared cattle: relationship between temperature and animal activity

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Abstract. A study was conducted to track a group of grazing cows by GPS-GPRS technology. GPS devices were placed in the neck of 3 non-gestating and non-lactating Morucha cows (averaged 8 years old). The GPS units emitted data regarding animal position every 10 minutes for a period of 28 days in which the animals could range freely in the experimental farm. Data were processed using the appropriate software to generate parameters related to animals' activity, such as velocity of movement or estimated grazing area. It was observed that the hours of activity and rest matched those of daily daylight and night time, albeit a period of two hours of little activity was observed during the early afternoon. Likewise, activity varied along the days of study, probably due, among other factors, to the changes in weather conditions. A significant positive correlation between the activity shown by the animals and the temperature registered throughout the day was noted, although the latter directly depends on daylight and night time periods. The development and implementation of these monitoring systems in the future on a practical level may contribute to an appropriate and efficient management of extensively reared cattle, especially in remote, difficult to access and large areas, while providing valuable information about the interactions between animals and the environment.

Keywords. Management – Remote – Global position system – Grazing area – Movement.

Outils basés sur le GPS pour le contrôle de l'élevage extensif du bétail: relations entre la température et l'activité des animaux

Résumé. Une étude a été réalisée, en utilisant la technologie GPS, pour faire un suivi à un groupe de vaches au pâturage. Les dispositifs, qui ont été placés au cou de 3 vaches de race Morucha non gestantes ni en lactation ($8 \pm 2,5$ ans), ont émis des données sur la position des animaux chaque 10 minutes pendant une période de 28 jours dans lequel ils se déplaçaient librement dans la ferme expérimentale. Les données ont été traitées avec un logiciel approprié pour obtenir les paramètres liés à l'activité des animaux (vitesse de déplacement, surface de pâturage...). Il a été noté que les heures d'activité et de repos des animaux coïncident avec les heures de lumière et d'obscurité, et qu'il y avait une période de moins d'activité dans le milieu de la journée. De la même manière, l'activité a varié au fil des jours de l'étude, probablement, entre autres facteurs, à cause de la variation des conditions météorologiques. Il y a eu une corrélation significative entre l'activité des animaux et la température tout au long de la journée, bien que celle-ci soit affectée par des périodes de lumière et d'obscurité. Le développement et l'implémentation au niveau pratique de ces systèmes dans le futur peuvent contribuer à contrôler et gérer le bétail d'une manière plus appropriée et efficace, surtout dans les zones de pâturage grandes et de difficile accès, et aussi à étudier les interactions entre les animaux, et entre eux et l'environnement dans lequel ils se déplacent.

Mots-clés. Gestion – À distance – Système de positionnement global – Zone de pâturage – Mouvement.

I – Introduction

There is an increasing interest in the use of gps-gprs technology to monitor livestock activities, the effects of weather on animal behaviour still remain to be fully considered. Nevertheless, not only will climate conditions influence animal welfare, but also animal performance (Roselle *et al.*, 2013). The study of the response of animals' behaviour throughout the year in different locations to temperature changes (increases and decreases) may serve as a model to estimate animals' reaction to unfavourable weather conditions. Morucha is a rustic cattle breed traditionally reared on pasturelands ("dehesa") on the west of Spain, particularly in Salamanca province. It is characterized by medium adult size that has evolved into a compact format during the last 30 years, thus improving its meat yield, which is under Geographic Protected Indication "Carne Morucha de Salamanca" (De la Fuente *et al.*, 2014). The objective of this experiment was to study the activity throughout the day of this cattle breed usually reared under extensive pastureland conditions and to describe the possible influence of weather on this activity.

II – Materials and methods

1. Animals, location and data sampling

Three specially designed GPS-GPRS devices were fitted to the neck of three, non-gestating and non-lactating, 8 years old morucha cows. The hardware was able to real-time record and transmit position data every 10 minutes for a 28 days period. Data were automatically uploaded into a website where they were also real-time available.

The trial was conducted in "Finca Muñozela" (817 m above sea level; 40°54'13" N; 5°46'47" W), owned by the "Instituto de Recursos Naturales y Agrobiología" of Salamanca (IRNASA, CSIC) in Barbadillo (Salamanca, Spain), where the animals had been grazing for at least one month before the commencement of the trial. The area is characterized by temperate climate, with dry and temperate summers (Köppen-Geiger climatic classification: Csb; AEMET, 2011).

Weather conditions were recorded by a weather station located in the same farm where the animals were grazing. Temperature-humidity index (THI) was calculated according to Dikmen and Hansen (2009): $THI = (1.8 \times T + 32) - [(0.55 - 0.0055 \times RH) \times (1.8 \times T - 26.8)]$, where T is temperature (°C) and RH is relative humidity (%). As the experiment progressed, humidity values were decreasing; however, the rise in temperature resulted in an increase in THI (Fig. 2), rainfall being almost irrelevant.

2. Data processing

Position data were recorded in worksheets and processed by using Excel, Access and ArcGis software to calculate the distance to interest points (such as, e.g., ponds), distance travelled by the animals and speed of these movements (the latter can be assumed as an indicator of the animal's activity through the field; Dolev *et al.*, 2014; Trotter *et al.*, 2010). Regression analyses and graphs were performed on SigmaPlot 9.01 (Systat Software, Inc., Chicago, USA).

III – Results and discussion

Daily pattern of movement can be seen in Figure 1A. As can be seen, activity and rest peaks are recorded in daylight and night hours, respectively. Cows increase their activity around 7:00 and reach a maximum around 12:00, in which activity starts decreasing. Afterwards there is a rest-like period between 14:00 and 16:00. A hiccup is observed at 17:00, speed increasing until 19:00, when the maximum peak is attained. Then there was a sharp decrease in speed which remained at a relatively low level all night long.

This pattern of daily activity is very similar to the one reported by previous authors: there is an increase in activity during the morning; movements decrease by early afternoon and gradually increase by late afternoon (Trotter *et al.*, 2010). Thus, high speed values are indicative of travelling periods, very low values indicate resting periods, whereas grazing events usually occur at intermediate speed levels (Sarova *et al.*, 2010). By representing animals' position in a map (data not shown) it could be confirmed that animals were moving and travelling from 9:00 to 12:00 and from 18:00 to 20:00. It could be concluded that grazing periods were around sunrise (6:00-7:00) and sunset (21:00-22:00), whereas drinking activity took place in the two occasions when animals passed by the ponds (14:00 and 21:00).

The study of the relationship between THI and animals' speed of movement give rise to a significant linear direct correlation (Fig. 1 B). Thus, as the THI increases, so does the speed at which the cows move. Nevertheless, taking into account that correlations do not involve causality, it must be pointed out that THI variations within the day follow day-night pattern and, hence, animals movement.

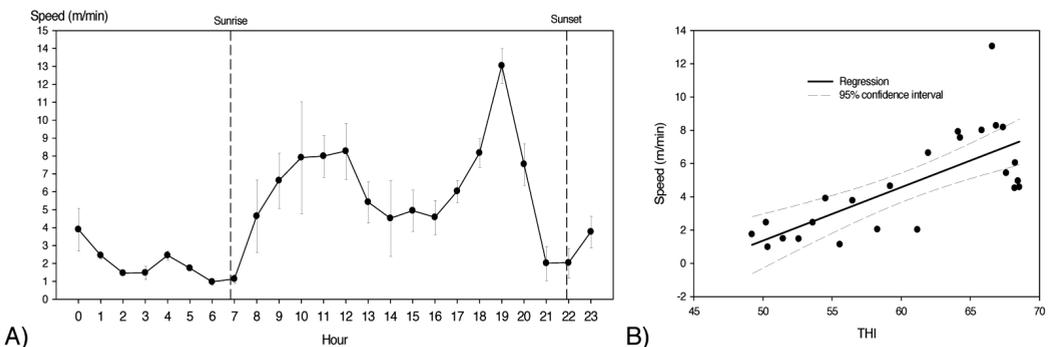


Fig. 1. A) Evolution of average hourly speed of monitored animals during the day. B) Linear regression of hourly speed vs. THI values: speed = 14.7 + 0.32*THI; $r^2 = 0.530$; $P < 0.001$.

The average daily speed of animals during the experimental period and the evolution of THI are shown in Figure 2A. As the experiment progressed, an increase in THI was observed, as well as subtle decrease in animals' activity (speed of movement). Even though some authors opine that grazing time through the day may be independent of weather conditions, this idea is not generally accepted. Conversely, animals seem to look for shaded places in the early afternoon or when the temperature rises (central and hottest hours of day; Roselle *et al.* 2013; Trotter *et al.*, 2010).

When the weather conditions are maintained, animals tend to show similar patterns of activity and grazing over days (Hejzmanová *et al.*, 2009). In the present experiment we could observe a significant linear inverse small relationship between ITH and animals' speed of movement (Fig. 2B). Thus, despite keeping the same intra-day movement pattern, the average daily activity of the animals throughout the study (inter-days) may have decreased, at least partly, in response to the increase in ITH. In this regard, animals' behaviour evolves over time due to changes in climatic conditions (Hejzmanová *et al.*, 2009). Although, as previously indicated, it can be assumed that this fact does not necessarily entail a reduction in grazing times (and hence in animal's performance), this question is still to be answered.

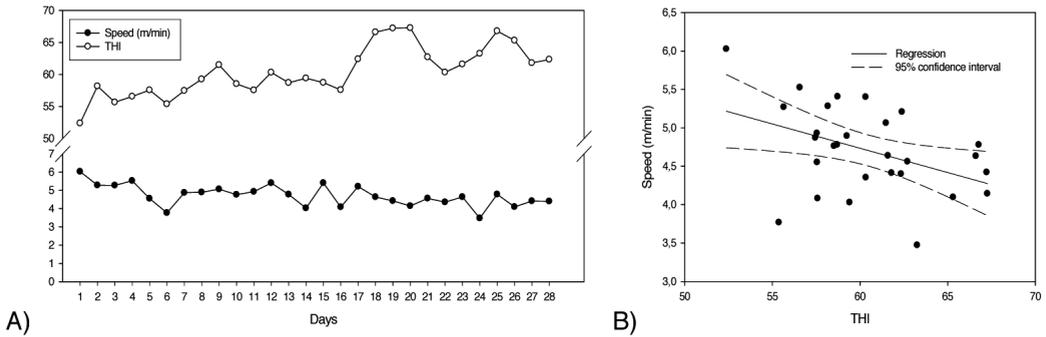


Fig. 2. A) Evolution of average daily speed of monitored animals and temperature and humidity index (THI) during the experimental period. B) Linear regression of average daily speed vs. THI values: $\text{speed} = 8.53 - 0.06 \times \text{THI}$; $r^2 = 0.179$; $P < 0.05$.

The development and implementation of these monitoring systems in the future on a practical level may contribute to an appropriate and efficient management of extensively reared cattle, especially in remote, difficult to access and large areas, while providing valuable information about the interactions between animals and the environment.

IV – Conclusions

Morucha grazing animals are more active during the daylight hours, maximum and minimum speeds of movement being reached during the afternoon and the night, respectively. This scheme positively correlates with intra-day pattern of THI. However, as the average daily THI increases over days, animals tend to modify their behaviour towards a decrease in speed of movements and, hence, overall activity.

From a practical viewpoint, these monitoring systems may contribute in the future to an appropriate and efficient management of extensively reared cattle.

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Scenario analysis of alternative management options on the forage production and greenhouse gas emissions in Mediterranean grasslands

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Abstract. Grazing businesses need to develop an understanding of their greenhouse gas (GHG) budget and be able to assess the impact of alternative management options. In this study annual emissions of the three main agricultural GHGs (CO₂, CH₄ and N₂O) were generated for contrasting management scenarios using 50-year simulations with a biogeochemical model in a sheep-grazing system of Northern Sardinia (Italy). Three stocking rates (0.21, 0.42 and 0.84 LSU ha⁻¹ yr⁻¹) combined with three N fertilization rates (0, 100, 150 kg N ha⁻¹ yr⁻¹) were assessed. CO₂ emissions showed higher sensitivity to interannual weather variability than CH₄ and N₂O emissions, with the system holding its sink capacity but with lower rate of sequestration in the most arid years. When N rates did not exceed 100 kg ha⁻¹, a trade-off can be identified between an adequate pasture production and relatively low GHG emissions. The analysis indicated that there is scope for grazing businesses to choose alternative management options to influence their GHG budget. Studies of this type are challenging for livestock industries and policy makers to work through.

Keywords. Forage production – Greenhouse gas (GHG) emissions – Management options – Mediterranean pastures – Simulation.

Analyse des scénarios des options alternatives de gestion des pâturages méditerranéennes sur la production de fourrage et les émissions de gaz à effet serre

Résumé. L'évaluation des bilans de gaz à effet de serre (GES) dans les systèmes prairiaux pâturés vise à quantifier les émissions liées à la gestion de ces mêmes systèmes. Dans cette étude, un modèle biogéochimique de simulation a été utilisé pour générer les émissions annuelles des trois principaux GES agricoles (CO₂, CH₄ et N₂O) d'un système prairial du nord de la Sardaigne (en Italie), pâturé par des moutons. Les valeurs de GES ont été estimées sur une période de 50 ans en simulant des scénarios contrastés de gestion. Trois taux de chargement animal (0,21, 0,42 et 0,84 UGB ha⁻¹ an⁻¹) ont été évalués, combinés avec trois taux de fertilisation azotée (0, 100, 150 kg N ha⁻¹ an⁻¹). Les émissions estimées de CO₂ ont montré une plus grande sensibilité à la variabilité météorologique interannuelle que les émissions de CH₄ et N₂O. Globalement, le système maintient sa capacité de séquestration bien que celle-ci soit plus faible dans les années les plus arides. Lorsque le taux d'azote ne dépasse pas les 100 kg ha⁻¹, la continuité de la production pastorale s'accompagne d'émissions de GES relativement faibles. L'analyse indique qu'il est possible, pour ce type de pâturages, d'opter pour des options alternatives de gestion influençant leur bilan de GES. Ces études posent des défis au secteur de l'élevage et fournissent des informations aux décideurs.

Mots-clés. Production fourragère – Émissions de gaz à effet de serre (GES) – Options de gestion – Pâturages méditerranéens – Simulation.

I – Introduction

Mediterranean grasslands contribute to agricultural production and ecosystem services provision (EIP-AGRI, 2014). Their complex plant communities are characterized by the prevalence of therophytes annual species. The growing season typically starts in autumn with the germination of seedlings of annual species and ends in late spring (Caballero *et al.*, 2009). Pasture management

practices contribute considerably to the relationships between different ecosystem functions such as forage and livestock productions, biodiversity and soil carbon sequestration. Scenarios analysing the impact of alternative management options on grassland functions may help identifying suitable practices and provide decision support tools to stakeholders. In this paper the results of a model-based simulation of the effects of contrasting management options on the forage production and greenhouse gas emissions in Mediterranean grasslands are reported.

II – Materials and methods

1. Study site

The study site is the Berchidda-Monti Long Term Observatory (NE Sardinia, Italy) (40° 49' N, 9° 18' E, 300 m a.s.l.). Mean annual rainfall is 632 mm, concentrated in autumn-winter period, and mean annual temperature is 14.2° C. Soil type is Typic Dystroxerept (Lagomarsino *et al.*, 2011). Grassland is the prevalent land use, including dairy sheep and beef cattle grazing systems (Cballero *et al.*, 2009).

2. Study Design

A simulation study was run with the Pasture Simulation model (PaSim, <https://www1.clermont.inra.fr/urep/modeles/pasim.htm>), as calibrated and validated for the study-area in a previous work (Pulina *et al.*, 2015). Starting from actual management conditions, i.e. mean annual stocking rate equals to 0.42 livestock units (LSU) ha⁻¹ yr⁻¹ and no N fertilization, two management options (animal density, N fertilization rate) were assessed following a factorial approach by increasing/decreasing by 50% the animal density combined with introducing N fertilisation at two rates (100 and 150 kg N ha⁻¹), which resulted into nine management scenarios (Table 1). The decreasing animal density (-50%) was intended as a mitigation option, while the other options served the purpose of assessing if the management intensification would lead to increased emissions.

To assess the effect of interannual weather variability, the model was run on a sample of 50 years of daily weather data representative of local climate, as generated from the climate generator WX-GEN (Nicks *et al.*, 1990).

Monthly and yearly means of temperature and precipitation were calculated to elaborate the De Martonne-Gottmann aridity index ($b \geq 0$, extreme aridity), based on De Martonne (1942).

PaSim was run in a multi-year simulation to generate daily values of ecosystem respiration (RECO) and gross primary production (GPP) and thus to calculate yearly budgets of net ecosystem CO₂ exchanges (NEE = RECO-GPP) as well as annual emissions of methane (CH₄) and nitrous oxide (N₂O). Maximum total biomass production (dry matter, DM) was also assessed, assuming that the peak of grass production occurs at mid-May, as observed from field data.

Results are illustrated for three contrasting years singled out from the simulated series: the most and the least arid year, and a year representing intermediate conditions.

Table 1. Management scenarios codes

Stocking rate (LSU ha ⁻¹ yr ⁻¹)	N fertilization (kg N ha ⁻¹ yr ⁻¹)		
	0 (actual N rate)	100 (high N rate)	150 (very high N rate)
0.21 (-50% stocking rate)	-50_0	-50_100	-50_150
0.42 (actual stocking rate)	Act_0	Act_100	Act_150
0.84 (+50% stocking rate)	+50_0	+50_100	+50_150

III – Results and discussion

Scores for the aridity index (b) ranged from 7.35 (arid) to 22.32 (sub-humid), with average value of 13.91 (arid). Arid conditions were observed in 60% of the simulated years, while semi-arid and sub-humid conditions were in 32% and 8% of the years, respectively.

Based on NEE estimates (Fig. 1A), the grassland system results in a C sink ($NEE < 0$), similar to other Mediterranean grasslands (Xu and Baldocchi, 2004), with large interannual variability characterised by less pronounced sink capacity in arid years. The trajectory of the C sink tends to increase with higher N supply, ranging from $-0.1 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$ in Act_0 most arid year to $-4.4 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$ in 50_150 intermediate year. The C sink in the most humid year was lower than in the intermediate year, likely owing to a higher C consumption, particularly in soil, due to conditions (presence of water) favouring organic matter mineralization.

N_2O emissions are expected to increase with increased N rates, which are amplified with N fertilization higher than $100 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ (Fig. 1B), in the range $0.0013\text{-}0.0151 \text{ Mg N-N}_2\text{O ha}^{-1} \text{ yr}^{-1}$. A reduction in N emissions is observed as a consequence of a reduction in animal density. Clear differences in N_2O emission trends were not shown in contrasting years, suggesting that N-cycle processes are less dependent on aridity conditions.

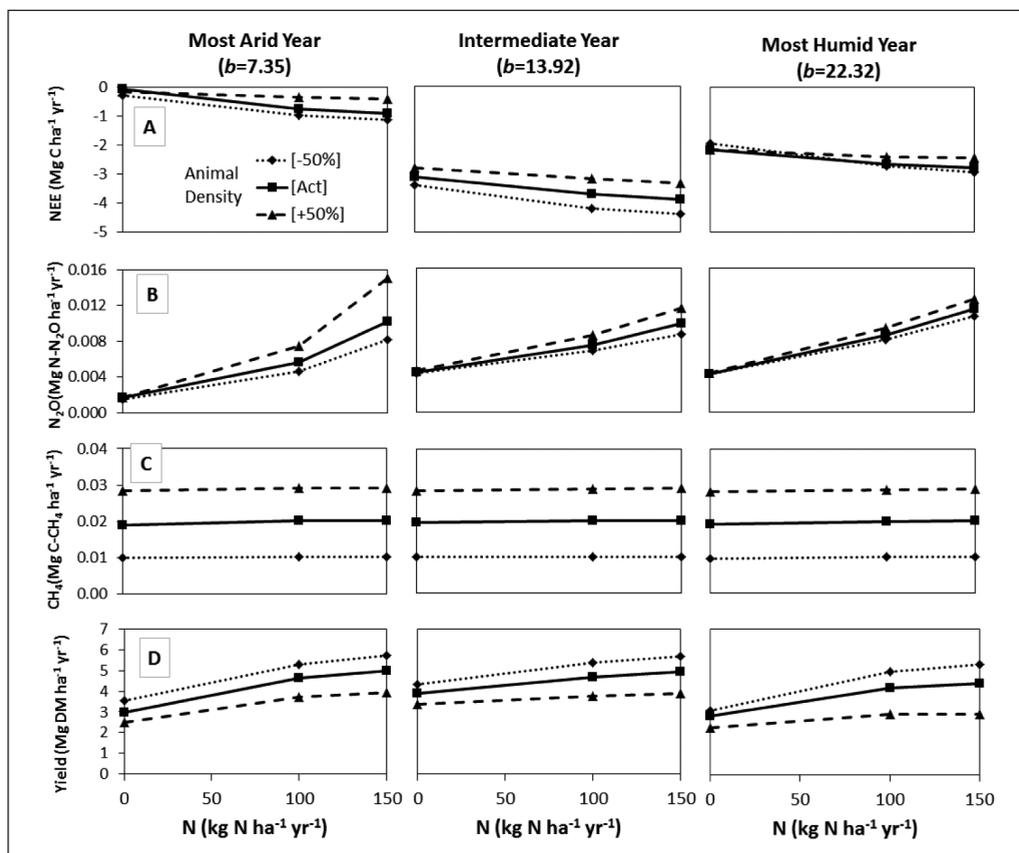


Fig. 1. Annual NEE ($\text{Mg C ha}^{-1} \text{ yr}^{-1}$), N_2O emissions ($\text{Mg N-N}_2\text{O ha}^{-1} \text{ yr}^{-1}$), CH_4 emissions ($\text{Mg C-CO}_2 \text{ ha}^{-1} \text{ yr}^{-1}$), and maximum biomass production ($\text{Mg DM ha}^{-1} \text{ yr}^{-1}$) simulated by PaSim for alternative management scenarios (Table 1) and contrasting years.

CH₄ emissions are expected to increase/decrease by 40-50% with increasing/decreasing animal density by 50% (Fig. 1C). In contrasting years, neither N supply nor aridity conditions affected CH₄ emissions. Average values were 0.1, 0.2 and 0.3 Mg C-CH₄ ha⁻¹ yr⁻¹ for -50%, current and +50% stocking rate, respectively.

N supply supports biomass production, with less effect at rates higher than 100 kg ha⁻¹ yr⁻¹ (Fig. 1D).

IV – Conclusions

This simulation study indicates that GHG emissions from Mediterranean pastures may vary in relation to yearly rainfall patterns. As general conclusions:

- (1) Decreasing density of grazing animals can be envisaged as an option to reduce emissions of CO₂, N₂O and CH₄.
- (2) CO₂ emissions (NEE) are highly affected by interannual weather variability. Sardinian grassland sites are expected to reduce their sink capacity in dry years without becoming a C source.
- (3) Increasing N fertilization can promote forage production with relatively limited impact on N₂O emissions if N rates do not exceed 100 kg ha⁻¹, which is rarely the case in current agricultural practice.

Acknowledgments

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Forage consequences of the continued reduction of stocking rate in subalpine grasslands: the case of *Festuca eskia* grasslands

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Abstract. From the mid-20th Century abandonment of rangelands is the biggest threat in the European high mountain. Although this grassland has been used as means of grazing for many centuries, there are no natural communities in *stricto sensu*; communities are semi natural with a good stability. The value of this grassland is exceptional (biodiversity reservoirs, chipper production with good nutritional qualities, protective from erosion, suitable for amenities, etc.). However, such values can only be maintained by keeping the farming activity. In this work we present continuous measurements during five years of the effect of *Festuca eskia* in grasslands from the Aigüestortes National Park in the Spanish Pyrenees, where the seasonal stocking rate was decreasing (from 0.72 to 0.18 LU·ha⁻¹·year⁻¹). Results show an increase in species richness (S, 13.4 vs. 18.2), biodiversity index (Shannon, 1.99 vs. 2.13) and non-legume forbs (7.1 vs. 11.4) when stocking rate was diminishing. Forage quality (measured through the pastoral value method, the content in crude protein, fat and phosphorus in the dry matter production) diminished in the same period.

Keywords. Upper timberline grasslands – Forage quality – Grazing abandon – Plant diversity – Pyrenees.

Conséquences fourragères de la réduction continue de la charge animale dans les prairies subalpines: le cas des pâturages de *Festuca eskia*

Résumé. Depuis le milieu du siècle dernier, l'abandon de l'activité pastorale est l'une des principales menaces dans les zones de haute montagne de l'Europe. Depuis des siècles, ces communautés végétales ont été utilisées par le bétail et, bien qu'elles soient semi naturelles, elles sont assez stables quant à leur diversité, leur qualité fourragère et leur production, ce qui leur confère une valeur exceptionnelle. Cependant, cette valeur ne peut être conservée (étant donné son caractère semi naturel) que si l'utilisation et la gestion pastorale sont maintenues. Ce travail montre l'effet, sur une période d'échantillonnage de cinq ans, de la diminution de la charge en bétail estivale (de -0,72 à -0,18 UBG·ha⁻¹·an⁻¹) sur différentes caractéristiques du système. Les résultats montrent une augmentation de la richesse spécifique (S, 13,4 vs. 18,2), de l'index de Shannon (1,99 vs. 2,13) et de la diversité des espèces (7,1 vs. 11,4). Simultanément, la qualité fourragère (mesurée selon la méthode de la valeur pastorale, ainsi que par l'analyse des teneurs en matière azotée totale, en graisses et en phosphore dans la matière sèche) diminue pour la même période.

Mots-clés. Prairies d'altitude – Qualité fourragère – Abandon du pâturage – Diversité botanique – Pyrénées.

I – Introduction

Most of European grassland ecosystems, such as the Pyrenean *F. eskia* pastures, have been used for centuries, and have thus maintained high values of biodiversity and forage quality (Humphrey and Patterson, 2000; Leeuw and Bakker, 1986). The abandonment of pastures in the mountain started with remote and badly connected farms, related with the migration process (farmers to cities) and the shift in working activities from the agricultural to the tertiary sector. On the contrary, the stocking rate has increased in pastures near farms. Abandonment (lower stocking rate than admissible) and overgrazing (more stocking rate than admissible) are similarly bad situations for the ecosystem. Our objective was to study the evolution of different variables (related with floristic diversity and forage quality) during a period of seven years in a pasture of *F. eskia* that was being gradually abandoned.

II – Materials and methods

1. Location

This study was conducted in the Aigüestortes National Park (Spanish Pyrenees; 42° 35' N, 010° 00' E; 2185 m a.s.l.; SE orientation; 15° slope). The climate (“oro-temperate hyper-wet” according Rivas-Martinez *et al.*, 2002) does not show significant differences in precipitation during the growth period over the seven sampling years (average of 238.6 mm). The stocking rate changed from 0.72 LU.ha⁻¹ in the first year (2002) to 0.18 AU.ha⁻¹ in the last year (2008). At the start of experiment, 0.72 AU was slightly higher than the admissible stocking rate calculated by means of dry matter production (0.68 AU), consequently the pasture was a bit overgrazed. The livestock grazed from July to the end of September.

2. Sampling

Two fenced plots of 10 x 12 m were established in a homogenous *F. eskia* pasture. On each plot, two quadrates of 1 x 0.5 m were randomly harvested every three weeks (from mid-June to the end of September) to calculate the dry matter (DM) aboveground production (not used for this paper) and the chemical nutritional components. We avoided cutting the same quadrate more than once in all samplings. Two linear transect of 10 m (randomly placed on the plot) was also used for botanical composition measurements. The plots were located in the same zone every year, but not in the same place, in order to detect any effects of the change in stocking rate.

3. Diversity and forage quality

The botanical composition (present and abundance species) was determined by the point-quadrat method (1 point every 20 cm; 100 points per transect) and the specific contribution was defined according to our works in the same kind of pasture (Fanlo *et al.*, 2015; Komac *et al.*, 2014). Data from transects were used to obtain the specific richness, Shannon and Berguer Parker indexes (Magurran, 1988), botanical functional groups and to calculate the pastoral value (PV) according to the Daget and Poissonet method (Daget and Poissonet, 1971). Forage parameters of the biomass were analyzed using the near-infrared spectrometry method after drying to obtain the crude protein (CP), fats (EE), lignin (ADL), crude fiber (CF), calcium (Ca), magnesium (Mg) and phosphorous (P) contents in DM by means of an NIR SYSTEM 6500, using a universal calibration obtained in the Catalan Agro-Food Laboratory (accreditation number 157/LE309).

III – Results and discussion

All the means obtained in the experiment are shown in Table 1. Species richness and diversity values (S and H') are significantly higher when pastures are being left and Berguer-Parker's dominance index is minor. The number of species is low, but it is within the same range as other acidic pastures (Komac *et al.*, 2014). For the analysis of “functional groups” we have grouped *Poaceae* and graminoides as “grasses”, only *Fabaceae* as “legumes” and the rest of species as “forbs”. Number of different “grasses” doesn't show significant difference between the different years, “legumes” vary with no clear pattern and “forbs” increase in number. The increase in “forbs” causes the increase of Shannon and a decrease in the dominance values. These results are the contrary to when Mediterranean pastures are abandoned, as functional diversity decreases (Peco *et al.*, 2012).

Quality assessment of grassland through pastoral value method is based on the presence of good forage species (values 4 or 5) and their proportion (Daget and Poissonet, 1971). Most of the species in our pastures have a medium quality (3) a low quality (2 and 1) or none (0). It is important to point

out that the mentioned method (VP) considers *F. eskia* as a species with no value. This is the reason why values are very low in general. The decreasing VP over time is related to the increase of “forbs” with no forage value. The nutrient contents obtained by means of the NIRS method show a similar result to those of the VP. The decrease of the stocking rate produces a significant reduction of the CP, EE, P and a tendency in Ca in the pasture biomass. Variations of CF are difficult to explain; they may be related to the increase of “forbs”, and the latter with the decrease of LAD.

Table 1. Supported stocking rate over the trial duration and observed means (\pm SD) from plant richness, Shannon, and Berger-Parker indices, grasses, legumes and forbs proportions, Forage quality (pastoral value, crude protein, crude fibre, lignin, fat, phosphorus and calcium in % of DM) (n = 35 for diversity variables; n = 145 for forage quality)

Year	2002	2004	2005	2006	2008
Supported stocking rate AU.ha ⁻¹ .year ⁻¹	0.72	0.60	0.50	0.21	0.18
Diversity parameters					
Richness (S)	13.40 \pm 1.89c	11.80 \pm 1.93d	14.33 \pm 1.4c	16.83 \pm 1.51b	18.20 \pm 2.38a
Shannon-Weber (H')	1.99 \pm 0.19b	1.82 \pm 0.20c	1.84 \pm 0.11c	2.26 \pm 0.15a	2.15 \pm 0.11a
Berger Parker (d)	0.37 \pm 0.05b	0.40 \pm 0.06b	0.47 \pm 0.02a	0.28 \pm 0.03c	0.28 \pm 0.03c
Grasses	6.30 \pm 0.67	5.70 \pm 0.48	6.22 \pm 0.83	6.00 \pm 0.63	6.00 \pm 0.70
Legumes	0.00	0.90 \pm 0.31a	0.88 \pm 0.33a	0.16 \pm 0.40b	0.60 \pm 0.54a
Forbs	7.10 \pm 1.66b	5.0 \pm 1.63c	7.22 \pm 0.9b	10.66 \pm 2.06a	11.40 \pm 2.07a
Forage quality parameters					
Pastoral Value (range 0-100)	19.67 \pm 2.36a	14.65 \pm 3.59b	10.45 \pm 2.77c	9.36 \pm 0.69c	5.38 \pm 0.80d
Crude protein (CP)	9.28 \pm 1.68a	7.26 \pm 1.26b	6.05 \pm 0.66c	6.19 \pm 1.64c	5.57 \pm 0.78d
Crude fiber (CF)	32.95 \pm 0.55ab	32.13 \pm 0.36b	34.00 \pm 0.34c	33.43 \pm 0.38ac	33.75 \pm 0.44ac
Lignin (ALD)	9.21 \pm 0.9a	9.32 \pm 0.63a	6.62 \pm 0.26b	5.22 \pm 0.13c	5.41 \pm 1.51c
Fat (EE)	2.97 \pm 0.29a	2.66 \pm 0.37b	1.69 \pm 0.33c	1.34 \pm 0.43d	1.18 \pm 0.23e
Phosphorous (P)	0.16 \pm 0.04 a	0.12 \pm 0.02b	0.09 \pm 0.01c	0.10 \pm 0.02c	0.07 \pm 0.01d
Calcium (Ca)	0.52 \pm 0.03a	0.41 \pm 0.01b	0.33 \pm 0.01c	0.32 \pm 0.01c	0.4 \pm 0.07b

Values in the same row followed by different letter are statistically different for $P \leq 0.05$ (LSD test).

Plant biodiversity losses due to abandonment entail a loss of animal and fungi diversity; this tendency could be reverted by going back to traditional management, and hence an increase in stocking rate (Fanlo *et al.*, 2015; Humphrey and Patterson, 2000). But this would only be possible in the case of mountain farmers receiving an economic compensation, in order to avoid polarization of agricultural activities. This would also allow having a feedback between conservation measures and field farming systems (Beaufoy, 1998).

IV – Conclusions

The decrease in the number of animals in upper timberline grasslands over the years produces a loss of quality and an increase in the specific richness. The interrelation between the variables studied (stocking rate, forage quality and biodiversity) shows an inverse relation between the stocking rate and the forage quality and plant biodiversity. These results prove the actuality of the old pastoral paradox: “good grazing management improves grassland”; at least from the pastoral point of view.

Acknowledgments

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Effect of grazing abandonment on arbuscular mycorrhizal diversity in Gorbeia Natural Park

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Abstract. Mountain pastures in the Basque Country (northern Spain) are the result of extensive grazing dating from the Neolithic. However, current management practices are resulting in the progressive abandonment of grazing in these mountain areas. Soil microbial communities are vital for many soil processes and the delivery of essential ecosystem services; in particular, arbuscular mycorrhizal fungi play a key role in plant nutrient acquisition. The influence of grazing on the diversity of arbuscular mycorrhizal communities remains poorly explored. Then, our main objective was to evaluate the effect of the abandonment of grazing on arbuscular mycorrhizal diversity through the study of twelve grazed versus non-grazed (simulated by 100 m² exclusions) areas in Atlantic mountain grasslands. We determined the diversity of arbuscular mycorrhizal fungi using both morphological (spore morphotyping under the microscope) and genetic (Illumina sequencing of ITS amplicons) approaches. After two years, only slight differences on arbuscular mycorrhiza were observed between grazed and non-grazed areas. In fact, the type of vegetation under which the exclusions were established accounted for the greatest amount of data variability. On the other hand, both approaches (morphological and molecular) gave similar results, highlighting the complementarity of these approaches for the study of the biodiversity of arbuscular mycorrhiza.

Keywords. Glomeromycota – Morphotypes – Metabarcoding.

Effet de l'abandon du pâturage sur la diversité mycorrhizienne dans le Parc Naturel Gorbea

Résumé. Les pâturages de montagne du Pays Basque (nord de l'Espagne) sont le résultat d'une pratique de pâturage extensif datant du néolithique. Toutefois, les pratiques de gestion actuelles se traduisent par l'abandon progressif du pâturage dans ces zones de montagne. Les communautés microbiennes du sol sont essentielles pour de nombreux processus du sol et la fourniture de services écosystémiques essentiels; en particulier, les mycorhizes arbusculaires jouent un rôle clé dans l'acquisition des éléments nutritifs des plantes. L'influence du pâturage sur la diversité des communautés mycorrhiziennes arbusculaires reste mal exploré. Notre objectif principal était d'évaluer l'effet de l'abandon du pâturage sur la diversité mycorrhizienne à travers l'étude de douze zones pâturées par rapport aux zones non pâturées (simulé par des exclusions de 10 m²) dans les prairies de montagne de l'Atlantique. Nous avons déterminé la diversité des champignons mycorrhiziens arbusculaires en utilisant à la fois des approches morphologique (spores morphotype sous le microscope) et génétique (séquençage Illumina des amplicons ITS). Après deux ans, seules des légères différences sur les communautés mycorrhiziennes ont été observées entre les zones pâturées ou non. En fait, le type de végétation dans lesquelles les exclusions ont été établies ont expliqué la plus grande part de la variabilité observée. D'autre part, les deux approches (morphologiques et moléculaires) ont donné des résultats similaires, mettant en évidence la complémentarité de ces approches pour l'étude de la biodiversité des mycorhizes arbusculaires.

Mots-clés. Glomeromycota – Morphotypes – Metabarcoding.

I – Introduction

Soil microbial communities are vital for many soil processes and the delivery of essential ecosystem services. Arbuscular mycorrhizal fungi (AMF), in particular, are considered natural biofertilizers, since they provide the host with water and nutrients, as well as pathogen protection, in ex-

change for photosynthetic products (Berruti *et al.*, 2016). However, plant species respond differently to different fungal species; AMF biodiversity might affect plant community (van der Heijden *et al.*, 1998) and, consequently, overall ecosystem services.

In mountain pastures of the Basque Country (Spain) grazing has been the most important economic activity since the Neolithic (Barandiaran and Manterola, 2000). These semi-natural grasslands deliver many valuable ecosystem services (Bullock *et al.*, 2011). If the management trends observed continue, a progressive medium- or long-term grazing abandonment could be expected. The question of whether diversity of AMF may be modified by livestock grazing remains poorly explored, and we hypothesize that thousands of years of herding activity has shape a distinct AMF diversity. In this respect, the main objective of our study was to evaluate the effect of the abandonment of grazing on AMF diversity through the study of twelve grazed versus non-grazed areas in Atlantic mountain grasslands.

II – Materials and methods

1. Study area and experimental design

The current study was carried out in the Gorbeia Natural Park (43°N 2.5°W), in the Atlantic region of the Basque Country (northern Spain). Within the Natural Park, four locations with distinct type of grassland vegetation were chosen; 3 in the mountain area at 630-720 m.a.s.l. (mountain 6230a, mountain 6230c and mountain 6170), and one in the valley at 240-410 m.a.s.l. (Valley). In spring 2012, three permanent exclusions of 10 x 10 m were placed in these locations, twelve in total.

2. Determination of arbuscular mycorrhizal diversity

A total of 24 soil samples (12 inside and 12 outside) were collected two years after the establishment of the exclusions. For the morphological characterization of mycorrhiza, spores were isolated from 50 g dry weigh of soil from each sample by wet sieving, decanting and centrifugation in sucrose medium. After manually selecting all the spores present under a microscope at 40x magnifications, they were mounted on slides in either polyvinyl alcohol –lactic acid– glycerol (PVLG) or a mixture of PVLG-Melzer reagent. Spore characteristics were observed under a microscope at 200x and 400x magnifications for the establishment and quantification of morphotypes. For the genetic characterization, DNA extraction was carried out from aliquots corresponding to 0.25 g of dry-weight soil from all samples using PowerSoil DNA Isolation kits. Fungal ITS amplicon library preparation, Illumina MiSeq sequencing, sequence data processing and taxonomic classification were performed as described in Lanzén *et al.* (2015). The effect of grazing on arbuscular mycorrhizal diversity was assessed through univariate (ANOVA analysis of variance followed by post-hoc Tukey test using Microsoft StatView software) and multivariate (canonical correspondence analyses using Canoco 5 to study the influence of experimental factors on mycorrhizal composition) statistical tests.

III – Results and discussion

A total of 18 spore morphotypes and 832 OTUs belonging to Glomeromycota division were distinguished. Regarding alpha diversity, the indexes calculated showed no significant differences between grazed and ungrazed areas nor with the morphological neither with the genetic approach (Table 1). However, the type of vegetation accounted for significant differences in both richness and Shannon's diversity index with the genetic approach, being the greatest in the valley. From this we can interpret that the edaphoclimatic conditions in the mountain may not favour the establishment of mycorrhiza (Lugo *et al.* 2012), but other factors, such as grazing pressure, could be involved since arbuscular mycorrhizal species diversity has been shown to increase with the altitude (Bonfim *et al.* 2016).

Table 1. Diversity indexes (average \pm standard deviation, n = 3, different letters denote significant differences according to Tukey test)

	Morphological approach		Genetic approach	
	Shannon	Richness	Shannon	Richness
Mountain 6230a NON GRAZED	1.75 \pm 0.19 ^a	14.0 \pm 1.0 ^a	2.03 \pm 0.33 ^a	18.9 \pm 1.1 ^a
Mountain 6230a GRAZED	1.79 \pm 0.11 ^a	13.7 \pm 1.2 ^a	2.01 \pm 0.35 ^a	19.8 \pm 5.1 ^a
Mountain 6170 NON GRAZED	1.62 \pm 0.06 ^a	14.3 \pm 1.2 ^a	2.79 \pm 0.29 ^{ab}	40.2 \pm 3.4 ^a
Mountain 6170 GRAZED	1.67 \pm 0.14 ^a	10.0 \pm 1.7 ^a	2.64 \pm 0.50 ^{ab}	35.1 \pm 14.9 ^{ab}
Mountain 6230b NON GRAZED	1.83 \pm 0.13 ^a	13.0 \pm 1.0 ^a	2.52 \pm 0.31 ^a	26.5 \pm 4.4 ^a
Mountain 6230b GRAZED	1.72 \pm 0.19 ^a	13.0 \pm 2.0 ^a	2.36 \pm 0.10 ^a	23.3 \pm 2.8 ^a
Valley NON GRAZED	1.32 \pm 0.32 ^a	14.3 \pm 2.3 ^a	3.54 \pm 0.36 ^b	61.6 \pm 12.8 ^b
Valley GRAZED	1.42 \pm 0.29 ^a	14.3 \pm 3.2 ^a	3.49 \pm 0.23 ^b	60.4 \pm 3.8 ^b

The results are similar in respect to the composition of the AMF community (Fig. 1). With both approaches, the variable that accounts for the greatest amount of data variability is the type of vegetation and not the grazing treatment. In the canonical correspondence analyses performed, valley samples separate from the rest along CCA-1, while the habitat 6170 separates from habitats 6230 along CCA-2. Having a closer look at the individual taxonomic level, there are four morphotypes in the 6170 habitat and some OTUs classified as “uncultured Glomerales” in the 6230c habitat that increase significantly ($P < 0.05$; data not shown) inside the exclusions. Some studies have previously reported changes in soil microbial parameters (e.g., enzyme activities, microbial biomass, CO₂ emissions) as a consequence of grazing abandonment (Aldezabal *et al.*, 2015), which have been strongly related with the occurrence of certain fungal species (Bonfim *et al.* 2016).

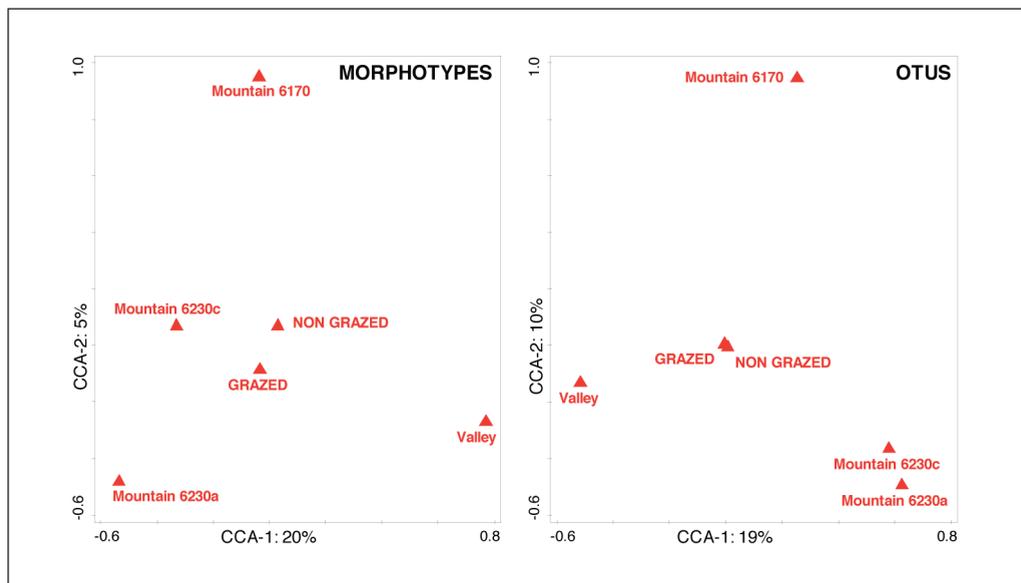


Fig. 1. Scatterplots of the canonical correspondence analyses performed using the treatments and Habitats as explanatory variables and the spore morphotypes (left; pseudo-F = 1.9, P = 0.014) or OTUs of the Glomeromycota division (right; pseudo-F = 2.8, P = 0.002) as response variables.

The reason for the few differences found in our case might be the short term character of the study (the exclusions were established just two years before the sampling) or the need to perform a more exhaustive sampling to overcome the huge spatial heterogeneity of soil microbial communities. Finally, the genetic approach allowed the detection of more OTUs than morphotypes found with the morphological approach. Therefore, it seems that several OTUs were considered to belong to the same morphotype under the microscope. Interestingly, both approaches gave similar results, strengthening the reliability of the data obtained.

IV – Conclusions

A longer period of time under exclusion and a more exhaustive sampling might be needed to observe consistent differences on AMF diversity as a consequence of grazing abandonment. Apart from that, a higher alpha diversity of AMF was found in valley areas compared to mountain areas. This study highlights the complementarity of the morphological and genetic approaches for the study of the biodiversity of AMF.

Acknowledgments

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Impact of grazing abandonment and phosphoric fertilization on *Nardus* grasslands floristic diversity in Gorbeia Natural Park (Bizkaia, Northern Spain)

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Abstract. Among the different grazing habitats of Gorbeia Natural Park, *Nardus stricta* species-rich grasslands (habitat of community interest 6230*, Council directive 92/43/EEC) have special importance due to its large coverage, ecological value, landscape relevance, and its social-economic importance as the territorial base of livestock farms. This study focuses on this particular habitat and aims to assess the impact of grazing exclusion (which simulates abandonment) and the use of phosphoric fertilization on the floristic diversity of these grasslands in Gorbeia. Experimental treatments (4 replicates per treatment) included “non-grazing”, “phosphoric fertilization” and the control (“grazing and non-fertilization”). In each replicate (experimental plot of 10 × 10 m), randomly selected sampling squares (50 × 50 cm) were used to study species presence and cover (in 2012, 10 square per replicate; in 2013, 5). Differences between treatments and years in both richness and the equivalent number of species (i.e., the number of equally-common species, a proper measure of species diversity) were studied through curves of accumulated richness and diversity. The results showed different patterns according to the year. In 2012, the lowest richness and species diversity were found in the fertilization treatment. No differences were detected between the control and exclusion treatments. In 2013, the highest richness and species diversity were observed in the control; the species richness was intermediate in the fertilization treatment and lowest in the exclusion treatment. Our results will contribute to the knowledge and implementation of management guidelines aiming to the conservation of biodiversity of mountain habitats.

Keywords. Diversity – Species richness – *Nardus stricta* – Natura 2000 network – Floristic composition – Community interest habitat 6230 *

Impact de l'abandon du pâturage et de la fertilisation phosphorique sur la diversité floristique des prairies de *Nardus* dans le Parc Naturel Gorbea (Bizkaia, Nord de l'Espagne)

Résumé. Parmi les différentes formes de végétation liées au pâturage dans le Parc Naturel de Gorbea, les prairies de nard raide (*Nardus stricta*) (habitat d'intérêt communautaire 6230*, Directive 92/43/CEE) présentent une importance toute particulière en raison de leurs grandes surfaces, leurs valeurs écologique et paysager ainsi que d'un point de vue socio-économique du à leurs rôles comme base territoriale des exploitations d'élevage. L'objectif de cette étude était d'évaluer les effets de l'abandon du pâturage et de la fertilisation phosphorée sur la diversité botanique des prairies de *N. stricta* dans le massif de Gorbea. Les traitements expérimentaux (4 répétitions par traitement) étaient constitués par le “non-pâturage” et “fertilisation phosphorée” ainsi qu'un traitement témoin “pâturage et non-fertilisation”. Dans chaque répétition (parcelle expérimentale de 10 × 10 m) un inventaire botanique et le % de couverture végétale ont été réalisés dans la surface d'un carré (0,5 × 0,5 m) lancé au hasard. En 2012, dix lâancements par répétition ont été réalisés et cinq en 2013. Les résultats ont montré des tendances différentes selon l'année. En 2012, le traitement “fertilisation phosphorée” a montré les valeurs les plus petites de richesse et de diversité botanique. Aucune différence n'a été décelée entre les traitements témoin et d'exclusion. En 2013, les valeurs de richesse et de diversité les plus élevées ont été observées dans le traitement “fertilisation phosphorée”; la valeur de la richesse de la flore était intermédiaire pour le témoin et la plus faible dans le traitement de l'exclusion. Les résultats de cette étude contribueront à la connaissance et la mise en œuvre des directives de gestion qui visent à la conservation de la biodiversité de ces habitats de montagne.

Mots-clés. Diversité – Richesse en espèces – *Nardus stricta* – Réseau Natura 2000 – Composition floristique – Communauté d'intérêt habitat 6230 *

I – Introduction

Pastoral mountain landscape in the Basque Country is dominated by community interest priority habitat 6230*. Currently, it remains well-conserved despite threats such as the abandonment of its use caused by the lack of generational handover and some management practices (like fertilization, clearing and herbicide application) that could be deemed as inadequate (Rigueiro *et al.*, 2009). Grazing abandonment is a medium term threat that can lead to a secondary succession with the invasion of pastures by tall grasses, shrubs and trees (Galvanek and Janák, 2008; Mandaluniz *et al.*, 2007). In fact, the technical report 2008/14/24 of the European Commission Management of “Natura 2000 habitats * Species-rich *Nardus* grasslands 6230” recommends grazing as one of the main practices for this habitat management. On the other hand, several guidelines in the context of agricultural practices have been defined on the use of mineral fertilizers in order to avoid serious and irreversible biodiversity loss (Rodríguez *et al.*, 2001). The *Nardus stricta* priority species present in this habitat 6230* requires the prohibition of actions that modify soil conditions where it develops (Rigueiro *et al.*, 2009).

In this context, the aim of this research was to evaluate the impact of grazing exclusion and phosphoric fertilization on the structure of herbaceous communities by using biodiversity indexes, such as species richness and the equivalent number of species (i.e., a proper measure of the ‘true species diversity’; see Jost, 2006; Jost and González-Oreja, 2012).

II – Materials and methods

1. Study area and design

The study was carried out on Oderiaga grazing area, located in the Gorbeia Natural Park (Bizkaia; Northern Spain), with a surface of 1555 ha of which 147 ha correspond to the habitat 6230* (dominant species: *Festuca gr. rubra*, *Agrostis curtisii*, *A. capillaris*, *Gallium saxatile*, *Potentilla erecta*). The area lays on siliceous parent material and predominantly faces the south. It is the most important area within the natural park in terms of grazing livestock, with 24.5% of the total stocking rate (Albizu *et al.*, 2010).

Experimental treatments (4 replicates per treatment) included “non-grazing”, “phosphoric fertilization” and the control (“grazing and non-fertilization”). Applied ecologic phosphoric fertilization was FERTIGAFSA TDVIDA TD 1-32, in a dose of 192 kg ha⁻¹. In each replicate (experimental plot of 10 × 10 m), randomly selected sampling squares (50 × 50 cm) were used to register species presence and cover (in 2012, 10 square per replicate; in 2013, only 5). Differences in richness (observed and extrapolated number of species) and the “true diversity” (exponential of Shannon diversity index) of plant species between treatments and years were studied through curves of accumulated richness and diversity.

Conceptually, species richness is the most intuitive and direct parameter for measuring biodiversity (Gotelli and Colwell, 2001). However, its determination is not simple due to the increase in the number of observed species along with the sampling effort. As a result, it is necessary to undertake a complete, laborious, time-consuming and thorough sampling in order to obtain a comprehensive measure of the true richness of a plant community. EstimateS version 9.10 (Colwell 2013) was used for calculating diversity indexes, and also for obtaining curves of accumulated richness and diversity, as well as extrapolation of richness for 120 and 60 squares for 2012 and 2013, respectively. At comparable levels of sampling effort (as measured by the number of sampled squares), mean values and corresponding 95% confidence intervals (CI) for species accumulation and diversity curves were computed following Colwell *et al.* (2004); differences were judged as statistically significant ($P < 0.05$) if CI did not overlap. For more details on CI, please see analytical formulas as presented in Colwell (2013). The considered effects were “grazing, non-fertilization”, grazing with “phosphoric fertilization” and “non -grazing”.

III – Results and discussion

In 2012, the curves of accumulated richness of “grazing, non-fertilization” and “non-grazing” treatments were parallel to each other and had only minor differences (both in terms of specific richness and extrapolated until 120 squares) (Fig. 1). The curve for “phosphoric fertilization” always remained lower, which means that the fertilization treatments were linked to less species richness in studied grasslands. However, in 2013 the observed pattern was different: the richness was higher in fertilized grasslands, while the number of extrapolated species in control (“grazing, non-fertilization”) was intermediate and lowest in non-grazing areas.

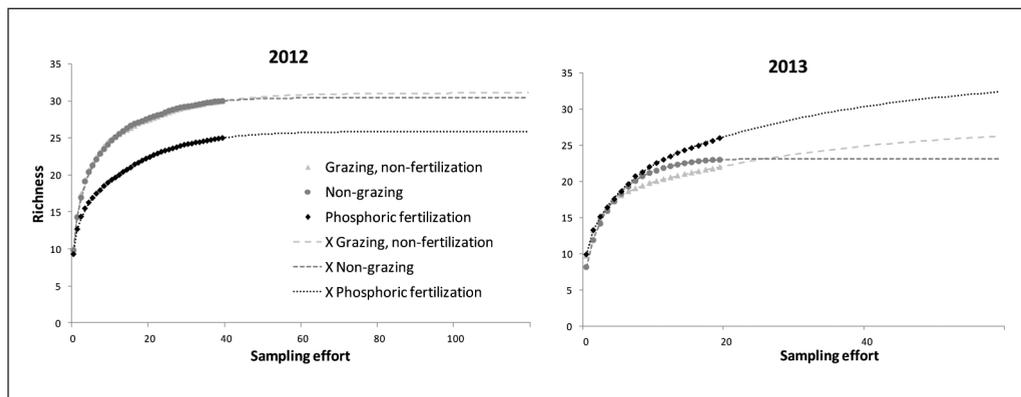


Fig. 1. Observed and extrapolated (X) richness for grazing, non-fertilization, non-grazing and phosphoric fertilization treatments during the years of 2012 and 2013, for a sampling effort of 40 (2012) and 20 (2013) quadrants treatment⁻¹. Sampling effort measures the number of sampled quadrats.

As for the diversity index, the number of equivalent species was similar to that observed in 2012: similar curves between “non-grazing” and “grazing, non-fertilization” treatments while in phosphoric fertilization, species diversity was the lowest. During 2013, diversity was the maximum in the control treatment (“grazing, non-fertilization”) for any sampling effort, followed by the “phosphoric fertilization” and finally, “non-grazing” treatments. There was no overlapping between the confidence intervals corresponding to 95 % (dashed lines, Fig. 2). Thus, we can accept that the differences between treatments were statistically significant. In 2013, when the number of observations was greater than 10, differences were significant among treatments. Differences were higher with increasing sampling efforts. That is, diversity in 2013 was highest in “grazing, non-fertilization” treatment, followed by “grazing, non-fertilization” and finally for “non-grazing”.

The results are in line with many other studies that have shown the importance of grazing in the conservation of plant biodiversity and the decline of it with abandonment (see, for instance, Mariotte *et al.*, 2013). In this regard, it is necessary to highlight the importance of the type of grazing for conservation. In trials under the project FARMING LIFE REGEN carried out for testing free versus guided grazing, higher biodiversity values were detected for directed grazing (Mandaluniz *et al.*, 2016, accepted for EGF congress). At the same time, timescale effect is important and thus, it is necessary to analyze grazing abandonment effect on biodiversity in a longer term. As for the effect of phosphoric fertilization, our results are in line with studies in which it was observed that pastures with phosphoric input have lower species richness and diversity, and showed a decrease of diversity with a progressive increase in phosphoric fertilization doses (Puerto *et al.*, 1990) or with studies that related a higher floristic richness in soils with low or intermediate nutrients levels (Rodríguez *et al.*, 2001).

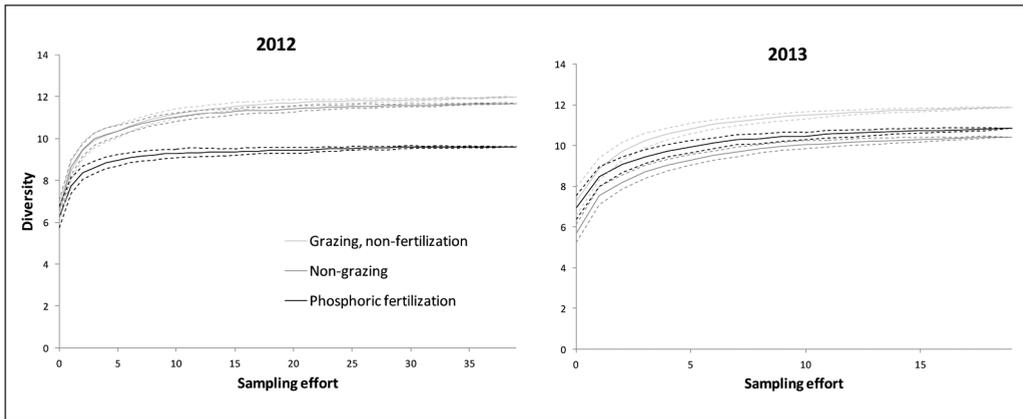


Fig. 2. Shannon exponential diversity values (and 95% confidence intervals) for grazing, non-fertilization, non-grazing and phosphoric fertilization treatments during the years of 2012 and 2013, for a sampling effort of 40 (2012) and 20 (2013) quadrants treatment⁻¹. Sampling effort measures the number of sampled quadrats.

IV – Conclusions

The effect of abandonment and phosphorus fertilization treatments differ depending on the time lag between the application and observations. In this sense, the fertilization has a negative impact on the richness and diversity of species when it is applied. However, the effect of the exclusion is increasing so that, although at first no effect is detected, after one year from the applications, the decline of diversity values is significant. All of the tested experimental treatments involve a loss of species diversity.

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A multivariate approach in the analysis of the nutritional quality of woody pastures in NW Spain

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Abstract. Nutritive quality and productivity assessment of food resources in pastures is essential in developing efficient and environmentally friendly management strategies. In this study, 12 nutritional parameters have been compared for 26 plants commonly found in scrublands and understory of forest communities in Galicia (Northwest Spain). Energy and protein available in range forages were analyzed in terms of dry matter (DM), crude protein, *in vitro* digestibility (OMD), structural carbohydrates (acid detergent fiber (ADF), lignin, cellulose, and silica) and nitrogen-complexing compounds (condensed and hydrolysable tannins). Mineral content in forages are crucial in animal health as well, thus phosphorus (P), calcium (Ca), magnesium (Mg), and potassium (K) concentrations were considered. Principal Components Analysis (PCA) was used to assess similarities among plant species and to reduce a large number of nutritional parameters into a small set that could explain the variability of the data. Four variables, namely ADF, OMD, DM and Mg, showed the highest percent of variance that was accounted for by the two retained principal components. The first component, represented by ADF and DM in the positive side of the axis, and by K and OMD in its opposite, separated plants with low digestibility and small content of available crude protein (i.e. heathers) from a group of plants with better nutritional quality mostly represented in oak forests understory. This was categorized as the “nutritional quality component. Three variables loaded heavily on the second component (Mg noticeably stronger than Ca and total tannins) explaining the data variability only to some extent. This was categorized as the “nutritional disorders component”.

Keywords. Principal Component Analysis – ADF – Digestibility – Tannins – Ericaceae.

Une approche multivariée pour l'analyse de la qualité nutritionnelle des pâturages ligneux dans le NO de l'Espagne

Résumé. L'évaluation de la qualité nutritive et de la productivité des ressources alimentaires des pâturages est essentielle pour développer des stratégies de gestion efficaces et respectueuses de l'environnement. Dans cette étude, 12 paramètres nutritionnels ont été comparés pour 26 plantes couramment rencontrées dans les broussailles et l'étage inférieur des communautés forestières en Galice (nord-ouest de l'Espagne). L'énergie et les protéines disponibles dans les fourrages des parcours ont été analysés en termes de matière sèche (MS), protéine brute, digestibilité *in vitro* (DMO), hydrates de carbone structurels (fibre acido-détergente (ADF), lignine, cellulose, et silice) et composés de complexation d'azote (tannins condensés et hydrolysables). La teneur minérale des fourrages est cruciale pour la santé animale, donc on a considéré les concentrations en phosphore (P), calcium (Ca), magnésium (Mg), et potassium (K). L'analyse en Composantes Principales (ACP) a été utilisée pour évaluer les similarités entre espèces végétales et pour réduire un large nombre de paramètres nutritionnels à un petit ensemble qui puisse expliquer la variabilité des données. Quatre variables, à savoir ADF, DMO, MS et Mg, ont montré le plus fort pourcentage de variance qui correspondent aux deux composantes principales retenues. La première composante, représentée par ADF et MS du côté positif de l'axe, et par K et DMO du côté opposé, séparaient les plantes à faible digestibilité et faible teneur en protéine brute disponible (c.-à-d. bruyères) par rapport à un groupe de plantes ayant une meilleure qualité nutritionnelle représentées notamment par le sous-étage forestier des chênes. Ceci était catégorisé comme “composante de qualité nutritionnelle”. Trois variables pesaient lourdement sur la deuxième composante (Mg nettement plus fort que Ca et tannins totaux) expliquant seulement en partie la variabilité des données. Ceci était catégorisé comme “composante de désordres nutritionnels”.

Mots-clés. Analyse en Composantes Principales – ADF – Digestibilité – Tannins – Ericaceae.

I – Introduction

Plant species composition determines the nutritional quality of range forages as nutritional quality may vary greatly among plants (Van Soest, 1982). Alternatively, nutritional quality of vegetation can be explained using multiple nutritional parameters. For both reasons, nutritional quality assessment of range forages may involve a substantial number of correlated variables and plant species, making data interpretation a difficult task. Multivariate analysis, as a dimension-reduction tool, can facilitate the understanding of relationships (distance) among a large number of plant species defined by a variety of nutritional parameters. Principal Components Analysis (PCA) in particular, has been proved very useful, as it reduces a large number of nutritional parameters into a small set that still contains most of the information. Our main objective was to give an overall approach on the similarities and differences on nutritional quality of plants frequently present in forest communities in Northwest Spain. We also wanted to evaluate to what extent the information on 12 nutritional parameters could be reduced to the most relevant and still explain the variability of the data.

II – Materials and methods

1. Material

Data on nutritional parameters of plants from oak woods, conifer stands and scrublands (broom, gorse and heather lands) in Galicia (Northwest of Spain) for which contents in P, Ca, Mg, K, ADF, lignin, cellulose, silica, DM, OMD, CP and total tannins (TA) were reported before (González-Hernández and Silva-Pando, 1999, González-Hernández *et al.*, 2000, González-Hernández *et al.*, 2003) were subjected to a PCA. Detailed information of extraction procedures and techniques applied for chemical analysis can be found in the above studies.

2. Methods

PCA was performed for 12 original nutritional parameters across 26 plant species (a 26 x 12 data matrix). To solve the matter on “number-of-components” to retain we tested various criteria such as the eigenvalue-one criterion, the scree test, the cumulative percent of variance accounted for, and the interpretability criterion; combining all four in a structured sequence. Components extraction was followed by a varimax (orthogonal) rotation, with the aim of determining what is measured by each of the retained components. This involved identifying the variables that contribute most to the component (i.e. high factor loadings on a given component), determining what these variables have in common, and labeling each retained component. To perform the data analysis, we used the software STATGRAPHICS Plus Version 5.0.

III – Results and discussion

The purpose of the PCA was to obtain a small number of linear combinations of the nutritional parameters which account for most of the variability in the data. As PCA is normally conducted in a sequence of steps, three correlated parameters, namely lignin, cellulose and silica (which accounted for the total ADF), were removed from the 26 x 12 original data matrix after initial analysis. Accordingly, subsequent PCA analysis was performed for a final 26 x 9 data matrix. Table 1 shows the strength of the linear relationship between the variables measured by Pearson's correlation coefficient analysis.

Table 1. Pearson's correlation matrix between nutritional parameters. ADF: Acid Detergent Fiber, DM : dry matter, OMD : organic matter digestibility, CP : crude protein, TA : total tannins

	P	Ca	Mg	K	ADF	DM	OMD	CP	TA
P									
Ca	-0.1030								
Mg	-0.1442	0.5077[†]							
K	0.4646[†]	0.2156	0.4316[†]						
ADF	-0.2941	-0.3934[†]	-0.3691	-0.5551[†]					
DM	-0.3442	-0.3572	-0.3794	-0.801[†]	0.7333[†]				
OMD	0.3674	0.3281	0.2008	0.6269[†]	-0.8310[†]	-0.751[†]			
CP	0.2822	-0.0638	0.1503	0.4411[†]	-0.5842[†]	-0.573[†]	0.6478[†]		
TA	-0.1618	0.1239	0.5062[†]	-0.0708	0.0551	0.0784	-0.3466	-0.1614	

[†] indicate statistically significant non-zero correlations at the 95% confidence level.

PCA extracted 2 major components of variation based on eigenvalues ≥ 1 and the results of a scree test; consequently, only the first two components were retained for rotation. Combined, components 1 and 2 accounted for 66.8 % of the total variance. In interpreting the rotated factor pattern, a nutritional parameter was said to load on a given component if the factor loading was 0.60 or greater for that component, and was less than 0.60 for the other. Using these criteria, five nutritional parameters were found to load on the first component and only three loaded on the second component (Table 2). Estimated communality indicated that four variables, ADF, OMD, DM and Mg explained the highest percent of variance that was accounted for by the two retained components.

Table 2. Factor loading matrix after varimax rotation and final communality estimates from PCA of nutritional parameters. Parameters consider to load on a given component are shown in bold case

Variable	Factor 1	Factor 2	Estimated communality
P	0.54125	-0.3565	0.42002
Ca	0.25559	0.67471	0.52056
Mg	0.24958	0.87340	0.82512
K	0.79977	0.19707	0.67847
ADF	-0.8388	-0.2527	0.76747
DM	-0.8782	-0.2412	0.82942
OMD	0.91904	0.00805	0.84470
CP	0.73736	-0.1134	0.55657
TA	-0.2941	0.69613	0.57112

The first component explained 45.8% of the variability of the data. It showed that ADF and DM loaded most heavily on positive values, whereas K content and OMD had the highest weight in the negative values. Although CP is an essential figure for the nutrition of the animal, this nutritional variable did not account greatly in explaining the data variability. Thus, component 1 separated plant species of low digestibility and high ADF content, such as heathers, from plants of high digestibility for browsers (González-Hernández and Silva-Pando, 1999) as *Lonicera periclymenum*, *Hedera helix*, *Frangula alnus* and *Asphodelus albus* (Fig. 1). As a result, component 1 was labeled as "nutritional quality component".

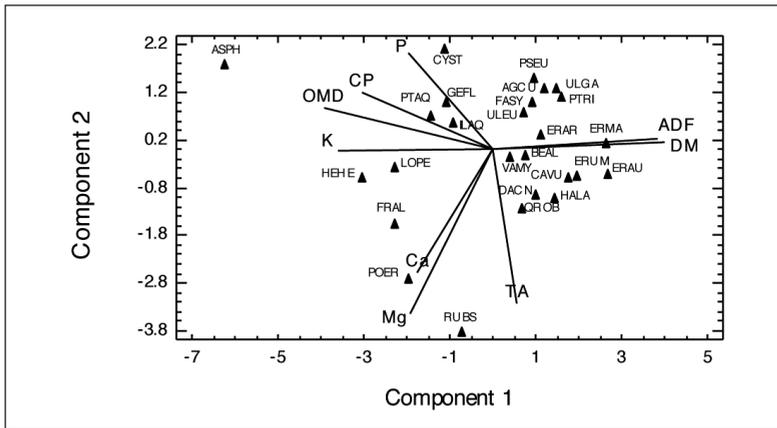


Fig. 1. Two-dimensional biplot with rays that represent the magnitude and direction for each variable.

(AGCU: *Agrostis curtissii*, ASPH: *Asphodelus albus*, BEAL: *Betula alba*, CAVU: *Calluna vulgaris*, CYST: *Cytisus striatus*, DACN: *Daboecia cantabrica*, ERAR: *Erica arborea*, ERAU: *Erica australis*, ERMA: *Erica mackaiana*, ERUM: *Erica umbellata*, FASY: *Fagus sylvatica*, FRAL: *Frangula alnus*, GEFL: *Genista florida*, PTRI: *Pterospartum tridentatum*, HALA: *Halimium lasianthum*, HEHE: *Hedera helix*, ILAQ: *Ilex aquifolium*, LOPE: *Lonicera peryclimenum*, POER: *Potentilla erecta*, PSEU: *Pseudarrhenatherum longifolium*, PTAQ: *Pteridium aquilinum*, QROB: *Quercus robur*, RUBS: *Rubus* sp., ULEU: *Ulex europaeus*, ULGA: *Ulex gallii*, VAMY: *Vaccinium myrtillus*).

The second component accounted for 21% of the total variance and explained a Mg-Ca-tannin gradient. It separated plants with higher content in Ca (*Fangula alnus*, *Hedera helix*), Mg and total tannins (*Rubus* sp., *Potentilla erecta* and *Quercus robur*) in negative axis from leguminose and grasses displayed in the positive axis. It is widely known that low levels of Mg or Ca, as well as high K intake relative to Ca and Mg intake, may induce hypomagnesemia (grass tetany). Plant species in this study had low Mg content (< 2g Mg/kg DM) but an optimum K (Ca+Mg) ratio (< 2.2) (González-Hernández *et al.*, (2000). Legumes that contain leaf tannins help break up the foam when bloat problems occur, and beneficial antimicrobial properties from tannins are also acknowledged. On the other hand, tannins are widely recognized as important factors influencing feeding by mammals on woody plants and may reduce digestion of protein and fiber (Hagerman *et al.*, 1992; Starkey *et al.*, 1999, González-Hernández *et al.*, 2003). As a result, component 2 was identified as the “nutritional disorders component”. Magnesium should be included to prevent grass tetany, and potassium is often deficient in dormant warm-season grasses (Holecheck *et al.*, 2004). Because Ca/P ratios for nearly all forages fall within an optimum range in terms of animal performance they are not an important factor influencing grazing animal productivity (Holecheck *et al.*, 2004, González-Hernández *et al.*, 2000).

Although Mg, tannin and Ca defined component 2, and therefore accounted for some of the variance, they slightly supported organizing the species by similarities. As an example, *Betula alba* and *Vaccinium myrtillus*, showed lower tannin content than *Fagus sylvatica* (González-Hernández *et al.*, 2003), but this was not consistent with their distribution in Fig. 1. We also included hydrolysable and condensed tannins in the PCA, but they did not facilitate interpretation. Tree species displayed closer to the intersection of both components as nutritional parameters showed intermediate values in the overall ranges.

IV – Conclusions

PCA analysis can be a useful tool that minimizes the complexity of correlated data reducing a number of observed variables into a smaller number of artificial variables that account for most of the variance in the data set. In this study, PCA showed that four nutritional parameters, ADF, OMD, DM and Mg explained the highest percent of variance that was accounted for by the two retained components. Component 1 neatly separated heathers (poor nutritional quality) from plant species very frequent in oak forests understory (rich nutritional quality) and consequently was categorized as “nutritional quality component”. Component 2 reflected, to some extent, a Mg-Ca-tannin gradient and, as a result, was identified as “nutritional disorders component”.

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The potential role of seedbanks in maintaining grassland vegetation in a Mediterranean oak woodland

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Abstract. Soil seedbank ecology, by allowing substantial flexibility for potential changes in plant communities, can provide important information about vegetation development and persistence. It partly reflects the history of the vegetation and its composition. Most plant species can produce seeds that remain dormant in the soil for several years. During 3-year, our study has investigated on the potential role of the seed bank in maintaining grassland vegetation in silvo-pastoral systems and the effect of grazing regime on seedbank dynamics. We have analysed across 11 different sites, taking soil-core samples of 8 cm in diameter and 10 cm deep, both collected in ungrazed (fenced) and grazed (unfenced) areas. Results highlight, although without interaction, the effects of grazing regime and year, both on seed dispersal bank size and germinable seed fraction of the seed bank, and pointed out the potential role of permanent seed bank on future establishment of grassland.

Keywords. Soil seedbank – Grassland communities – Silvo-pastoral systems – Grazing.

Le rôle potentiel des banques de semences dans le maintien de la végétation des prairies dans un bois de chênes méditerranéens

Résumé. L'écologie de la banque de semences du sol, en permettant une grande flexibilité pour les changements potentiels dans les communautés végétales, peut fournir des informations importantes sur le développement de la végétation et de sa persistance. Il reflète en partie l'histoire de la végétation et de son composition. La plupart des espèces de plantes peuvent produire des graines qui restent en dormance dans le sol pendant plusieurs années. Cette étude de 3 ans a analysé le rôle potentiel de la banque de semences dans le maintien de la végétation des prairies dans un système silvo-pastoral, et l'effet du pâturage sur sa dynamique. Nous avons analysés, dans 11 sites différents, des échantillons du sol de base de 8 cm de diamètre et 10 cm de profondeur, également prélevés en zones pâturées et non pâturées, afin d'évaluer les effets de pâturage. Les résultats soulignent, bien que sans interaction, les effets du régime de pâturage et de l'année, à la fois sur la taille et sur la fraction de semences germinables et le rôle potentiel de la fraction permanente de la banque de semences sur le pâturage.

Mots-clés. Banque de semences du sol – Communautés prairiales – Système silvo-pastoraux – Pâturage.

I – Introduction

Inland abandonment is a crucial phenomenon that is occurring in several Mediterranean countries. Consequently, the disappearing of traditional activities in rural areas, such as silvopastoralism, means not only a lack of typical micro economies, but also the risk of strongly affecting the structure of plant communities, with relevant effects on biodiversity, wildfire prevention and erosion control at the landscape level (Hobbs *et al.*, 2007). The species composition of a plant community may be assessed through the vegetative spread of plant species and the determining of seedlings establishment from the seed bank (Peco *et al.*, 1998). Seed banks have received considerable at-

attention in relation to the conservation, management and restoration of natural ecosystems because soil seed banks are important components of vegetation dynamics and resilience (Bertiller and Aloia, 1997). Soil seed bank composition is influenced by the surrounding vegetation and former successional stages, reflecting partly the history of the vegetation, and its composition (Godefroid *et al.*, 2006) and can undergo significant changes depending on the management applied (Wellstein *et al.*, 2007). Ecologists and conservationists have looked at the role of seed banks in woodland and forest regeneration presumed that play a role in the rehabilitation of degraded ecosystems (Erenler *et al.*, 2010). Seed bank ecology allows a substantial flexibility for potential changes in the plant community and can provide important information on the dynamic of vegetation and its persistence. The objectives of our research were to evaluate the role of grazing on the dimension of seed bank components (germinable, RGS and permanent, PSB) and so, to check out the probable effects of abandonment of rural areas on the resilience of silvopasture vegetation.

II – Materials and methods

The trial was carried out during 3 years (2012-2014) in the Forest of Monte Pisanu (40°43' 145 N, 8° 97' 838 E, Central Sardinia, Italy), identified as a Site of Community Importance (SIC). The vegetation is characterised by *Quercus ilex*, *Quercus pubescens*, *Taxus bacata*, *Ilex aquifolium*, *Quercus suber* and *Castanea sativa*. Around 200 herbaceous species were identified, mainly therophytes, hemicryptophytes and geophytes, referable to 34 families, mainly Graminaceae, Leguminosae and Compositae, with a high presence of *Asphodelus microcarpus* Salzm. *et Viv.* (Re *et al.*, 2014). In this area, grazing is commonly carried out where the tree canopy is open or less dense (gaps, cleared areas). It is rotational heavy for dairy sheep and continuous light for cattle, with an estimated livestock of 650 Livestock Units (L.U.) per year on a total surface of 2000 ha. Eleven representative grazed areas, located between 600 m and 1200 m a.s.l., were identified. In order to simulate the exclusion of grazers and the consequent response of seedbank accumulation, metallic cages of 4 m² were placed on each site. The readily germinable seed bank (RGS) was assessed by collecting five intact soil cores (8 cm large and 10 cm deep) in each site, three in the grazed area and two inside the cage and counting the number of germinated seeds (seedlings) after one month in open-air conditions. Then, the soil samples, were washed on a fine sieve (mesh width 0.2 mm) and placed in Petri dishes to be processed to the following germination/dormancy breakdown treatments (Perez *et al.*, 1998): (i) watered field conditions; 21 days diurnal cycle of 8/16 darkness/light at 20/30°C; (ii) 21 days dormancy assessment test, 3 - 5°C; and (iii) 35 days chemical breakdown test, 600 mg/kg-solution of gibberellic acid, diurnal cycle of 8/16 darkness/light at 15/35°C. The number of seedlings counted after these treatments was considered as an estimate of the PSB (Permanent Seed Bank). TSB (Total Seed Bank) was estimated by summing all the seeds germinated in watered field conditions (RGS) and after each dormancy breakdown treatment (PSB). Combined ANOVA over the three years on seedlings number per square meter of each TSB component was performed (GLM Procedure, Statgraphics XVI).

III – Results and discussion

The impact of grazing on seed bank species richness and composition has been studied mainly in grasslands and to a lesser extent in forests, scrubs and rangelands. The RGS size ranged from 28,264 seedlings m⁻² in MP11 (2012) to 995 seedlings m⁻² in MP4 (2013) in grazed area and from 20,303 in MP8 (2012) to 299 seedlings m⁻² in MP4 (2013) in ungrazed areas (Table 1). PSB size ranged between 9,289 (MP2, 2014) and 597 (MP1, 2014) seedlings m⁻² in grazed areas and from 14,630 (MP2, 2014) and 597 (MP5, 2013) in ungrazed areas. Both in grazed and ungrazed areas, we have found that average grasses abundance (data not shown) was higher than the other species, as well as reported by Koc *et al.* (2013), even if in a study area with different climate conditions.

Table 1. Number of seedlings m⁻² (RGS and PSB) in grazed and ungrazed conditions

Sites	m a.s.l.	2012				2013				2014			
		RGS [†]		PSB [†]		RGS		PSB		RGS		PSB	
		G ^{††}	NG ^{††}	G	NG	G	NG	G	NG	G	NG	G	NG
MP1	1195	14630	11545	2289	2588	13800	4379	597	2090	1725	2886	3782	5772
MP2	739	15028	4080	3981	3085	2853	100	1990	1891	1592	199	9289	14630
MP3	727	19108	9156	3483	3782	1460	1990	1990	796	4644	3682	5971	3185
MP4	725	7365	9853	5673	697	995	299	1062	697	7033	7962	6104	3483
MP5	736	3483	7166	2588	2389	3317	6867	796	597	1327	1791	2057	2488
MP6	722	7564	15326	4877	1891	3583	3384	1924	1592	3848	2687	6502	3682
MP7	726	7265	12142	1493	796	5839	1194	1261	697	1062	597	3782	2886
MP8	752	6071	20303	4479	5474	3052	5374	2123	1294	5573	3981	4644	3782
MP9	697	5872	7166	2488	7962	4246	3682	3384	1592	6768	2687	1393	2189
MP10	690	5971	6967	3384	4080	4379	3981	1327	1990	2455	3782	3450	1393
MP11	689	28264	7166	1692	896	5507	1990	2521	896	2521	1194	6436	2986

[†] RGS = Readily Germinable Seedbank, PSB = Permanent Seed Bank.

^{††} NG = Ungrazed area, G = Grazed area.

Marage *et al.* (2006) reported that species richness decrease with grazing pressure. On the contrary, in accordance to our results, Heinken *et al.* (2006) at temperate forest in Germany and Malo *et al.*, (2000) in Mediterranean dehesas, found an increase in the seed bank diversity under grazing.

Table 2. Analysis of variance for the total seed bank dataset of 2012, 2013 and 2014 (grazed vs. ungrazed areas – GLM model ($p \leq 0.05$). Year as random variable)

Source	Levels of treatment	Means	Standard error	F-ratio	P
Years	2012	6853 ^a	97.8998	493,73	†††
	2013	2622 ^c			
	2014	3861 ^b			
Grazing	G	4803 ^a	79.9349	40,03	†††
	NG	4087 ^b			
Seed treatments	PSB	3076 ^b	466.505	17,22	†††

[†] Means followed by the same letters within a column are not significant different ($p \leq 0.05$).

The GLM model (Table 2) shows that the seedling number was influenced significantly by the grazing regime, year and seed treatments. No significant differences were recorded between sites and for the interactions among the considered variables. According to Koc *et al.* (2013), herbivores affecting the plant community either directly or indirectly, are a crucial part of the grazing ecosystem. The same authors reported significant differences with respect to seed bank composition among grazed sites. Nevertheless, in our results, there were no differences among grazing sites with respect to the composition of the seed bank, in accordance with Peco *et al.*, 1998.

IV – Conclusions

Our study found that soil seed bank size declines significantly under ungrazed conditions and that in the environmental and management conditions of our study site, the livestock pressure promotes the increase of seed bank size. In a condition of high variability of pastoral types and of their spe-

cific livestock carrying capacity, an adequate and site-specific grazing management, which combines ecological and productive aspects, is advisable. An appropriate and site-specific grazing management may represent a strategy for the conservation of resilient and biodiverse grasslands within Mediterranean oak-based silvopastoral systems.

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Effect of forage conservation and inclusion of condensed tannins on *in vitro* gas and methane production

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Abstract. Condensed tannins can reduce methane emissions coming from the ruminal fermentation of forage. The aim of the study was to evaluate the effect of forage conservation (hay vs. fresh) and the inclusion of condensed tannins [CT, 10% of Quebracho (*Schinopsis Balansae*) with 75% of CT] in the concentrate (Control vs. CT) on *in vitro* gas and methane production and the ruminal degradability of organic matter (IVOMD) at 24 h. The diets contained 70% forage and 30% concentrate. Gas production (ml/g organic matter (OM)) was not affected by the forage conservation or tannin inclusion in the concentrate ($P>0.05$). Regarding the kinetic parameters of gas production, the asymptotic gas production was similar in both forages, but the gas production rate was greater in pasture than in hay ($P<0.001$). The kinetic parameters were not affected by tannin inclusion. Methane production (ml/g OM) was affected by the interaction between the forage conservation and concentrate ($P<0.01$). Methane production decreased by 20.5% when tannin was included in the hay diet but did not change in the pasture diet ($P>0.05$). The IVOMD was only affected by the forage conservation in the diet, being greater for the diet with fresh vs. hay pasture (74.1% and 61.6%, respectively; $P<0.001$). In conclusion, the use of concentrate with condensed tannins in ewes' diets reduced methane production in diets containing hay but not in those based on pasture. Gas production and IVOMD were unaffected by the inclusion of condensed tannins in the diet, regardless of the conservation of forage

Keywords. *In vitro* digestibility – Fermentation kinetics – Ovine – Quebracho – Condensed tannins.

Effet de la conservation du fourrage (foin vs. frais) et de l'inclusion des tanins condensés dans la production in vitro de gaz et méthane

Résumé. Les tanins condensés peuvent réduire les émissions de méthane provenant de la fermentation ruminale de fourrage. L'objectif de l'étude était d'évaluer l'effet de la conservation du fourrage (foin vs. frais) et de l'inclusion des tanins condensés [TC, 10% de Quebracho (*Schinopsis balansae*) avec 75% de tanins condensés] dans le concentré (par rapport au témoin QUE) sur la production in vitro de gaz et méthane et la dégradabilité ruminale de la matière organique (DRMO) à 24 h. Les régimes contenaient 70% de fourrage et 30% de concentré. La production de gaz (ml/g de MO) n'a été pas affectée par la conservation du fourrage ou par l'inclusion des TC dans le concentré ($P>0,05$). En ce qui concerne les paramètres cinétiques de production de gaz, la production de gaz asymptotique était similaire dans les deux fourrages, mais le taux de production de gaz était supérieur pour le fourrage frais par rapport au foin ($P<0,001$). Les paramètres cinétiques n'étaient pas affectés par l'inclusion des TC. La production de méthane (ml/g OM) a été affectée par l'interaction entre la conservation du fourrage et l'inclusion des TC ($P < 0,01$). La production de méthane a diminué de 20,5% avec l'inclusion des TC dans le concentré dans le régime de foin, mais n'a pas changé dans le régime de fourrage frais ($P > 0,05$). La DRMO a été affectée par la méthode de conservation du fourrage, étant supérieure pour le régime de fourrage frais vs. foin (74,1% et 61,6%, respectivement; $P<0,001$). En conclusion, l'inclusion de concentré avec des tanins condensés dans l'alimentation des brebis réduit la production de méthane dans les régimes constitués par du foin, mais pas dans ceux qui sont constitués par du pâturage frais. La production de gaz et l'IVOMD n'ont pas été affectées par la présence de tanins condensés dans l'alimentation, quelle que soit la méthode de conservation du fourrage.

Mots-clés. Digestibilité in vitro – Cinétique de fermentation – Ovin – Quebracho – Tanins condensés.

I – Introduction

Ruminants are responsible for 28% of methane (CH₄) emissions, which are related to global warming and climate change (IPCC, 2013). In ruminant, the production of methane during enteric fermentation contributes to an important loss of energy of up to 12% (Johnson and Johnson, 1995). Thus, strategies to reduce the CH₄ production during the enteric fermentation and to improve feed efficiency have been studied. Condensed tannins (CT) are a diverse group of polymeric flavanols with functional groups that chelate metal ions and are capable of binding protein and fibre components of feed as well as interacting with microbial populations of the rumen (Min *et al.*, 2003). Their presence in the diet can reduce enteric methane emissions, as it has been observed *in vitro* to different extents (Hassanat and Benchaar, 2013). However, tannins have a wide variety of chemical structures, which may explain their different effects on methano-genesis, which is also depending on the dose, the used substrate and the type of tannin (Getachew *et al.*, 2008). The objective of this experiment was to study the effects of inclusion of CT in the concentrate in diets using forages with different conservation on rumen fermentation characteristics.

II – Materials and methods

Two forages (fresh vs. hay pasture) and two concentrates (control vs. CT) were used to create four diets, each consisting of 70% forage and 30% concentrate. Fresh and hay pasture were obtained in La Garcipollera Research Station, in the mountain area of the southern Pyrenees (North-Eastern Spain, 42° 37' N, 0° 30' W, 945 m a.s.l.). The pasture was composed of 68% grass, 20% legumes and 12% of other species. The meadow was harvested in October 2013 to produce hay (75 g CP/kg DM and 680.5 g NDF/kg DM) whereas it was sampled in April 15, 2014 to obtain fresh pasture (263.2 g crude protein (CP)/kg dry matter (DM) and 487.6 g neutral detergent fibre (NDF)/kg DM) samples. The Control (C) concentrate was a commercial concentrate for ewes (153.3 g CP/kg DM and 1.03 eq-g cyanidin/kg DM). The CT concentrate (155.1 g CP/kg DM and 7.67 eq-g cyanidin/ kg DM) was similar to C but contained 10% of Quebracho extract (SYLVAFEED ByPro Q, Spain) with 75% of condensed tannins. All ingredients were dried at 60 °C and ground through a 1-mm sieve (ZM200 Retsch, Germany). The resulting diets were: hay + C; hay + CT, Fresh + C and Fresh + CT.

In vitro gas production was carried out using rumen fluid collected from 4 rumen fistulated rams fed 70% alfalfa hay and 30% barley grain. The rumen fluid was strained through 4 layers of cheesecloth and mixed with the buffer solution, based on the protocol of Menke and Steingass (1988). Three 0.5 g DM sub-samples of each diet were incubated in bottles with 60 ml of incubation solution in a water bath (39 °C) for 24 h. After this period, 8 ml of gas were collected in 5 ml tubes to quantify methane production. At the end of gas sampling, the fermentation was stopped. To study the fermentation kinetics, gas production was recorded at 1 h intervals during 24 hours (Ankom Technology, NY, USA). The data for the nonlinear gas production were fitted to the following exponential equation (Orskov and McDonald, 1979): $P = A^*(1 - e^{-ct})$, where P is the cumulative gas production (ml) at time t (h), A is the potential gas production (ml g⁻¹) and c is the rate of gas production (ml h⁻¹). Methane was analysed with gas chromatograph HP-4890, equipped with a capillary column TG-BOND Q+ (Thermo Scientific). The temperature of the inlet, the detector and the oven was maintained at 200, 250 and 100 °C, respectively. Methane identification was based on the retention time as compared with the standard.

In vitro organic matter digestibility (IVOMD) was estimated by filtering residues using pre-weighed bag (50 µm; Ankom, NY, USA). The bags with sample were dried at 103 °C for 48 h to obtain the dry matter content. After 48 h, bag content was weighed and was placed at 550 °C for to obtain the ashes. The organic matter of bag content was obtained as DM-ashes and the IVOMD was obtained as: (Incubated OM-bag content OM)/Incubated OM.

Data were analysed with a general lineal model with the forage conservation, the inclusion of CT and its interaction as fixed effects. Differences were significant for P<0.05 and tendencies for P<0.10.

III – Results and discussion

The conservation of forage tended to affect gas production ($P=0.06$), influenced the rate of gas production (c) ($P<0.001$) and the IVOMD but did not affect the asymptotic gas production (A) (Table 1). Pasture-based diets had higher rate of gas production and IVOMD than hay-based diets. This can be explained by differences in the quality between fresh and hay pasture, due to differences in the maturity stage and the process of haymaking. The kinetics of gas production and IVOMD depend on the relative proportions of soluble and degradable particles of the feed (Getachew *et al.*, 1998).

Table 1. Effect of the inclusion of the concentrate with condensed tannins (CT) or the Control concentrate in a diet with fresh pasture or hay on *in vitro* fermentation characteristics at 24 h

Variables	Forage		Concentrate		s.e.††	P values†	
	Hay	Fresh	Control	CT		Forage	Concentrate
Gas production (ml/g OM)	147.49	161.74	159.82	149.42	14.07	0.06	0.16
Ruminal fermentation kinetics							
A (ml/g)	73.47	66.77	72.93	67.31	8.80	0.15	0.22
c (ml/h)	0.07	0.11	0.09	0.09	0.02	0.001	0.63
IVOMD (%)	61.57	74.07	67.55	68.08	3.96	0.001	0.79

† The interaction between the forage and the inclusion of CT was not significant ($P>0.05$).

†† Standard error of mean.

The inclusion of CT had no effect on total gas production and IVOMD ($P>0.05$). Similarly, Hassanat and Benchaar (2013) reported that the inclusion of Quebracho at 20 g/kg in diet did not decrease gas production and IVOMD. The fermentation kinetics showed that the asymptotic gas production (A) and the rate of gas production (c) were not affected by the inclusion of CT in the concentrate as well (Table 1). In contrast, Hervás *et al.* (2000) observed that the inclusion of tannic acid (10%) in soya bean meals reduced both rate and extent of cumulative gas production.

Methane production was affected by the interaction between the forage conservation and inclusion of CT in the concentrate ($P<0.05$). The inclusion of CT in the diet decreased methane production in the hay-based diet ($P<0.05$) but did not affect it in the fresh forage-based diet ($P>0.05$). In this sense, the addition of 20 g Quebracho tannin extract/kg of dietary DM to barley silage failed to reduce enteric methane emissions (Beauchemin *et al.*, 2007).

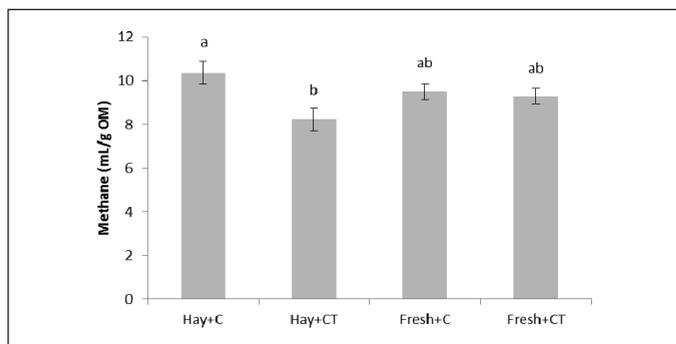


Fig. 1. Effect of the inclusion of the concentrate with condensed tannins (CT) or the Control concentrate in a diet with fresh pasture or hay on methane production after 24 h incubation.

Different superscripts (a,b) denote differences at $P<0.05$.

A reduction in methane production could be due to a decrease in organic matter degradability (Tan *et al.*, 2011). In the present study, IVOMD was not affected by inclusion of CT in the concentrate regardless of forage, thus the reduction of methane production in hay diet can be related to the affinity of CT for feed protein vs. microbial protein (Beauchemin *et al.*, 2007). The affinity of CT for protozoa and microbial methanogenic population is particularly important due to their role on methane production (McAllister *et al.*, 1996). In the current experiment, hay had lower crude protein content than pasture; whereby in hay-based diet the CT could be bound to the methanogenic microbial population instead to link to the feed protein, reducing methane production.

IV – Conclusions

The inclusion of condensed tannins at 22.5 g CT/kg in hay diets could be an interesting alternative in hay-based diets as it reduced *in vitro* methane production with no effect on gas production or IVOMD. However, this inclusion in a fresh pasture diet seems not to be as interesting because it did not reduce *in vitro* production of gas and methane.

Acknowledgments

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Assessment of pasture renovation systems in an area of northern Apennines

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Abstract. Vegetation evolution in pastures produces often negative effects on botanical composition and on pastoral value, and this is emphasized in relation to reduced stocking rates. In order to assess the development of pastoral resources along time and to analyze the effect of management activities on botanical composition and on grazing value, a survey was conducted in summer 2015 on a pastoral area of about 65 ha grazed by Limousine cows and placed inside the Dynamo Camp of Limestone (a WWF Oasis), in the Northern Apennine (Tuscany Region). The area is located at an altitude ranging from 900 to 1,100 a.s.l. with pastures that are periodically sown with appropriate seed mixtures or mechanically treated to remove shrubs and undesirable species. Linear transects were assessed in order to compare the effect of sowing and of shrubs cutting on botanical composition and on pastoral value. The comparison between different techniques of pasture renovation, showed a better performance of sowing in terms of overall botanical composition (a presence of more than 70% of grasses and legumes in sown pastures, less than 50% in brush-cutted ones) and of pastoral value (55 vs. 40); on the contrary the latter kind of restoration presented higher floristic richness in terms of species occurring along transects. Regression analysis between years since sowing and botanical composition or pastoral value gave evidence of the close relationship of these two variables with age of pastures, providing useful technical suggestions for the future renovation programs in the area.

Keywords. Botanical composition – Grazing value – Vegetal evolution – Seed mixtures.

Évaluation des systèmes de rénovation de pâturage dans une zone du nord des Apennins

Résumé. La réduction du chargement animal conduit très souvent à des effets négatifs sur la composition botanique et sur la qualité des ressources pastorales. Afin d'évaluer ces effets, une étude a été conduite dans une zone pastorale (environ 65 ha) exploitée par des vaches de race Limousine et localisée à l'intérieur du Dynamo Camp de Limestone (une Oasis WWF), dans les Apennins du Nord (Toscane, Italie). Le site est situé à une altitude comprise entre 900 et 1100 mètres et il est composé de pâturages qui sont périodiquement semés avec des mélanges d'espèces fourragères ou soumis à un traitement mécanique pour réduire les arbustes et les espèces indésirables. L'évaluation des techniques d'amélioration a été effectuée au moyen de relevés linéaires afin de comparer l'effet de semis et du débroussaillage sur la composition botanique et sur la valeur pastorale. En plus, la connaissance de la constitution des mélanges utilisées et de l'année de l'intervention dans chaque secteur pastorale a également permis d'analyser les changements de la végétation dans le temps. Pour ce qui concerne la comparaison entre les techniques de rénovation des pâturages, les interventions de semis ont produit les meilleures performances en termes de composition floristique (plus de 70% de la présence de graminées et de légumineuses dans les pâturages, moins de 50% dans les surfaces débroussaillées) et de la valeur pastorale (55 vs. 40). Par contre, le débroussaillage a montré une plus grande richesse floristique dans le transect linéaire. En réalisant des régressions entre l'année de l'intervention et la composition botanique on a obtenu des suggestions techniques utiles pour les futurs programmes d'amélioration des surfaces fourragères de l'Oasis.

Mots-clés. Composition botanique – Valeur pastorale – Dynamique de la végétation – Mélanges fourragères.

I – Introduction

Botanical composition and grazing value of pastures are deeply affected by management, such as stocking rate and grazing system (Cavallero *et al.*, 2002), or by agronomical interventions, such as ploughing, sowing, shrub control, etc. (Prach *et al.*, 2014). In this way semi-natural pastures can be regulated and developed. This is especially true in many pastoral lands that are subjected to a reduced animal utilization (Peeters, 2008) and characterized by undergrazing which can lead to many undesirable consequences both from a productive but also ecological point of view (Mc Allister *et al.*, 2014). To provide useful data for management purposes, an assessment on a pastoral area located in the north Apennines was performed, in order to evaluate the effect of different renovation techniques on botanical and pastoral characteristics.

II – Materials and methods

The experimental site is located inside the Dynamo Camp area (a WWF Natural Oasis), in Limestre (Pistoia, north Tuscany). The analyzed pastures cover an area of about 70 ha, mainly on sandstone, and are located at an altitude from 900 to 1,100 m a.s.l. The available pasture for grazing was divided by a fence into the inner area (38.6 ha) and the outside area (23.7 ha). The inner area was managed by periodical ploughing and reseeded of seed mixtures adapted to the local conditions, whereas in the outside area shrubs and other undesirable species were periodically eliminated (mainly *Pteridium aquilinum*).

To compare effects of these two treatments a survey was performed in summer 2015 by means of 10 transects according to Daget and Poissonet (1969) to survey botanical composition of investigated swards in terms of species abundance and species proportion. The pastoral value within different pasture sectors was estimated according Argenti and Lombardi, 2012. Sown species and species from natural recolonization of the sward were evaluated as well as the development of botanical composition along time.

Data were statistically analyzed by means of t-tests to compare effects of intervention methods on botanical data and by linear regression to evaluate floristic development along time.

III – Results and discussion

Remarkable differences were found in pastures treated with different kinds of intervention (Table 1). Pastures sown after ploughing showed a botanical composition dominated by grasses with higher values than those recovered by cutting the shrubs. Presence of legumes showed no significant differences between the two techniques but in general ploughed and sown pastures presented higher proportion of species with better forage quality (*i.e.* grasses and legumes) than those subjected to a periodical mechanical treatment (71.6 vs. 49.9 in total), which were dominated by forbs. Introduction of forage species by sowing caused a remarkable change in the botanical composition and this effect is prolonged for many years. Results are consistent with previous studies conducted in a nearby area under similar environment conditions (Argenti *et al.*, 2012) and emphasize the importance of periodical intervention of ungrazed areas to reduce shrubs encroachment and presence of undesirable species. Anyway, a high pastoral value was observed also in areas recovered by shrubs clearing. Even though this value is significantly lower compared with ploughed and sown area (40 vs. 55) it demonstrates the positive effect of mechanical intervention in habitat restoration, as already observed in similar environments Cervasio *et al.* (2016).

Table 1. Results of pasture assessment in the two sectors of pastures

Parameter		Ploughing/sowing	Shrub removal	Sign.
Specific proportion	Grasses	49.9	31.6	*
	Legumes	21.7	18.3	ns
	Forbs	28.4	50.1	**
N. of species	Grasses	7.2	7.8	ns
	Legumes	3.5	4.3	ns
	Forbs	9.0	14.5	*
	Total	19.7	26.5	*
Pastoral value		55	40	

*Sign.: ** P<0.01; * P<0.05; ns: not significant (P > 0,05).

Concerning floristic diversity (represented by number of species occurring along a transect) pastures renewed by shrubs removal showed higher values of forbs, with a remarkable effect on total diversity, as the average number of grasses and legumes is not significantly different.

Specific contribution (SC) of sown species and pastoral value tend to decrease along time (Fig. 1) and this development is independent on the kind of restoration system applied. This aspect allows identifying a proper time span for every intervention in order to maintain a desired proportion of sown species or quality of pastures. In our case, an appropriate interval of 6-8 years between each treatment of pasture recovery was hypothesized. The same development in similar environments was reported by Ponzetta *et al.* (2010).

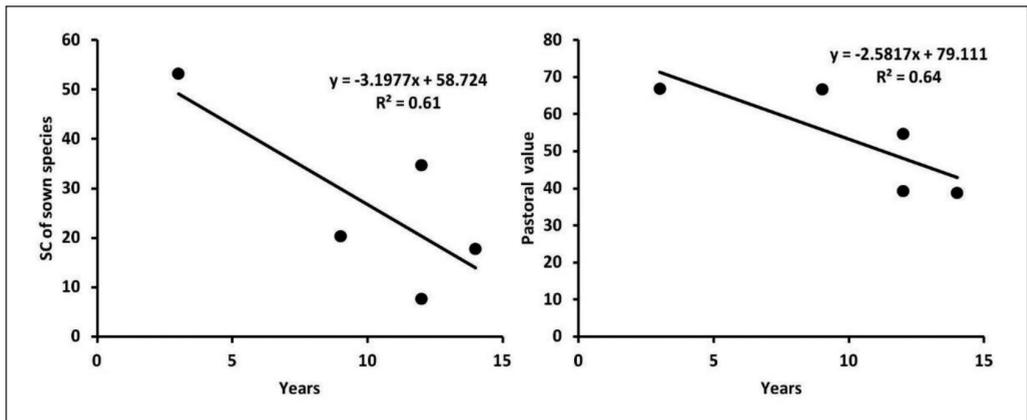


Fig. 1. Relationships between specific contribution (SC) of sown species (left) and pastoral value (right) with years since pasture recovery.

IV – Conclusions

The analysis of the pastoral resources in the area indicates that the actual stocking rate is under the potentiality evaluated by the pastoral value. Moreover, mechanical interventions caused remarkable improvement of the pastures, although for some features re-sowing performed better. Finally, analysis of some botanical and qualitative characteristics of the pastures along time development provide useful data and information for future renovation programs in the area.

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Plant functional type effects on soil function change along a climatic gradient

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Abstract. Global change modifies plant community composition in mountain grasslands through shifts in the balance of plant guilds. Above- and below-ground systems are tightly linked, and changes in plant community composition and structure can be accompanied by changes in soil function and structure. For a thorough understanding of this link, we carried out a study to evaluate the relative importance of regional variables, local soil properties, and local plant diversity on soil activity. We sampled soil and vegetation of six sites along a climatic gradient (334 to 2479 m) in the Eastern Pyrenees. At each site, we sampled patches with the dominant plant functional types (PFTs) in the site, -grasses, legumes and non-legume forbs. We harvested the aboveground biomass and then measured soil chemical variables and the size and activity of soil microbial populations. We performed Variation Partitioning analysis on soil activity variables and tested simple effects between three groups of environmental variables: (a) regional geographical, climatic and management variables, (b) local soil variables, and (c) local plant diversity variables. Our results showed that regional, local soil and local plant biodiversity variables accounted for 64.4%, 64.8 and 15.5% of the total variability of soil activity, respectively. However, the unique effects of the three sets of variables were small compared with the shared variation, with the highest variability being explained by the overlap between regional and local soil variables (45.6% of all variation including unexplained). Thus our findings suggest that plant guild effects on soil activity are modulated by regional environmental variables.

Keywords. Plant guilds – Soil changes – Climatic gradient – Community composition.

Les effets des groupes fonctionnels de plantes sur les fonctions du sol changent à travers d'un gradient climatique

Résumé. Le changement global modifie la composition végétale dans les prairies de montagne, à travers des changements dans l'équilibre des regroupements végétaux. Les systèmes souterrains et aériens sont étroitement liés, et les changements dans la composition végétale peuvent être accompagnés par des changements de fonction et structure du sol. Pour une compréhension approfondie de cette relation, nous avons réalisé une étude afin d'évaluer l'importance proportionnelle des variables régionales, des propriétés du sol, et de la biodiversité sur l'activité du sol. Nous avons recueilli des échantillons de sol et de végétation de six sites le long d'un gradient climatique (334 à 2479 m) dans les Pyrénées Orientales. Nous avons récolté la biomasse aérienne des colonies dominées par des graminées, légumineuses, et herbacées non légumineuses et mesuré les variables chimiques et l'activité des populations microbiennes du sol. Nous avons effectué une analyse de partition de la variance sur les variables de l'activité du sol, et testé les effets entre trois groupes de variables environnementales : (a) régionales géographiques, climatiques, et de gestion, (b) locales du sol, (c) de la diversité végétale. Nos résultats montrent que les variables régionales et locales du sol, et celles de la diversité végétale représentent 64,4%, 64,8% et 15,5% de la variabilité totale de l'activité du sol, respectivement. Pourtant, la plus forte variabilité est expliquée par le chevauchement entre les variables régionales du sol et celles locales. Ainsi, nos résultats suggèrent que les effets des regroupements végétaux sur l'activité de sol sont modulés par les variables environnementales régionales.

Mots-clés. Regroupements végétaux – Fonctions du sol – Gradient climatique – Composition végétale.

I – Introduction

Global change alters plant community composition of grasslands (Aguiar, 2005). Particularly, as a response to climate warming, the balance of forbs and sedges in mountain grassland ecosystems shift (Sebastià, 2007), and an increasing shrub encroachment is observed as a result of both climate change (Sanz-Elorza *et al.*, 2003) and grazing abandonment (Casasús *et al.*, 2007). Changes in plant community structure and composition imply changes in soil function and structure (Thakur and Eisenhauer, 2015). While several studies suggest that diversity effects on soil processes (e.g. nutrient limitations and/or microbial community composition) are driven by climate (Jing *et al.*, 2015), little is known about the relative contribution of the regional climatic conditions, the local soil properties, and the local plant diversity on soil activity. For a thorough understanding of this link, we carried out a study to evaluate the relative importance of regional variables (climate and management), local soil properties (soil water content, pH, total nitrogen, dissolved organic nitrogen, dissolved organic carbon, nitrate, ammonium), and local biodiversity (plant diversity and guild interactions) on soil activity. Mountain ecosystems offer a climatic gradient within a relatively small area, being thus an ideal place to study the diversity-climate effects on ecosystem processes.

II – Materials and methods

1. Study site and experimental design

The six study sites are located in Catalonia, Northeastern Spain along a climatic gradient, ranging from arid up to semi-natural subalpine grasslands with a low-intensity management of extensive seasonal grazing. Altitude, mean annual temperature (MAT) and mean annual precipitation (MAP) ranges are 334-2479 m, 2.4-13.9 °C and 225-1302 mm, respectively. Sampling was carried out at the peak of vegetation growth in the six study sites during 2014. Sampling points were chosen to represent the dominant plant functional types (PFTs), –grasses, legumes, and non-legume forbs–, with three replicates per PFT. In total, nine points were sampled in each study site by placing nine collars of 25 cm diameter where the vegetation was cut at ground level. In the two sites at lowest altitudes, a total of only six collars (grasses and forbs) were placed because legumes were not dominant at the peak vegetation growth. Vegetation samples were separated into species, then oven-dried at 60°C for 48 hours to obtain dry weight of PFT of each collar. For chemical and microbiological analyses, vertical soil samples were extracted with a spatula from the first soil layer (0-10 cm) of each collar. Soil samples were kept at 4°C until further analyses.

2. Soil analyses

Ammonium and nitrate pools were determined in 2M KCl extractions by a segmented flow analyser AA3 and microbial biomass C and N (MBC and MBN) by chloroform fumigation-direct extraction (Davidson *et al.*, 1989). Nitrification potential (NP) was determined following the soil-slurry method. Soil enzyme activities were determined in homogenised and sieved (2 mm) soils. β -glucosidase and acid phosphatase activities were measured using a 96-well microplate approach (Tian *et al.*, 2010) based on p-nitrophenol release after breaking up a synthetic substrate (p-nitrophenyl glucoside and p-nitrophenyl phosphate, respectively). Urease activity was determined following Kandeler and Gerber (1988).

3. Data analysis

We performed a Variation Partitioning Analysis (PA) on soil activity variables (urease, phosphatase, glucosidase, microbial biomass nitrogen, microbial biomass carbon, potential nitrification) using CANOCO 5. We tested simple effects among three explanatory environmental sets of variables: (a) regional-geographical, climatic and management variables: mean annual temperature

(MAT), mean annual precipitation (MAP), mean annual minimum temperature (TMIN), mean annual maximum temperature (TMAX), mean summer temperature (MST), mean summer precipitation (MSP), sheep grazing, and cattle grazing; (b) local soil variables: soil water content (SWC), pH, total nitrogen, nitrate, ammonium, dissolved organic nitrogen (DON), dissolved organic carbon (DOC); and (c) local plant diversity variables: species richness (S), grass, legume and non-legume forb biomass proportion, and the binary interactions between the three plant functional types. The three datasets of potential explanatory variables had a similar number of variables (8 regional, 7 soil and 7 biodiversity variables).

III – Results and discussion

Variation Partitioning Analysis showed that regional variables accounted for 64.4% of the total variability of soil activity, of which TMIN was the best predictor for soil activity (it adds 57.1 % to explanatory power of this set), followed by management (22% for sheep grazing and 12.8% for cattle grazing). None of the precipitation variables were needed to improve the fit and therefore were not included in the final model. Local soil variables accounted for 64.8% of the variability of soil activity, of which soil ammonium content added 69.3% to the explanatory power of this set. Local plant diversity variables accounted for 15.5% of the variability of soil activity, of which species richness was the single first variable selected by the forward procedure and adds 26.4% to the explanatory power of this set. Nonetheless, PFT and their interactions were the most explanatory variables, as they accounted for the rest of the variability in the biodiversity set. PFT binary interactions were more explanatory than the main effects, overall adding 55.4% to explanatory power of the biodiversity set, as compared to 19.46% of main effects. Among them, the effects of forbs were the most relevant (16.8%). The interaction between legumes and non-legume forbs added 24.3%, being the second single most explanatory variable. The unique effects of the three sets of variables were small compared with the shared variation (Fig. 1), with the highest variability being explained by the overlap between regional and soil variables (55.6% of all variation including unexplained), and followed by the overlap among the three sets (12.7%; Fig. 1).

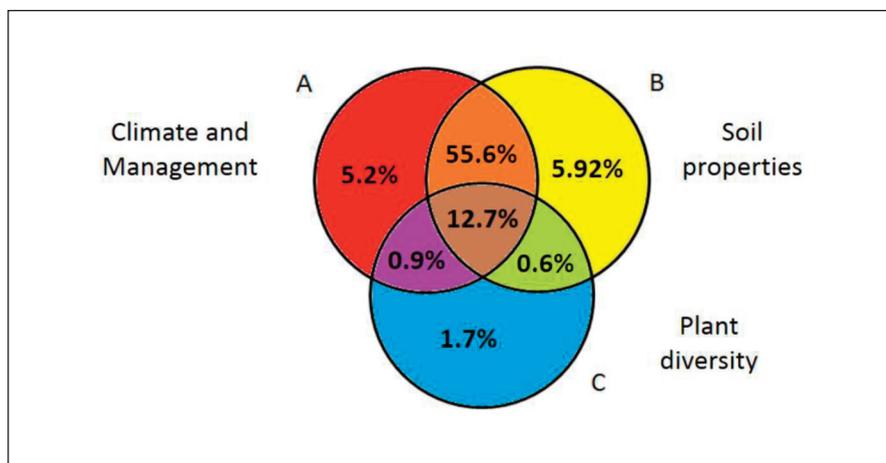


Fig. 1. Distribution of explained variation of soil activity by the three sets of variables. A: regional variables related to climate and management (MTMIN, Sheep, Cattle, MST, MAT); **B,** local soil variables (Ammonium, pH, Moisture, Total N, Nitrate, DOC, DON); **C,** local plant diversity variables (S, FL, GL, GF, Forb, Grass, Legume).

Classen *et al.* (2015) distinguished between direct and indirect effects of climate change on ecosystem processes, indirect effects being defined as those mediated by shifts in diversity, community composition and functional traits. These authors hypothesize that indirect effects of climate change on microbes mediated through plants may be stronger than direct effects of climate on shaping microbial community composition and function. Our results show that soil activity is better explained by the combined effects of climate, management, soil properties and plant diversity and that no unique factor can explain the variability of soil activity. On the contrary, Thakur *et al.* (2015) found that soil microbial biomass carbon is driven by plant diversity and that no interactions with global environmental change factors occur. The relative importance of management as a driver of soil activity should be pointed out, suggesting a relevant role of management to attenuate global change effects on soil activity.

IV – Conclusions

The effects of plant guilds on soil activity are modulated by regional environmental variables. The combination of climate, management, soil properties and plant diversity explains the variability of soil activity better than any of the single factors.

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Biomass production and use of silvopastoral areas in the Rif Mountains of Morocco

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Abstract. In Northern Morocco, the forest rangelands provide goods and services, which satisfy the diverse needs of local population. These silvopastoral areas represent the most important feed sources for goats in the Rif Mountain. This study aims to evaluate the biomass production and investigate the use of a silvopastoral area (Derdara) exclusively used by goatherds. For biomass production, we used the method of the reference module. A survey on using pasture by breeders was realized during the biomass evaluation period. The pastoral shrubs, mainly *Arbutus unedo*, *Cistus crispus*, *Cistus monspeliensis*, *Erica arborea*, *Lavandula stoeches* and *Mentha pulegium*, represent the fundamental diet for goats. Breeders use pasture throughout the year, except on rainy days where they resort to limbing. The pasture was characterized by a diversity average level of pastoral flora (94 species) dominated by shrubs. The biomass produced was estimated at 1867 kg dry matter per hectare composed for 74% by shrubs. Significant differences were observed concerning the intensity of the canopy cover, depending on the season and according to sampling sites. The continuous use of the same pasture for a long time, can explain the appearance of low pastoral value species in the study area, such as *Arisarum vulgare*, *Daphne gnidium* and *Ranunculus sardous*. The reasonable use of silvopastoral resources, including a reduction in grazing pressure, should be developed to ensure better productivity and sustainability of these resources.

Keywords. Pasture – Goat – Derdara – Sustainability.

La production de biomasse et l'utilisation des zones sylvopastorales dans les montagnes du Rif du Maroc

Résumé. Au nord du Maroc, les pâturages forestiers fournissent des biens et services, qui répondent aux divers besoins de la population locale. Ces zones sylvopastorales représentent la principale source d'alimentation pour les caprins dans les montagnes du Rif. Cette étude vise à évaluer la production en biomasse et à étudier le mode d'utilisation d'une zone sylvopastorale (Derdara) exclusivement utilisée par les caprins. Pour la production en biomasse, nous avons utilisé la méthode du module de référence. L'enquête avec les éleveurs sur le mode d'utilisation des pâturages a été réalisée pendant la période d'évaluation de la biomasse. Les arbustes pastoraux, principalement *Arbutus unedo*, *Cistus crispus*, *Cistus monspeliensis*, *Erica arborea*, *Lavandula stoeches* and *Mentha pulegium*, constituent les principaux aliments consommés par les caprins. Les éleveurs utilisent pâturage toute l'année, sauf pendant les jours pluvieux où ils ont recours à l'ébranchage. Le pâturage est caractérisé par un niveau moyen de diversité de la flore pastorales (94 espèces) dominées par des arbustes. La biomasse produite a été estimée à 1 867 kg de matière sèche par hectare composé à 74% d'arbuste. Des différences significatives ont été observées selon la saison et selon les sites d'échantillonnage concernant l'intensité du couvert forestier. L'utilisation continue du même pâturage pendant une longue période, peut expliquer l'apparition d'espèces de faible valeur pastorale, dans la zone d'étude, tels que *Arisarum vulgare*, *Daphne gnidium* et *Ranunculus sardous*. L'utilisation raisonnable des ressources sylvopastorales, y compris une réduction de la pression de pâturage, devrait être développé pour assurer une meilleure productivité et la durabilité de ces ressources.

Mots-clés. Pâturage – Caprin – Derdara – Durabilité.

I – Introduction

Silvopastoral areas in the Mediterranean basin are dynamic social-ecological systems with a high diversity of management and ecological conditions (Pinto-Correia, 2000). Silvopastoral systems are characterized by integrating trees with forage and livestock production, and pastures that can be natural, improved or cultivated (Castro *et al.*, 2010). In Northern Morocco, traditional forest and silvopastoral management practices are still prevalent. These forest rangelands provide goods and services, which satisfy the diverse needs of local population, and represent the most important feed sources for goats in the Rif Mountain. Silvopastoral area is under pressure due to climate change, overgrazing, population and especially bad operating practices of silvopastoral resources such as limbing (Chebli *et al.*, 2012). For a sustainable and integrated development of silvopastoral area, it is essential to establish a resource assessment system.

We conducted this study in a silvopastoral area of the Moroccan Rif Mountains (Derdara) exclusively used by goat's herds to assess botanical composition and biomass production, and investigate the use of this silvopastoral area.

II – Materials and methods

The study was conducted in Derdara, a part of the Chefchaouen district, located in the Northern Morocco. The pasture concerned in our study is located at 35° 28' N 5° 18' W and from 1195 to 1250 m above sea level. The climate is Mediterranean, with mean min and max temperatures of 3°C and 41°C respectively, while the total annual precipitation is 500 mm.

The area of study is forest rangelands exploited by goat breeders. The study was investigated over a period of eight months to assess the species composition and the productivity of pastoral plants by evaluating the vegetation qualitatively and quantitatively.

The qualitative evaluation of vegetation concerned the floristic diversity. In each sampling period, a herbarium was collected to determine the floristic composition.

For quantitative evaluation, biomass production has mainly concerned the palatable species. Measurements were performed during three seasons (Winter, Spring and Summer 2015). Plant biomass was measured using the non-destructive method known as the reference module. In order to control spatial heterogeneity, we used the stratification method as proposed by Qarro (1996), Kouraimi (1997), Chebli *et al.* (2012 and 2014). According to the density of cork oak, four homogenous sites were identified. In each site we identified the number of quadrats needed to control heterogeneity of silvopastoral area (6 quadrats/site). The size of the quadrats adopted for measurement of biomass is 2m x 5m for shrubs strata and 1m x 1m for herbaceous strata.

Several surveys were conducted with breeders during the study period to gather information on modalities of using pastures.

III – Results and discussion

Derdara pasture is characterized by a relatively rugged topography. Soil is poor and strongly susceptible to erosion. Vegetation structure is mainly shrub-dominated.

1. Botanical composition

In Derdara, pasture was characterized by an average level of diversity of pastoral flora (94 species) dominated by shrubs (Table 1). Pastoral species that dominate Derdara pasture and who constitute over 50% of the forage species selected by goats are represented in Table 1. These last year's breed-

ers noticed abundance of unpalatable species in degraded areas (Site 3 and 4) dominated by annual unpalatable plant species such as *Arisarum vulgare* (Targioni-Tozzetti) and *Coriaria myrtifolia* L. This situation can be explained mainly by misuse of some part of rangeland (Site 3 and 4), causing overexploitation of pastoral resources and contributes to appearance of low palatability species.

Table 1. Principal botanical composition of palatable and unpalatable flora in Dardara pasture

Plant	Site 1	Site 2	Site 3	Site 4
Palatable species				
<i>Arbutus unedo</i>	+++	+++	++	+
<i>Cistus crispus</i>	++	+++	+	+
<i>Cistus monspeliensis</i>	++	+++	+	+
<i>Erica arborea</i>	+++	++	+	+
<i>Quercus suber</i>	+++	++	+	–
<i>Lavandula stoechas</i>	+	++	+	+
<i>Myrtus communis</i>	+	+		
<i>Pistacia lentiscus</i>	++	+++	+	–
Unpalatable species				
<i>Anagallis arvensis</i>	–	–	++	++
<i>Arisarum vulgare</i>	–	–	+	++
<i>Coriaria myrtifolia</i>	–	–	+	+
<i>Daphne gnidium</i>	–	–	–	++
<i>Ranunculus sardous</i>	–	–	+	+

+ + + Species very abundant.

+ + Moderately abundant species.

+ Weakly abundant species.

– Absent.

2. Biomass production

Dardara pasture (Sites 1 and 2) is characterized by dense vegetation mainly dominated by shrub strata. The pastoral feed offer is very high compared to Site 3 and Site 4 (Table 2). The difference in pastoral production, depending on the season and according to sampling sites, is statistically highly significant ($P < 0.001$). The higher pastoral production is estimated in Site 1 (3607 kg DM per hectare). The other sites are considered as permanent pasture sites, mainly Sites 3 and 4. This difference can be explained in part by continuous use of pastoral resources and lack of appropriate pasture management. For season, the higher production is observed in the spring (2465 kg DM per hectare), which coincides with the growth phase of most species groups (vegetative peak).

Table 2. Effect of sampling site and season on biomass production in Dardara pasture

	Site (Si)				Mean	SEM1	SEM2	SEM3	Signification		
	1	2	3	4					Si	Season	Si*Season
Winter	2149	1096	928	554	1182 ^c	38.13	33.10	66.04	<.0001	<.0001	<.0001
Spring	4779	2404	1785	893	2465 ^a						
Summer	3894	1837	1362	726	1955 ^b						
Mean	3607 ^d	1779 ^a	1358 ^b	724 ^c							

SEM1: Standard error of the mean for comparison between sites.

SEM2: Standard error of the mean for comparison between seasons.

SEM3: Standard error of the mean for comparison between site*season.

a-c Different letters in the same line or same column indicate that values are significantly different ($p < 0.05$).

3. The use of silvopastoral resources

Goat herds are driven mostly by breeders themselves. Grazing is practiced throughout the year from mid-winter to mid-autumn. During this time of the year, pastures are in restoration phase of their groundcover with maximum forage production during the months of April and May. Goats spend most of the day on silvopastoral areas (7-8 hours per day). During rainy periods, intensity of pasture use decreases, with a reduced frequency during winter (2-3 hours per day) as access to the pastures become difficult, which explains the use of delimiting by breeders to reduce burdens of supplementation.

The herd movements in silvopastoral areas are anarchic. Goats concentration for long time on the same pasture causes overgrazing and therefore the appearance of unpalatable species and disappearance of palatable species. Goats travel itinerary are based on access and availability of forage. The average distance traveled by goats was estimated to eight km per day.

IV – Conclusions

Silvopastoral areas in Dardara remain a large area for forest grazing. Biomass production varies greatly from one site to another. The anarchic use of silvopastoral resources contribute to appearance of overgrazed pastures and of unpalatable plant species.

The silvopastoral resources on these areas, despite all forms of degradation, continues to play an important role for all agricultural activities of the local population, representing a fundamental source of feed for livestock. A lack of actions for the development of these resources could prevent the animal and people needs to be met.

The pressure on the silvopastoral resources in the mountain Rif could lead to their irreversible degradation. Consequently, it will be necessary to adopt a rational use of rangelands, on a seasonal schedule and / or depending on the state of resources, convincing breeders to work together for pasture use.

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Session 4

Mountain pastures and society: biophysical, economic and socio-cultural valuation of ecosystem services

Enabling sustainable pastoral landscapes: building social capital to restore natural capital

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Abstract. Sustaining pastoral landscapes is distinguished from stewardship of most other landscapes by the often far-reaching mobility of the large herbivores that have evolved with them. The scale of rangeland use is set by the cultural and animal adaptations needed for rangeland landscapes, and today, the connections needed for supplementary support of animals, households, communities, and government. The extent and inherent need for flexibility in pastoral systems clashes with the increasingly fragmented landscapes and hardening borders of today's world. Rangelands and pastoralism generally exist at the ecological, political, and economic margins, constrained by more profitable land uses on better lands. Regardless of their location, pastoral peoples and rangelands face growing political, economic, and climatic stresses that challenge their coupled resilience and ability to adapt. Focusing on the United States, in this paper I discuss at the landscape level key enablers for continued rangeland livestock production and the ecosystem services it provides, concluding with a discussion of how two grassroots groups in the United States have developed to help grazing communities have used innovation to maintain access to rangelands. Key enablers include having large grazing areas and connections among grazing areas needed at different times of year, a year round affordable forage and feed supply; tenure security; proximity or transportation to markets, processors, and employment; recognition and exploitation of the multi-functionality of rangelands; a "critical mass" of livestock producers in the area; and participation and leadership from a livestock-rearing community working and communicating across existing social, political, and physical boundaries.

Keywords. Rangelands – Grassroots groups – Mobility – Social-ecological systems – Pastoralism.

Favoriser la durabilité des paysages pastoraux : construction de capital social pour restaurer le capital naturel

Résumé. Le maintien des paysages pastoraux se différencie de la gestion de la plupart des autres paysages par la mobilité, souvent sur de longues distances, des grands herbivores qui ont évolué avec eux. L'échelle d'utilisation des terres de parcours dépend des adaptations culturelles et animales nécessaires aux paysages de parcours, et de nos jours, des liaisons requises pour les besoins supplémentaires des animaux, des ménages, des communautés et par rapport au gouvernement. L'étendue et la nécessité inhérente de flexibilité dans les systèmes pastoraux se heurte à des paysages de plus en plus fragmentés et aux frontières plus strictes du monde d'aujourd'hui. Les parcours et le pastoralisme existent généralement de façon marginale dans le domaine écologique, politique, et économique, étant évincés par des utilisations plus profitables sur de meilleures terres. Où qu'ils se trouvent, les pastoralistes et les parcours affrontent des difficultés politiques, économiques et climatiques croissantes, qui mettent à l'épreuve à la fois leur résilience et leur aptitude à s'adapter. Concernant les États-Unis, dans cet article j'examine au niveau du paysage les éléments-clés favorables à la continuation de la production animale sur parcours et les services écosystémiques qui en découlent, pour conclure en examinant comment deux groupes locaux aux États-Unis se sont développés pour aider les communautés des pâturages, en utilisant l'innovation pour maintenir l'accès aux parcours. Parmi les éléments-clés favorables se trouvent le fait d'avoir de grandes surfaces de pâturages et des connexions entre les zones de pâturage nécessaires à différents moments de l'année, un approvisionnement en fourrage et concentré disponible sur toute l'année ; la sécurité de la tenure des terres ; la proximité ou le transport aux marchés, aux transformateurs, et à l'emploi ; la reconnaissance et l'exploitation de la multifonctionnalité des parcours ; une "masse critique" de producteurs de bétail dans la zone ; et la participation et le leadership d'une communauté d'éleveurs travaillant et communiquant à travers les frontières sociales, politiques, et physiques existantes.

Mots-clés. Parcours – Groupes locaux – Mobilité – Systèmes socio-écologiques – Pastoralisme.

I – Introduction

Sustaining pastoral landscapes is distinguished from stewardship of most other landscapes by the often far-reaching mobility of the large herbivores that have evolved with them. The scale of rangeland use is set by the cultural and animal adaptations needed for rangeland landscapes, and today, the connections needed for supplementary support of animals, households, communities, and government. The extent and inherent flexibility of pastoral systems clashes with the increasingly fragmented landscapes and hardening borders of today's world.

The name, “rangeland” implies a land for ranging. For millions of years, the dependence of herbivores on rangelands for sustenance has meant the ability to move, sometimes over vast distances and across biomes, between elevations, to water, and away from drought or extreme cold. Pastoral societies, in turn, interact with social and political forces at multiple scales, including the costs of pasture access, the availability of employment in local communities, urban and crop expansion into rangelands, and livestock prices worldwide.

Pastoralism and pastoralists have been defined many ways (Huntsinger *et al.*, 2010). Globally, rangelands and pastoralism generally exist at the ecological, political, and economic margins, constrained by more profitable land uses on better lands (Sayre *et al.*, 2013). Regardless of their location, pastoral peoples and rangelands face growing political, economic, and climatic stresses that challenge their coupled resilience and ability to adapt (Reid *et al.*, 2014). For the purposes of sustaining pastoral landscapes, there is considerable overlap between the needs of modernized, market-driven livestock production and traditional, subsistence pastoralism. Here we use the term pastoralist loosely to mean people with a mode of life centered on livestock rearing on rangelands.

Based on a meta-analysis of stated preference studies on European agrarian landscapes, Van Zanten *et al.* (2014) concluded that landscape attributes that include livestock presence, a mosaic of land cover, or historic buildings generally receive the highest stated preferences across 345 studies in diverse European landscapes. Unique cultures may be rooted in interactions with livestock and rangelands. Ecologically, because cultural practices and the behavior of grazing animals have created and maintained many rangelands, landscape conservation may be linked to continued grazing or cultural activities. Biodiversity may be enhanced by grazing, and domesticates can be used to manipulate habitat and enhance ecosystem service at the behest of the manager (Huntsinger and Oviedo, 2014). Depending on the particular circumstances, herbivory can create moderate disturbance that stimulates diversity (Perevolotsky and Seligman, 1998); helps to control invasive species (Germano *et al.*, 2012), and prevents or reduces conversion to woody vegetation (McBride and Heady, 1968; Rowntree, 1994; Johnson and Cushman, 2007). On the other hand, again depending on circumstances, large herbivore grazing can reduce biodiversity through changes in vegetation composition and structure, increase erosion through trampling and reduction of ground cover, facilitate woody plant invasion, and reduce habitat and food for other fauna. Pastoral landscape stewardship at the landscape level is about managing the spatial configuration of resources to make possible environmentally positive outcomes for rangelands and the people using them.

Rangeland fragmentation and loss of access may be the most serious problem facing the world's pastoralists. This includes fragmented landownerships, vegetation types, travel corridors, support networks, and infrastructure. Rangelands in the United States today are a mosaic of ownerships. Privately held croplands and pastures may be interspersed with government rangelands, forests, and residential developments. Herds need connectivity between different topographies and vegetation types, and pastoralists need connections to markets, employment, government, and other pastoralists. The constellation of land types and facilities that support rangeland production must be considered and often linked if pastoralism is to continue on rangelands.

Focusing on the United States, in this paper I discuss key enablers for continued rangeland livestock production and the ecosystem services it provides, concluding with a discussion of how two

grassroots groups in the United States have developed to help grazing communities overcome some of their problems in order to maintain access to the rangelands they need. Key enablers include having enough and the right types of grazing lands, providing a year round affordable forage and feed supply; tenure security; access to markets, processors, and employment; recognition and exploitation of the multi-functionality of rangelands; a “critical mass” of livestock producers in the area; and government recognition and appropriate policy. In the end, however, the real “key enablers” must be the pastoralists themselves.

II – Large areas to graze: the imperative of mobility

Among mammals, the most characteristic evolutionary adaptation to rangeland is the ability to use rangeland plants of low and even hostile nutritional quality. Large grazers, including ruminants such as cows, sheep, caribou, deer, yaks, and other herbivores like horses and camels, have evolutionary adaptations that enable them to flourish on a low protein diet, one that is often loaded with silica, indigestible fiber, and toxins. Rangeland herbivore adaptations include the ability to digest a lot of fiber, including cellulose, the ability to run swiftly and travel long distances, digestive systems that can defuse many toxins, and teeth that can stand up to silica and a life of eating tough plants. Migration, or mobility of various sorts, is an adaptation by large grazers to an environment where nutrient sources are spread over a large area and may differ in quality by species or locality, and where forage production is heterogeneous in time and space. Movement may be regular and seasonal, or may be opportunist to escape drought or cold, or to find the best forage at any given time within a particular set of conditions.

Beginning around 13,000 years ago, as the domestication of large herbivores began, people used them to make use of lands where, by and large, cultivation was impractical. Juliet Clutton-Brock, who has written extensively on domestication and pastoralism, refers to domesticated grazers as a “walking larder” (1989), food “on the hoof.” By domesticating and herding, humans earned an assured supply of meat, dairy foods, skins, and numerous other goods, produced by livestock from low-protein and widely dispersed vegetation that is mostly indigestible and sometimes toxic to humans. Livestock are able and eager to move around and find the food they need for themselves on landscapes where food and water is, per unit area, scarce. A fundamental aspect of herding cultures, then, has always been facilitating the ability of the animals to express their great capacity for mobility and using unarable land. As a result, livestock herding peoples have developed cultural traditions and practices that support and facilitate the mobility of grazing animals over the large areas of land they need to acquire sufficient sustenance (Fernandez and LeFebvre, 2006). For modern ranchers, this means having access to rangelands for as much of the year as possible, because they are generally the least costly source of food for the animals.

There is a complex web of social relations and institutions that have enabled cultures to adapt to mobility and highly variable rangeland productivity, and U.S. pastoralists are no exception (Ellickson 1986; Ellis 2003). “Reciprocity,” a common characteristic of pastoral societies, facilitates shared responsibility for widely dispersed livestock, and in the U.S., neighbor trusts neighbor to return wandering animals (Ellickson, 1986). Traditions for sharing forage resources, as well as labor and equipment, are often present within a ranching community (Bennett, 1968).

Landscape stewardship for rangelands, whether they are used for livestock production or not, must be rooted in an understanding of the need for mobility, and along with it, contiguity and extent. Mobility of grazing animals means that they must be able to get from one place to another, often to use multiple types of vegetation occurring at different elevations. For stewardship of rangelands, this means assessing the different types of rangelands available for grazing, and the corridors and connections among them. The ability of the people and cultures rearing livestock on rangelands to manage and facilitate mobility is crucial. This may mean access to distant pastures, use of mo-

torized vehicles, or ability to hire workers with the needed skills. For domestic animals, this can also include substitutes for mobility such as harvested forages and feeds, which may increase monetary and environmental costs, but which can also be mutually beneficial. Livestock can consume by-products and provide fertilizing manure.

As an example of an integrated landscape of croplands and rangelands, the nineteenth century community land grants of the Mexican government in New Mexico, USA, included small private parcels near water sources titled to individual households for growing crops, while the surrounding much larger areas of rangeland were held in community ownership, facilitating animal mobility, labor savings, and forms of transhumance. In another example, Alpine farmers often keep their stock in a barn or in privately held paddocks for much of the winter, consuming meadow hay, feeds, and crop residue until they are sent up to mountain meadows to graze community-owned or municipal summer pasture. The forms of ownership were made null when the United States government acquired the southwest.

III – Tenure security and fragmentation

Tenure security is often weak when it comes to the rangelands used by pastoralists. The scale of pastoralism rarely conforms to political, ownership, and land use boundaries, and there is strong competition from alternative uses. Because of mobility, and the semi-natural appearance of grazing lands, the land can look unoccupied. As returns from grazing are not high per unit area, a broad array of competing land uses impinge on rangelands globally. Crop production, mining, urbanization, and recreation successfully annex rangelands. Pastoralists lose range to grazing exclusion for recreation, tree-planting, and environmental or wildlife protection. Protection of predators or feral grazers like wild horses can reduce the utility of rangelands for pastoralism. Yet security of access to large grazing areas, and key resources like water, are needed by pastoralists (Fernandez-Gimenez and Le Febre, 2006).

Traditional herding peoples have generally managed a significant part of their rangeland resources as a commons with community management, or in an open access condition where animal numbers are limited by periodic droughts, winters of exceptional cold, or other factors (Fernandez-Gimenez and Le Febre, 2006). Grazing animals together and sharing rangelands maximizes the amount of land and the diversity of habitats, elevations, water sources and so on available to each animal. Sharing a large landscape also makes it more likely that livestock can access different types of vegetation in different seasons, including transhumance from mountain meadows in summer to lowland grasslands in winter. In North America, pre-U.S. hispanic institutions and nineteenth century emerging institutions for grazing management were cut short by the inability of local communities, in part restrained by governmental stricture, to control massive speculative introductions of stock onto the unsettled public domain of the western U.S. late in the century (Nelson, 1995). The result, due to the consequences of an open-access condition, was transfer of most arid and montane public domain rangeland to the government for management.

Today, 50% of the land area of the 11 western states is in federal ownership, with grazing and other uses largely controlled by land management agencies (Huntsinger and Starrs, 2006). A livestock producer on U.S. rangelands may summer on montane lands managed by the United States Forest Service, winter on desert lands managed by the Bureau of Land Management, and spend the times in between on privately owned irrigated pasture, crop stubble, or meadow land near the house (Fig. 1). Hay or other feed is used when forage is not available, sometimes grown on the small but comparatively well-watered private property of the ranch. Private lands may also be rented. A significant problem for transhumance is the loss of trailing routes to highways and urban sprawl. In a recent survey of ranchers in California, those practicing transhumance were significantly more likely than other nearby ranchers to be affected by vegetation change on government land, largely due to fire suppression, and conversion of private land (Huntsinger *et al.*, 2010). To create a landscape that offers the security of tenure ideal for sustainable rangeland stewardship, coordination among multiple forms of ownership and governance may be required.

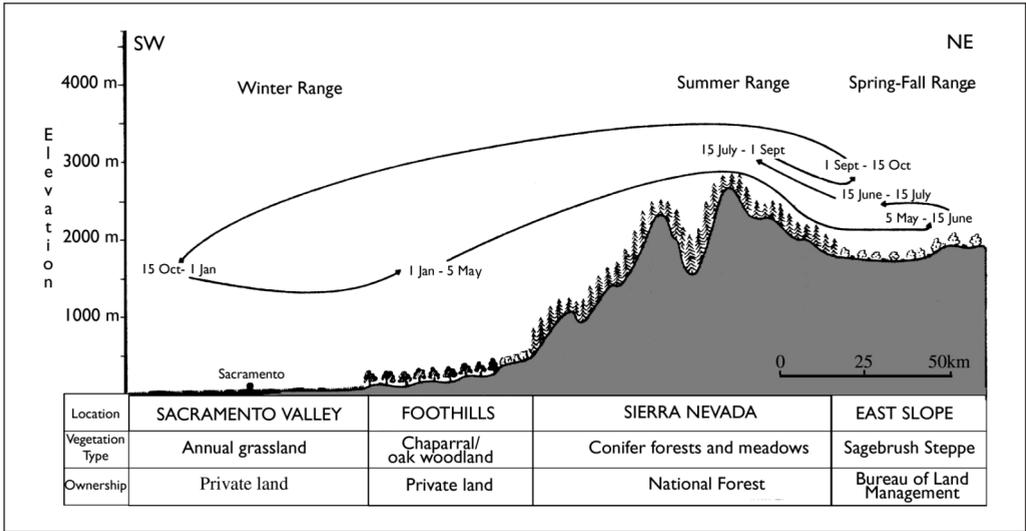


Fig. 1. In transhumance, livestock travel among vegetation types, topographies, and land ownerships in California's western Sierra Nevada (adapted from Rinshede, 1984).

1. Maintaining critical mass

Veterinary services, packing facilities, and local markets rely on what has been termed a “critical mass” of livestock producers (Hart, 1991; Liffmann, 2000). Once that is lost, the loss of infrastructure, neighbors, and rangelands augments the departure of rangeland producers, and in scenic or peri-metropolitan areas, increases land conversion (Fig. 2). A socio-ecological feedback loop has been described for private ranches in the United States (Huntsinger, 2009). When one ranch is developed and converted, the overall rangeland available to livestock husbandry gets smaller, as does the local labor pool, the size and political influence of the grazing community, and the support for markets, feed stores, veterinary services, and slaughterhouses. The urban-agricultural “edge” expands, leading to greater conflicts between agricultural practices and new, amenity-seeking residents, and potentially increasing the land price of the remaining ranches. These pressures increase the probability that more ranches will sell.

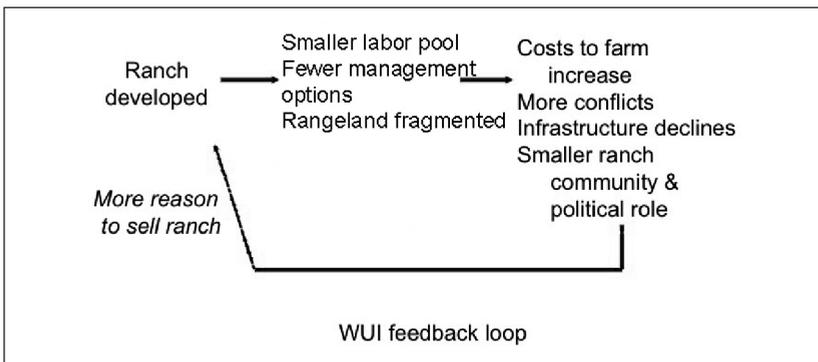


Fig. 2. The loss of one ranch to urbanization feeds back to the community in a way that leads to more losses of ranches (adapted from Huntsinger, 2009).

2. Recognition of multi-functionality

Recognition that alternative land uses can take place concurrently with livestock production, and can even at times be synergistic with other uses, can help increase the rangelands available for grazing. A wide number of species depend on and make use of rangelands, some benefiting from livestock grazing (Huntsinger and Oviedo, 2014). Hunting, trekking, camping, birdwatching, mushroom and herb collection, firewood and wood production, some or all of these things typically occur on grazed rangelands. Species important to crop pollination may find refugia on nearby rangelands (Chaplin-Kramer *et al.*, 2011). Rangelands are often scenically attractive and culturally resonant.

Because livestock production from rangelands is generally not enough to support ranchers, there is considerable interest in finding ways to gain income from non-livestock uses, yet payments for ecosystem services programs are rare in the United States. Even though many were unfamiliar with the specific term “ecosystem services,” more than two-thirds of ranchers surveyed in California 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” (Cheatum *et al.*, 2011). The length of time they would have to commit to an activity, and the size of the payment, were important factors in rancher willingness to participate in such ecosystem services production programs, with ranchers preferring shorter contracts and higher payments. Who would offer the payments was also important to prospective sellers, with non-profit organizations or private firms strongly preferred over governmental agencies (Cheatum *et al.*, 2011). Perhaps because self-motivation and education still remain the primary motivators for more conservation-minded behaviors (de Snoo *et al.*, 2013), U.S. ranchers making such changes usually have strong ideas about why they chose to make changes, and why they are important.

Forestry may conflict with grazing, or provide opportunities. Livestock and other large herbivores may graze the understory of orchards, savannas, woodlands, and even forests, as well as forest meadows and clearings as part of “agroforestry,” or more specifically, “silvo-pastoralism.” The interactions between large herbivores, forest growth, and fire are complex and depend on site environmental conditions, the pattern of grazing, the species of grazer, and the relative palatability of forest species. By reducing fuels livestock grazing can reduce the severity of fires, acting as a substitute and more selective alternative to natural fire regimes or prescribed burning (Tsiouvaras *et al.*, 1989; Blackmore and Vitousek, 2000). In U.S. pine plantations livestock grazing has been found a cost-effective way of controlling understory vegetation (Allen and Bartolome, 1989). Coordination and communication between herders and foresters is needed. However, despite calls for policy reform in U.S. forest management, including the use of deliberate burning to reduce fuels (North *et al.*, 2015), there remains a strong prejudice against the use of livestock grazing for forest management in the United States.

Tree planting has become one of the most well-publicized methods of combating climate change. This has led to the planting of trees in grasslands and meadows, often to the detriment of biodiversity (Veldman *et al.*, 2015), and evidently often without benefit for carbon sequestration (Naudts *et al.*, 2016). Planting more open forests that still provide forage for grazing animals and consist of more deciduous and broad leaved vegetation may help. In the United States, huge fires have left a blank slate for forest regrowth, and there is deep concern among many of us that they will be restored at densities that facilitate re-burning, especially given warming conditions. Livestock should be part of mediating regrowth to create clumped and less dense patterns of tree growth that resist fire. Particularly in climates with dry seasons and fires, rangeland soils may be the most secure way to store carbon for the long run (Booker *et al.*, 2013). Payments for the ecosystem service of carbon sequestration are sought by rangeland owners in the U.S., but so far opportunities have been minor, in part because of the difficulties and costs of demonstrating additionality.

IV – Proximity to employment and markets

To create a sustainable pastoral landscape, proximity and access to towns and cities, and the markets and employment they provide, is important and becoming more so.

The large areas of rangelands needed to support livestock, low productivity per unit area, and competition from modern agriculture, including the use of crops to feed livestock, means that in the developed world and even in many less developed countries, to achieve a reasonable standard of living as a participant in the market economy, livestock rearing households need additional income streams, beyond that from their stock. In the western United States, study after study has confirmed that significant income for ranching households comes from non-livestock sources including wage labor, and that rangeland real estate prices are not justified by their production value. As early as 1969, Smith and Martin (1972) found that ranchers in Arizona depended on outside income, and that local towns were part of their support network by providing wage jobs and business opportunities. The largest ranch in the United States, the King Ranch in Texas, hosts numerous industries designed to supplement their livestock production income, including marketing branded trucks and hosting paying hunters. U.S. ranches also enjoy tax reductions and other financial benefits from the federal and state government. In California only 25% of livestock producers earned most of the income from livestock in 2005 (Huntsinger and Bartolome, 2014).

V – Governance and the grassroots

As we have seen, stewardship for rangelands that intends to foster rangeland cultures, protect rangeland wildlife, and assure healthy vegetation and environment must consider diverse ecosystems and their drivers, agricultural practices, forage and feed sources, land uses, individual and community tenure and governance systems, sources of employment and relationships with proximate land uses, and the spatial or social arrangements among them. Because of their changing and semi-natural character, and the ways that ecological, economic, and social change are deeply interwoven, they can be characterized as co-evolving social-ecological systems (Olsson *et al.* 2004; Liu, 2007). It is also important to consider vertical scale. For rangeland landscapes, politics, climate change and the global economy are obvious drivers from higher levels. At lower levels, whether or not herbivory is well-managed in a pasture, the individual decisions of landowners and their heirs, and even the economic well-being of livestock producing families will have feed back to the capacity for landscape stewardship (Huntsinger and Oviedo, 2014).

Ranchers often consider themselves to have a distinct culture from those engaged in other forms of agriculture, or than the dominant culture, and feel that understanding of rangelands and their imperatives is weak. The most innovative efforts at “collaborative and adaptive approaches” for landscape stewardship these days seem to be evolving from rangeland livestock producers themselves, in what ironically are termed “grassroots” efforts. Grassroots stewardship may be conceived of as community governance that arises organically in response to complex and shifting demands from society and the ecosystem. In the United States, grassroots alliances of ranchers have emerged to protect access to rangelands (Huntsinger *et al.*, 2014). Contrasting two different organizations in two different regions, and the innovations they have made, provides insight into how each alliance reflects their unique political and ecological landscape.

1. Malpai Borderlands Group (<http://www.malpaiborderlandsgroup.org>)

The Malpai Borderlands Group (MBG) is a self organized group of Arizona ranchers that began collaborating to facilitate controlled, deliberate burning of their brush-invaded rangelands. Ownership of the semi-arid rangelands in the area is 59% private, 18% federal, and 23% state (Arizona and New Mexico). Ranchers may need to use lands in all of these ownerships as they seek to ful-

fill their annual forage needs. The group developed connections to state and federal representatives of the land management agencies that control much of the grazing lands in their geographic locale, including some 800,000 acres of relatively unfragmented rangelands in southeastern Arizona and southwestern New Mexico (<http://www.malpaiborderlandsgroup.org/>). They worked with the agencies to create a first of its kind coordinated, trans-ownership burn plan to help fire-fighters to allow some areas to burn safely on interdigitated private and government lands.

Eventually the group also became concerned about the growing demand for residential real estate parcels that was driving the fragmentation of private rangelands and conflicts on government range. The group's goals grew to include resisting rangeland fragmentation by using "conservation easements," a legal tool that restricts development rights on private land by changing the property title. Conservation easements are established voluntarily between a conservation organization or government agency and a landowner. To motivate participating ranchers to set up conservation easements, access additional grazing land during drought was provided to those with an easement. These became known as «grassbanks», another example of conservation innovation by the group (Gripne, 2005; White and Conley, 2007). For the MBG, it is a nearby ranch and wildlife reserve, owned by an NGO, that is only grazed when needed.

A third important innovation by the group is that conservation easements can be voided if federal or state grazing leases are lost by the rancher, because this would most likely make the ranch no longer economically viable. This enables a rancher to sell the land for development after all. As local land management agencies also find fragmentation and urban sprawl to be a problem for management and fire control, and large undeveloped ranches create a buffer between protected government lands and urban sprawl (Sulak and Huntsinger, 2007; Talbert *et al.*, 2007), the group now has a point of leverage in negotiation over possible changes in grazing policy.

2. California Rangeland Conservation Coalition (<http://carangeland.org>)

The statewide grassroots California Rangeland Conservation Coalition (CRCC) is more of a community of interest than of a specific geographic locale. In California the challenges ranchers face in accessing rangelands are shaped by a different land tenure configuration and a higher level of fragmentation. They manage a complex portfolio of owned and leased lands, leasing from government agencies, but also from private landowners who have retired from ranching, own land for investment, or own land for non-ranching purposes. Land trusts, utilities, and municipalities also lease grazing land. A rancher in the Sierran foothills, for example, reported use of 14 different leases (Sulak and Huntsinger, 2007), while another told us in 2012 that he had 33 small leases scattered throughout his local area, some grazed by only small groups of cattle (Huntsinger and Bartolome, 2014). Competition for leases is fierce, and it is not uncommon for ranchers to submit bids for leases that require a substantial commitment to stewarding and improving the range. Leasing from owners of such diverse interests can be overwhelming. In addition, there is great public scrutiny of rangelands, as rangelands often are interspersed with urban and suburban development. And with more land lost to development in this high-value area, ranchers are more reliant on lands that are not privately owned. The Coalition helps them negotiate and communicate with those who control the rangeland.

After a history of polarization over the impacts of livestock grazing, the innovative California Rangeland Conservation Coalition began in 2005, leveraging the notion that much habitat would be lost, as frustrated ranchers sold out to developers, if the ranching and environmental communities did not work together. In this region, livestock can be important to conservation of a variety of endangered species (Huntsinger and Oviedo, 2014). An important goal for the Coalition is to inform the public, environmental consultants, managers, and agencies that ranching is not only a preferred land use compared to development, but also is an essential resource management tool and can be used to benefit wildlife. They produced the unprecedented "Rangeland Resolution" signed by over 100 agricultural organizations,

environmental groups, and state and federal agencies. New signatories continue to sign on. The signatories have pledged to work together to preserve and enhance California's rangeland for species of special concern, while supporting the long-term viability of the ranching industry.

The CRCC is closely linked to and had a role in creating an innovative land trust, the California Rangeland Trust, run by ranchers themselves (<http://www.rangelandtrust.org/>). They partner with ranchers willing to establish a conservation easement. The group worked with an NGO to create an innovative, collaborative map of what they believe are the most important targets for establishing conservation easements within their scope of coverage in California (Huntsinger *et al.*, 2013). To help preserve access to rangelands, the CRCC also promotes and supports research on the environmental benefits of grazing, and holds workshops and an annual summit each year.

VI – Conclusions

Rangeland stewardship calls for adaptive governance at diverse environmental and ecological scales. While top down governance and development programs have only had limited success, there is evidence that in the complex rangeland context, bottom up processes characterised by collaboration and communication with other stakeholders and NGOs have been more effective and innovative in finding ways to adapt pastoralism to a changing context.

Pastoralists are united in their need for extensive rangeland that is often threatened by land conversion and alternate uses, in their ability to cope forage production that is highly variable in space and time, and in the importance of access to markets and supplementary income and feed sources. Yet each ranching household has a unique configuration of available resources and constraints, depending on the types of land they have access to and who owns it, the amount of family labor available, the condition of the resources they use, their sources of outside income and capital, their relations and shared culture with other pastoralists, and so forth. Given this complexity, innovative institutional arrangements that facilitate new forms of mobility, help to retain rangeland, and connect pastoralists to larger scale processes are needed. In our grassroots examples, NGOs played important roles in facilitating rancher organization and acquisition of resources, and helping them communicate with the public and government. U.S. advisory and outreach organizations, such as University Agricultural Extension services and the Natural Resources Conservation Service, also helped groups to communicate with scientists, the public, and government representatives, and to learn the scientific reasons behind desired practices. In both cases, the groups wound up supporting research to share the impacts of their good stewardship, and to learn how to improve stewardship. By working together as a group, ranchers developed negotiating power with the government regulators and agencies that influence their range use, and benefited such agencies by providing a conduit to communication with large numbers of ranchers.

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Expert views about farming practices delivering carbon sequestration in Mediterranean agro-ecosystems

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Abstract. Changing the farm management towards the delivery of ecosystem services (ES) can be promoted by the establishment of Payments for Ecosystem Services (PES). Designing a PES system requires measuring the biophysical effects of farming practices on the ES at farm scale. However, standardized methodologies that allow comparing results across spatial and temporal scales do not exist. The objective of this study was to estimate the contribution of several farming practices to ES delivery, specifically carbon sequestration, according to expert knowledge. We used a survey-based Delphi method to analyze the opinions of researchers, technicians/managers and Non-Governmental Organizations representatives, about the farming practices observed in representative sheep and mixed sheep-crops farms in Aragón, Spain. We asked experts to rate, along a six-point Likert scale, the positive contribution of these practices to carbon sequestration. The results showed that the farming practices with the highest potential to deliver carbon sequestration according to the experts were: maintaining semi-natural vegetation; utilizing manure correctly; maintaining grasslands; preserving hedges, shrubs and trees among arable fields; reducing ploughing/tilling; and active management of forest (forestry/silviculture). These results together with the consideration of other important ES will allow designing a generic PES system based on objective indicators that can be applied in the field.

Keywords. Farm management – Mixed farming – Sheep – Environment – Delphi method.

Opinion d'experts sur la contribution des pratiques agricoles à la séquestration du carbone dans les agro-écosystèmes méditerranéens

Résumé. Un changement de la gestion des systèmes d'exploitation vers l'approvisionnement de services écosystémiques (SE) peut être favorisé par la mise en place de paiements pour services écosystémiques (PSE). Concevoir un système PSE nécessite de mesurer les effets biophysiques des pratiques agricoles sur les SE à l'échelle de l'exploitation. Cependant, des méthodes standardisées qui permettent de comparer les résultats à diverses échelles spatiales et temporelles n'existent pas. L'objectif de l'étude était d'estimer la contribution de plusieurs pratiques agricoles à l'approvisionnement des SE, la séquestration du carbone précisément, selon les connaissances d'experts. Nous avons utilisé une méthode Delphi basée sur une enquête pour analyser les opinions des chercheurs, des techniciens / gestionnaires et des représentants des Organisations Non Gouvernementales avec de larges connaissances et expériences, sur les pratiques agricoles observées dans les systèmes mixtes ovins-cultures caractéristiques en Aragon, Espagne. Nous avons demandé à des experts d'évaluer, sur une échelle de type Likert à six points, la contribution positive de ces pratiques à la séquestration du carbone. Les résultats ont montré que les pratiques des exploitations permettant le plus grand potentiel de séquestration du carbone sont, selon les experts: le maintien de la végétation semi-naturelle; l'utilisation correcte du fumier; le maintien des prairies; la préservation des haies, des arbres et des arbustes au milieu des champs cultivables; la réduction du labour; et la gestion active de la forêt (foresterie / sylviculture). Ces résultats, conjointement avec d'autres SE importants, permettent la conception d'un système de PSE générique basé sur des indicateurs objectifs qui peuvent être appliqués sur le terrain.

Mots-clés. Gestion exploitation – Systèmes mixtes – Ovin – Environnement – Méthode Delphi.

I – Introduction

The future of animal farming is controversial due to its contribution to climate change through the greenhouse gas emissions from livestock (Steinfeld *et al.*, 2006). Many studies report that emissions per kg of product (milk or meat) decrease with the intensification of production. However, pasture based livestock systems perform other nonmarket functions (positive externalities), such as rural development and important ecosystem services (ES) such as the maintenance of agricultural landscapes or the conservation of biodiversity (Rodríguez-Ortega *et al.*, 2014). When we consider these other functions, emissions per kg increase with intensification (Ripoll-Bosch *et al.*, 2013).

In this context, apart from mitigation strategies, we need to design sustainable alternatives promoting the sequestration and storage of carbon in agro-ecosystems in the long term. Soil carbon sequestration has the highest mitigation potential in the agricultural sector (Soussana *et al.*, 2010). Promoting farm management towards higher carbon sequestration and delivery of other ES can be achieved with a Payment for Ecosystem Services (PES) system. Designing an effective PES system at farm scale requires rewarding the positive effect of farming practices on the targeted ES. Carbon sequestration is usually analyzed at the field/patch scale and direct relationships with livestock practices are difficult to establish (see Rodríguez-Ortega *et al.* (2014) for a review). Similarly, standardized methodologies that allow comparing results across spatial and temporal scales do not exist.

The objective of this study was to evaluate, according to expert knowledge, the contribution of farming practices to carbon sequestration in Mediterranean agro-ecosystems.

II – Material and methods

We carried out an expert consultation with an on-line Delphi panel, valuing the contribution of several farming practices on carbon sequestration for climate change regulation (the contribution was also analyzed for other important ES not presented here). The Delphi method allows many ‘informed’ individuals in different disciplines or specialties to contribute, with information or judgments, to understand a problem area that is much broader in scope than the knowledge that any one of the individuals possesses (Curtis, 2004).

The experts were chosen covering different types of knowledge and backgrounds: (1) researchers on agriculture-environment relationships ($n = 28$) and (2) technicians/managers from the government and Non-Governmental Organizations related to agriculture and environmental conservation, as well as professionals/practitioners of agricultural associations, local agribusiness and cooperatives in the area of study ($n = 28$). The minimum number of experts by category was fulfilled (Okoli and Pawlowski, 2004). From the 66 farming practices with potential to deliver public goods in Europe (Cooper *et al.*, 2009), we selected 26 that can influence carbon sequestration. These practices were adapted to 10 monitored sheep and mixed sheep-crops farms in Mediterranean mountains and semiarid lowlands in Aragón. The Delphi questionnaire had three parts. First, we included a brief illustrated description of the Mediterranean agro-ecosystems under study. Second, we collected some personal data and asked all experts to make a self-appraisal on their knowledge about each ES (carbon sequestration and others). In the third part, respondents had to rate the (positive) contribution of each farming practice to carbon sequestration (and other ES) according to a six-point Likert type scale (0: none, 1: very low, 2: low, 3: intermediate, 4: high, 5: very high contribution). We also included the “don’t know” option. The contribution of each farming practice on carbon sequestration was represented as a percentage of the total contribution of all farming practices to this ES. We plotted results with and without correcting for self-appraisal (0.2: very low, 0.4: low, 0.6: intermediate, 0.8: high and 1: very high knowledge). Differences between the two categories of experts (researchers vs. technician/managers) were analyzed with a Kruskal-Wallis test. Only the first round of the Delphi method is analyzed here.

III – Results and discussion

1. Contribution of farming practices to carbon sequestration

According to the assessment of the respondents on their own knowledge, the ES carbon sequestration was the least well known among those included in the study. Figure 1 shows the preliminary results (first round) of the Delphi questionnaire ranking the farming practices that contribute to carbon sequestration, with and without self-appraisal.

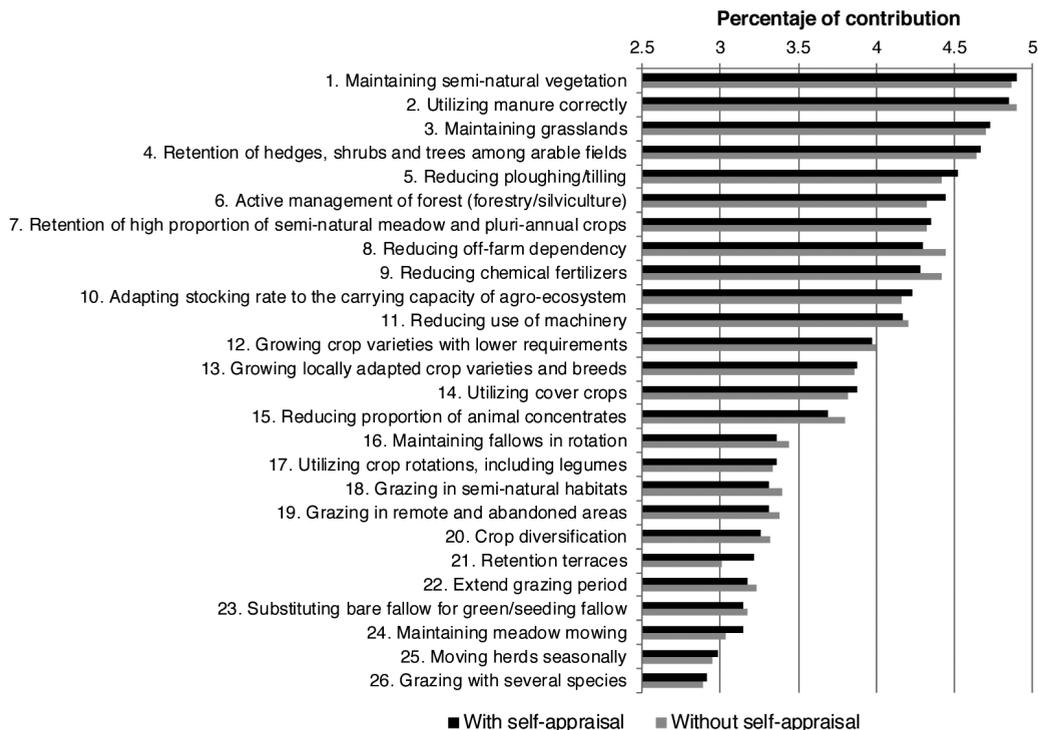


Fig. 1. Contribution of agricultural practices on carbon sequestration.

According to the experts, the farming practices related to management of vegetation and soils were the most important in carbon sequestration. In terms of vegetation, the maintenance of the *semi-natural vegetation* (shrubs and trees) and the *grasslands* had the highest potential of carbon sequestration. According to the bibliography, converting grasslands to forest can lead to an accumulation or to a release of soil carbon depending on the environmental conditions; however, both forest and grasslands accumulate more carbon in soils than arable lands (Soussana *et al.*, 2004). Experts also scored as high contribution the *retention of hedges, shrubs and trees among arable fields*. In terms of soils, the *correct use of manure* was the second practice in importance. Farm manure constitutes a large source of organic carbon. Spreading manure, especially when it is composted, contributes to maintain or increase the soil carbon stock, to a greater extent in grasslands than in arable lands (Soussana *et al.*, 2004). *Reducing ploughing/tilling* was also an important management practice to reduce carbon losses and increase sequestration (Aguilera *et al.*, 2013). Tillage

reduces the physical protection of the organic matter, reducing the humified soil organic matter fraction (Post and Kwon, 2000) and increasing the turnover of aggregates that accelerates the decomposition of soil organic matter within aggregates (Paustian *et al.*, 2000).

2. Differences between expert categories

Both expert categories (researchers and technician/managers) valued equally the contribution of the farming practices to carbon sequestration, except for two of them (Fig. 2): *growing crop varieties with lower requirements* ($p = 0.0182$) and *growing locally adapted crop varieties and breeds* ($p = 0.0280$); for which technician/managers estimated a higher contribution. This difference may disappear in the second round in which valuations are expected to converge.

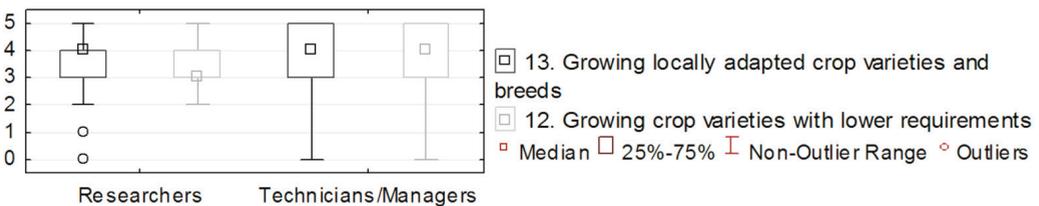


Fig. 2. Box-plot of the contribution of two agricultural practices to carbon sequestration according to the opinions of researchers and technicians/managers.

IV – Conclusions

The carbon sequestration service was less known than other ES provided by Mediterranean agro-ecosystems. Experts rated the highest those farming practices related to management of vegetation (semi-natural vegetation; grasslands; hedges, shrubs and trees among arable fields) and soils (manuring; ploughing/tilling). The assessment of farming practices and carbon sequestration, integrated with other important ES, allows comparing their relative contribution, so we could reward different farming practices according to policy priorities.

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Firebreak maintenance with equines in Serra de Tramuntana mountains (Mallorca, UNESCO world heritage)

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Abstract. Wildfires are a major problem in Mediterranean mountain areas due to dry and hot summer conditions that usually last for 1 to 4 months/year. Moreover, in the last decades, traditional pasture activities have been abandoned or reduced to a great extent as a consequence of socioeconomic changes underwent in many Mediterranean countries, what led to an increase of herbaceous and shrubby flammable material. At the same time, mountain areas are a point of interest for tourism and recreational activities, that has increased the number of visitors and thus, the wildfire risk. Wildfire prevention is therefore a major concern of the environmental services of those countries. Firebreaks are one of the most effective ways of reducing wildfires severity and spread. However, their maintenance with conventional methods is difficult, expensive and time consuming, especially in sloping and rocky areas. The objective of this work was to assess the effectivity of using herds of mixed equine species at high stock rates to maintain firebreaks in the Tramuntana Mountains (Mallorca Island, West Mediterranean Basin). Vegetation consumption by a herd of equine species (horses, mules and donkeys) was determined in a Mountain area dominated by *Ampelodesmos mauritanica*, *Calicotome spinosa* and *Pistacia lentiscus*. The results show that equines consume most biomass of the dominant species *A. mauritanica*, reducing flammable material to a great extent at the same time. In addition, they also consume tender leaves and the bark of *C. spinosa*. *Pistacia lentiscus* underwent low consumption rates. As a conclusion, equines appeared to be highly effective in firebreaks maintenance, especially in sloping and difficult access areas.

Keywords. Wildfire prevention – Equine – Mediterranean mountains – *Ampelodesmos mauritanica*.

L'entretien du pare-feu par les équidés dans les montagnes de Serra de Tramuntana (Majorque, patrimoine mondial d'UNESCO)

Résumé. Dans les régions Méditerranéennes montagneuses, les feux des forêts constituent un fléau majeur en raison d'étés secs et chauds, s'étalant habituellement de 1 à 4 mois. En outre, au cours de ces dernières décennies les activités de pâturage traditionnel ont été abandonnées ou bien réduites dans une large mesure suite aux changements socio-économiques subis dans de nombreux pays méditerranéens, induisant par conséquence une augmentation des matériaux herbacés et arbustifs inflammables. De plus, les montagnes présentent un point d'intérêt majeur pour le tourisme et les activités récréatives, ce qui a augmenté le nombre de visiteurs et par le même temps le risque d'incendies forestiers. Par ailleurs, la prévention des incendies est devenue une préoccupation majeure des services de l'environnement de ces pays. Pour réduire la vitesse de propagation et la gravité des incendies de forêt, des pare-feux ont été considéré comme l'un des moyens efficace pour faire face à ce fléau. Cependant, l'entretien de ces derniers avec les méthodes classiques est difficile, long et coûteux, en particulier dans les zones rocheuses avec de fortes pentes. L'objectif de ce travail est d'évaluer l'effectivité de troupeaux mixtes d'espèces équines de forte densité à fin de maintenir les pare-feux dans la « Tramuntana » (Majorque, Ouest du bassin méditerranéen). La consommation de la végétation par un troupeau d'équidés (chevaux, mulets et ânes) a été suivie dans une zone de montagne qui est dominée par *Ampelodesmos mauritanica*, *Calicotome spinosa* et *C. lentisque*. Les résultats obtenus montrent que les équidés consomment une grande partie de la biomasse de *A. mauritanica*, l'espèce dominante, ce qui réduit les matériaux inflammables de façon importante. En outre, ils consomment aussi des feuilles tendres et l'écorce de *C. spinosa*. Par contre, *C. lentisque* a subi un faible taux de consommation. En conclusion, les équidés semblent être très efficaces dans la zone d'entretien de pare-feu, en particulier dans les zones en pente et d'accès difficile.

Mots-clés. Prévention des incendies – Equine – Montagnes méditerranéennes – *Ampelodesmos mauritanica*.

I – Introduction

In Mediterranean mountain areas, wildfires are a major problem due to dry and hot summers. Moreover, in the last decades, traditional pasture activities have been abandoned or reduced to a great extent as a consequence of socioeconomic changes underwent in many Mediterranean countries, what led to an increase of herbaceous and shrubby flammable material. At the same time, Mountains are a growing point of interest for tourism and recreational activities, resulting in an increased number of visitors and thus, wildfire risk. In such a situation, wildfire prevention is a major concern of the environmental services of those countries. Firebreaks are one of the most effective ways of reducing wildfires severity and spread. However, their maintenance with conventional methods is difficult, expensive and time consuming, especially in sloping and rocky areas. The objective of this work was to assess the effectivity of using herds of mixed equine species at high stock density to maintain firebreaks in the Tramuntana Mountains (UNESCO World Heritage) in Mallorca Island (West Mediterranean Basin).

II – Material and Methods

The study was carried out in Galatzó area (39.6N, 2.5E), located at the Southwest edge of the Serra de Tramuntana (Mallorca, Spain) from 2014 to 2015. The climate during the experimental period was typically Mediterranean, with an annual precipitation of 355 mm and 566 mm in 2014 and 2015, respectively. Mean temperature was 16.7°C and 16.4°C in 2014 and 2015, respectively. Drought period lasted from June to August in 2014 and from April to July in 2015.

Firebreak maintenance was carried out by keeping a relatively large number of animals in small (2000 m²) stockyards during a limited number of days. Herd composition and the number of days that the animals were kept in the stockyard was fixed according to common practices and depended on the season and animal availability (Table 1). The instantaneous stock density was calculated as heads/ha.

Table 1. Biomass consumption (kg dry matter m⁻²) and stockyard traits: season, length of animals stay at the stockyard (days), number and type of animals, instantaneous stock density (n° of animals ha⁻¹). Values are means[†] ± standard error. Different letters denote Duncan's significant differences (p<0.05)

Season	N° of days	N° of mules	N° of horses	N° of donkeys	Stock density	Biomass consumption
Spring	5.1 ± 0.63ab	2.0 ± 0.00b	5.0 ± 0.00b	35.2 ± 1.27b	213.3 ± 6.87b	0.52 ± 0.055a
Summer	3.5 ± 0.96a	1.7 ± 0.21b	3.3 ± 1.05b	35.3 ± 2.95b	201.7 ± 21.08b	0.44 ± 0.135a
Autumn	6.8 ± 0.48b	1.0 ± 0.00a	0.0 ± 0.00a	26.0 ± 0.00a	135.0 ± 0.00a	0.51 ± 0.079a
Winter	5.5 ± 0.50ab	1.0 ± 0.00a	0.0 ± 0.00a	26.0 ± 0.00a	135.0 ± 0.00a	0.33 ± 0.055a

[†] Number of stockyards (replicates) per season were: 9 in spring, 6 in summer, 4 in autumn and 2 in winter.

Biomass consumption in each stockyard was estimated by measuring fresh biomass before animal entrance and after animal leaving in 4 plots of each 4 m². Dry biomass was calculated by determining water content (oven drying during 72 h at 70°C) of a fresh biomass subsample of each stockyard. Remaining biomass after grazing in each stockyard was negligible and it was not measured.

Botanic composition was determined along 20m x 1m transects in 8 stockyards before animal entrance and after animal leaving.

Statistical analyses were performed by using SPSS 19.0 statistical package (IBM, Chicago, IL, USA).

III – Results and discussion

Between 135 and 213 animals were kept in the stockyards, with stock densities significantly lower in winter and autumn than in spring and summer; grazing period ranged between 3 and 8 days (Table 1). As a result, annual stocking densities were between 1.8 and 3.7 heads ha⁻¹year⁻¹ (data not shown). Such annual stock densities can be considered high for Mediterranean shrublands (Bianchetto *et al.*, 2015). However, this kind of management of the herd and the stockyards allowed high biomass consumption within a short period of time, maximising firebreak maintenance. In that sense, biomass consumption ranged from 0.16 to 1.12 kg of dry matter m⁻², and it was neither correlated to stock density nor to the period animals stayed in the stockyard ($p > 0.05$ in both cases). Moreover, there were no significant differences in biomass consumption among seasons ($p > 0.05$, Table 1). Summing up, those results suggest that the maintenance procedure was efficient enough to ensure high consumption rates of biomass regardless animal availability and season.

Amelodesmos mauritanica was the most consumed species. The soil covered by that species decreased significantly from 55% before animal entrance to 13% after animal leaving the stockyard. In a similar way, non-vegetated areas increased significantly from 28% to 76% before and after foraging, respectively (Fig. 1). Other species which were significantly reduced by grazing were *Pistacia lentiscus* and *Chamaerops humilis*. On the contrary, *Calicotome spinosa*, *Juniperus oxycedrus* and *Hypericum balearicum* (an endemic species) were not significantly reduced by animal consumption (Fig. 1).

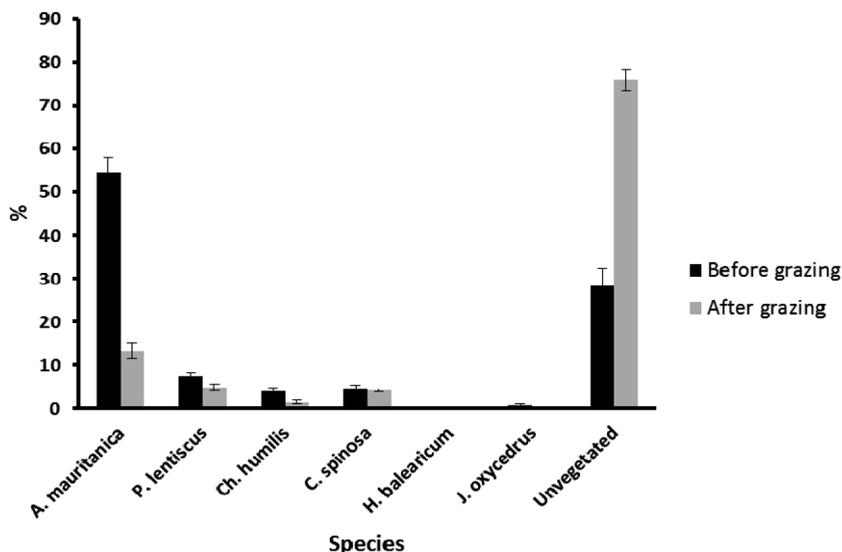


Fig. 1. Botanical composition of biomass before and after grazing (% of soil cover).

* Denotes significant differences ($p < 0.05$) within species.

IV – Conclusions

Equine grazing at high stocking densities for short periods appeared to be an efficient method in firebreak maintenance in Mediterranean rangelands dominated by *Amelodesmos mauritanica* since biomass consumption was high and the proportion of this species was significantly reduced. Future works should evaluate how long and how often those firebreaks need to be grazed in or-

der to assess economic viability of such practice. The analysis of plant biodiversity before and after grazing, as well as the animal health and welfare, would be also major objectives in the long term of the study.

Acknowledgments

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Animal welfare and ecosystem services in mountain areas

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Abstract. The ecosystem services framework describes the benefits that natural environments provide to human populations. Mountain ecosystems are extremely diverse and in fact support about one quarter of terrestrial biodiversity. The provision of ecosystem services in mountain areas depends upon good animal welfare and *vice versa*. Thus, proper assessment methods are needed to measure and ensure good welfare levels in mountain areas. In this study, we have tested five animal-based measures collected in eight mountain dairy farms and compared them to data collected in 124 small-scale dairy farms. Despite obtaining better mean results when looking at selected animal-based indicators in comparison to reference data, great variability was observed between farms similarly to what reported in other studies. Future research should aim at creating a reference database of animal-based measure collected in mountain farms only as well as measuring dairy cow welfare on pasture conditions considering that is a common practice in mountain dairy farms and often involves an abrupt change in husbandry and management systems.

Keywords. Ecosystem services – Dairy cows welfare – Small scale farms – Animal-based measures.

Les services écosystémiques et le bien-être des animaux dans les zones de montagne

Résumé. Le cadre des services écosystémiques décrit les avantages que les environnements naturels fournissent aux populations humaines. Les écosystèmes de montagne sont extrêmement diversifiés et en fait soutiennent environ un quart de la biodiversité terrestre. La fourniture de services écosystémiques dans les zones de montagne dépend du bien-être animal et *vice versa*. Ainsi, des méthodes d'évaluation appropriées sont nécessaires pour mesurer et assurer un bon niveau de protection des animaux dans les zones de montagne. Dans cette étude, nous avons testé cinq mesures recueillies dans huit fermes laitières de montagne et comparés aux données recueillies dans 124 petites exploitations laitières. Malgré l'obtention de meilleurs résultats moyens lorsque l'on regarde les indicateurs basés sur des animaux sélectionnés par rapport aux données de référence, une grande variabilité a été observée entre les exploitations agricoles de façon similaire à ce que rapporté dans d'autres études. Les recherches futures devraient viser à créer une base de données de mesure sur la base d'animaux recueillis dans les fermes de montagne seulement ainsi que la mesure de donné de la vache laitière et les conditions du pâturage considérant que c'est une pratique courante dans les fermes laitières de montagne et implique un changement brusque dans l'élevage et les systèmes de gestion.

Mots-clés. Services écosystémiques – Le bien-être des vaches laitières – Les petites fermes - Méthodes d'évaluation des animaux.

I – Introduction

The ecosystems services (ES) framework was first developed for the United Nations Millennium Development Assessment and was used to estimate the contribution of ecosystems to human well-being (MA, 2005). Mountain ecosystems occupies about one fifth of the terrestrial surface and because of the variety of habitats caused by a steep altitudinal and climatic gradient, they are considered more diverse than lowlands and in fact support about one quarter of terrestrial biodiversity.

The traditional breeding systems in the mountains are largely based on the use of meadows and pastures and deliver a variety of local products and ecosystem services, such as conservation of genetic resources, water flow regulation, pollination, climate regulation, landscape maintenance, recreation and ecotourism (Battaglini *et al.*, 2014).

At present, however, with the exception of some provisioning services (e.g. food), most of the ES are either undervalued or have no market value at all. Being able to measure and quantify in economic terms the value of ES would help inform policymakers and consumers about the real costs and benefits of what is produced and eventually support those systems that contribute the most to the maintenance and provision of ES.

Animal welfare (AW) is a major concern for many European citizens and thus high on the political agenda. However, animal welfare assessment is an ongoing challenge and several methods have been identified to assess it at herd level. The largest research project on animal welfare funded by the European Commission was the Welfare Quality® project (WQ, 2009) which combines animal-based, resource-based and management-based measures in order to determine an overall level of welfare. Few attempts (Comin *et al.*, 2011; Corazzin *et al.*, 2010; Mattiello *et al.*, 2005) have been made to measure welfare on mountain dairy farms and recently the European Food Safety Authority (EFSA) has published an adapted WQ protocol for small-scale dairy farms (EFSA, 2015).

The aim of this paper is to explore the relationship between AW and ES in mountain areas and present the preliminary results of welfare assessment in eight mountain dairy farms in the Province of Udine, Italy with the EFSA adapted protocol for small-scale farms.

II – Material and methods

Eight dairy farms were selected in the mountain areas of the Province of Udine and animal welfare was assessed during wintertime according to the EFSA adapted protocol for small-scale farms (EFSA, 2015). A selection of farm descriptors and animal-based measures describing the response of the animals to resources and management practices to which they were exposed to was used for the study. Five animal-based measures were chosen to describe three welfare principles defined in the Welfare Quality® protocol for dairy cattle (WQ, 2009):

- Body condition score (BCS) for the principle of Good Feeding. The animal were assessed from behind and from the side in the loin and tail head area.
- Lameness, lesions and swellings, high somatic cell count (SCC) for the principle of Good Health. Gait and integument alterations were assessed on the animal. SCC data was retrieved from milk records.
- Avoidance distance (AD) for the principle of Appropriate Behaviour. Good Human-animal relationship was measured by approaching the animals until they move back or the muzzle can be touched.

III – Results and discussion

1. Ecosystem services and animal welfare frameworks in mountain areas

The relationships between ecosystem services and animal welfare were hypothesized following the scheme displayed in Figure 1 in order to understand the role of animal welfare in mountain ecosystems. Animals rely on provisioning and regulating services to achieve good welfare levels. At the same time good animal welfare seems pivotal to ensure provisioning services (e.g. safe food), regulating services (e.g. disease regulation) and cultural services (e.g. humane treatment of animals).

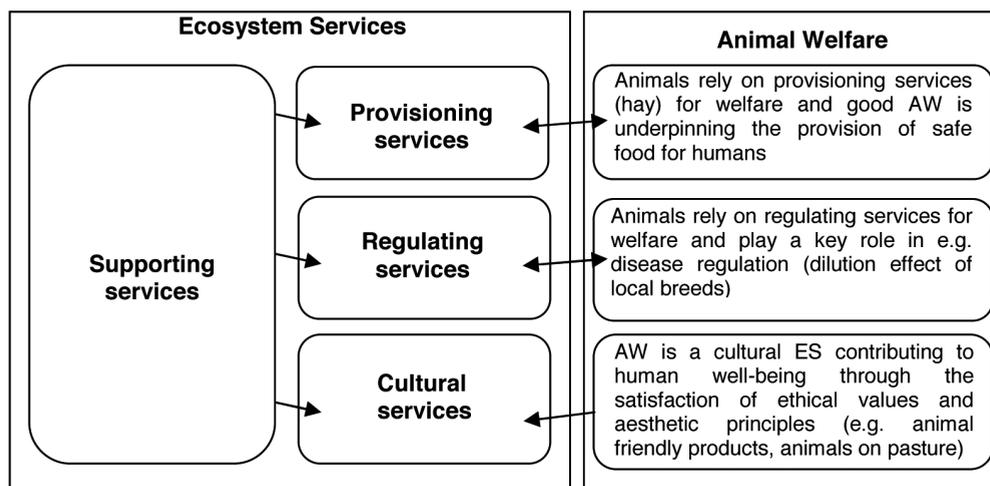


Fig. 1. Relationship and interdependences between the ecosystem services framework and animal welfare.

2. Dairy cow welfare assessment

Farm descriptors (Table 1) and animal-based measures (Table 2) collected on the eight farms considered in this study were compared against data collected on 124 small-scale farms (EFSA, 2015), which were considered as reference values.

Comparable values were obtained in the EFSA study and in our sample when looking at mean herd size (34 vs 24 respectively), mean milk yield (6125 vs 6006 respectively) and mean hours on pasture (2180 vs 2981 respectively).

Table 1. Farm descriptors collected in eight alpine dairy farms

Farm descriptors	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8
Dairy cows (n.)	21	16	15	10	26	20	34	47
Prevalent breed	Simmental	Simmental	Simmental	Alpine Gray	Simmental	Alpine Gray	Brown Swiss	Simmental
Milk yield (kg/cow/year)	7000	6000	4500	5400	5500	4850	7500	7300
Pasture (h/year)	360	3600	2896	2088	4320	4320	2808	3456
Housing (tie stall)	yes	no	yes	no	yes	yes	no	yes

Animal-based measures mean values obtained in our sample were better to those obtained in the EFSA study when looking at cows that could be touched (78 vs 62%), lame cows (8 vs 18%), cows with SCC higher than 400000 cells/ml (6 vs 13%), very lean cows (3 vs 8%), and cows with lesions or swellings (9 vs 16%).

Despite obtaining better mean results when looking at selected animal-based indicators, great variability was observed between farms similarly to what reported in other studies (EFSA, 2015; Fraser, 2014).

Table 2. Animal-based indicators collected in eight alpine dairy farms

Farm descriptors	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8
ADF (%)	86	63	87	60	96	86	50	92
Lameness (%)	9,5	25	0	10	11	0	10	2
SCC >400.000 (% of cows/farm)	9.5	12.5	0	0	3.8	5.0	11.8	6.4
BCS (%)	0	0	13	0	0	5	7	0
Lesions, Swellings (% of cows/farm)	14	25	7	10	8	0	7	2

ADF: avoidance distance test (% animals that can be touched); SCC: somatic cell count; BCS: body condition score (% of very lean animals).

IV – Conclusions

The provision of ecosystem services in mountain areas depends upon good animal welfare and *vice versa*. Thus, proper assessment methods are needed to measure and ensure good welfare levels in mountain areas. In this study, preliminary results on five animal-based measures collected in eight mountain dairy farms were presented and compared against data collected in 124 small-scale dairy farms.

Ongoing research is measuring dairy cow welfare on pasture conditions considering that is a common practice in mountain dairy farms and often involves an abrupt change in husbandry system and management practices. Future research should aim at identifying acceptable levels of welfare that will ensure the provision of ecosystem services in mountain areas.

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Balancing on the transhumant road: an updated political ecology of livestock driveways

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Abstract. The *cañada* or *vía pecuaria* is a trail or pathway that links highland and lowland Spanish livestock grazing regions, in the traditional practice of transhumance. This makes the stock driveway at once a path, a custom and ritual, a common-property resource, an economic undertaking, a historical fact, an ecosystem service, and an ongoing political controversy. Animals grazed over long distances can be sheep, cattle, goats, horses, or, historically, even swine; beyond Europe and North America, other animals are involved. In Spain, transhumant routes total 125,000 km extending from Andalusia and Extremadura to Castile and León, Galicia, and the Pyrenees, and traverse over 1% of the Spanish national territory. The use of *vías pecuarias* dates back at least to Roman times, if not to the Neolithic, preceding establishment of El Honrado Concejo de la Mesta de Pastores, a livestock association whose special privileges were decreed in 1273 by Alfonso the Wise. Stock driveways are by no means unique to the Iberian Peninsula, nor, obviously, is the practice of transhumance. There are more than 4 million hectares (10 million acres) of land across Europe associated with stock trails and driveways. In the United States, these also exist as an item of Spanish-Mexican heritage. Although regulations supposedly protect designated stock trails, the legal regime and enforcement varies widely. Across Europe some trails have been paved; others became home to squatters who expropriated land increasingly recognized in the law as common property resource. The legal and practical implications are serious, in this assault on common property resources — features owned not privately, but instead set aside for various forms of sharing. Implications for conservation biology corridors are no less significant. This discussion examines twenty-first century evolutions in the political ecology of “sharing economy” embodied in the livestock driveway.

Keywords. Transhumance – *Vía pecuaria* – Stock driveway – Political ecology – Common property resource.

État des lieux des routes de transhumance : une écologie politique actualisée des chemins parcourus par le bétail

Résumé. La *cañada* ou *vía pecuaria* est un chemin ou sentier qui relie les régions de pâturage de montagne et de plaine en Espagne, dans la pratique traditionnelle de la transhumance. Ceci fait que la voie qu'emprunte le bétail soit à la fois chemin, coutume et rituel, ressource de propriété commune, entreprise économique, fait historique, service de l'écosystème, et controverse politique en cours. Les animaux pâturant sur de longues distances peuvent être des ovins, bovins, caprins, chevaux, voire historiquement porcins ; au-delà de l'Europe et de l'Amérique du Nord, d'autres animaux sont aussi concernés. En Espagne, les chemins de transhumance totalisent 125 000 km, depuis l'Andalousie et l'Estrémadure jusqu'à Castille et León, la Galice, et les Pyrénées, et traversent plus de 1% du territoire national espagnol. L'usage de chemins de transhumance remonte au moins aux temps des Romains, si ce n'est au Néolithique, avant l'instauration de El Honrado Concejo de la Mesta de Pastores, une association de bergers dont les privilèges spéciaux furent décrétés en 1273 par Alfonso le Sage. Les chemins de transhumance ne sont nullement uniques à la Péninsule Ibérique, ni évidemment la pratique de la transhumance. Il y a plus de 4 millions d'hectares (10 millions d'acres) de terres en Europe concernées par les routes et chemins de transhumance. Aux États-Unis, ils existent aussi comme héritage mexico-espagnol. Bien que les réglementations soient censées protéger les chemins de transhumance reconnus, le régime juridique et exécutoire varie largement. En Europe certains de ces chemins ont été pavés ; d'autres ont été pris par des occupants qui ont exproprié des terres de plus en plus reconnues par la loi comme ressources de propriété commune. Les implications légales et pratiques sont sérieuses pour ces attaques aux ressources de propriété commune ressources non possédées.

dées de façon privée, mais réservées à plusieurs formes de partage. Les implications pour les couloirs biologiques de conservation ne sont pas moins significatives. Cette discussion examine les évolutions au XXI^e siècle de l'écologie politique de l' "économie du partage" incarnée par les chemins de transhumance.

Mots-clés. Transhumance – *Vía pecuaria* – Chemins de transhumance – Écologie politique – Ressource de propriété commune.

I – Introduction

The term “byway” in American or British English speaks to something set aside from the transportation mainstream; conventionally the term is contrasted with “highway,” which would serve as a main road or transit route. But a second definition of byway is as a little-known area of knowledge, something other than an immediately obvious feature or subject of conversation. Both are apropos, here. While the doctrine of efficiency seems often to govern discussions at the planning and policy level for the European Union and other developed countries, which seek to hasten movement and increase a perceived productivity, traditional systems of production often include time-tested practices that cost little, sustain cultures, decrease risk, and provide benefits in ecosystem services and other less recognized efficiencies. Taking the other road –the byway– may offer significant benefits and a utility that may be equally difficult for either postmodernists or neoliberals to acknowledge. The livestock trail, copiously documented in Spanish life, but less so outside the anthropological literature in other countries, is a notable example of a linear feature of great reach but relatively non-intensive use that provides crucial connections among distinct places.

This study looks at the identification, and, indeed, the identity, of byways in a landscape as features that merit recognition as far more than an afterthought. A complex political ecology governs the byways of the world that provide transit routes for livestock – and not incidentally, offer travel paths for mobile wildlife, the distribution of goods and services, and ambulatory human and other voyagers who prefer to follow less travelled routes. While created by customary practice and on occasion maintained by express legal statute, stock driveways are a form of land use that is crucial at certain times to owners of livestock and the tenders of those animals, whether they are herders or shepherds or swineherds or cowhands. Because livestock trailing routes are often long and move between regions of upper and lower elevation, they forge a special relationship between road and landscape, something long understood by practitioners on the road, but less so by theorists concerned with the identity of landscape (Moore, 2015).

While transhumance is a lively topic, generally well-studied in present-day Spain, it is less widely embraced as a theme of moment in other European countries where transhumance is generally considered a topic of relict anthropological interest. And rarely are drove roads or livestock trails considered as topics significant unto themselves – they are instead seen as the means to an end: seeking forage at the terminus of a journey. But just as ecologists in the 1980s launched intensive studies of habitat corridors as factors in conservation biology, so too are the corridors used to trail domesticated animals (and not incidentally, acting as wildlife transit routes) of significance.

Because Mediterranean-type ecosystems, with their cycle of wet season broken by nearly no summer precipitation, pose a particularly difficult requirement on livestock owners who must locate suitably lush forage during those summer-dry months, in particular because that is typically when an animal's young offspring are growing fastest and are beginning to find forage on their own instead of relying on nursing. Those are times when the byway is especially important and used, yet there are other uses for the common property resource trail, especially in the twenty-first-century, that merit examination and discussion.

The livestock trailing route is simultaneously a means to an end (forage in mountain or lowland environments) and an entity unto itself. A trail, like any road, has an independent reality, and forms

a distinctive space; typically, it is not privately owned, but instead a community or a government-controlled resource (Ingold, 2007). There is, in short, a clear political life to the livestock trail (Massey, 2013). Working from lessons gleaned in the historical circumstances and present-day realities in both Spain and the western United States, this study extracts larger principles and meaning from the livestock trail as a “byway” in European and North American life.

II – Materials and methods

Materials drawn on in this study include cartographic analysis of existing maps and aerial images; archival records; interviews; a sizable secondary literature including past conference reports and scholarly inquiries. Particularly important is photo-documentation and recording of past and existing routes to supplement the map-based resources. Cartographic research, undertaken as part of the Ley 3/95, has created a geographic information system database documenting the extent of all levels of livestock driveways in Spain. Livestock driveways or trails, known in Spain as *vías pecuarias*, occupy approximately one percent of the surface area of the country. An examination of controversies associated with lands formerly employed as livestock travel routes now no longer in use suggest that expropriation of land by individuals, corporate entities, and in some cases, cities and regional authorities is anything but rare, raising difficult issues in the geography of land use and legal authority, especially where remediation is unlikely.

Roads and trails are variously defined, which can only be dealt with in brief. A first part of this exercise delves into the literature, the oral history, and traditional local practice as described by residents and neighbors, to fill out the history of past use of the stock driveways in Spain. A second element sees the developing uses that exist now and in prospect for *vías pecuarias*, and documents those (Rodríguez Pascual and Maya Frades 2008). A third inquiry examines practical issues associated with the conservation and the protection, by regular use, of the trails. Finally, political issues associated with livestock trails are discussed as a novel frontier, one that is, as the geographer Timothy Ingold notes (2007), fundamentally linear rather than areal in extent, in much the same way that recognition of corridors altered the understanding of conservation biology in the 1980s.

III – Results and discussion

The important results of this project can only be described in this short paper by two images that capture the complexity of the rural byway, as a common property resource, being put to use (Figs 1 and 2). An extensive description of the project results are to be found in ongoing work that is forthcoming, and in the literature review that is available upon request.

IV – Conclusions

There are significant differences between nomadic and transhumant grazing. The livestock trail constitutes a route through political jurisdictions that necessarily goes along the edge of many properties and ownerships. This suggests a problem of moment in political ecology, which the geographer Peter Walker (2005) rightly identifies as a potentially sophisticated joining of biophysical ecology and social science realities. Mangas Navas (2004) goes to the heart of the matter in noting that livestock driveways employed in transhumance –or left in a relict state after the trailing of domesticated animal has ceased– “should be considered ecological corridors essential for migration, geographical distribution, and genetic exchange of wild species” (265). There are potential ties, for example, between the re-wilding movement that is active in Europe and the United States and these significant corridors (Oteros-Rozas *et al.*, 2012).



Fig. 1. Nearing Avila, Spain, this *vía pecuaria* is maintained by the movement of live-stock, but as seen above, also is useful for local residents out for their afternoon constitutional walk and exercise. The varied uses of such common property resources are nothing to be minimized. (Photograph by PF Starrs, 2016).



Fig. 2. At the largest and highest level of recognition as a *vía pecuaria* is the “Cañada Real Soriana Occidental,” established under the ancient rules of the Mesta (Photograph by PF Starrs, 2016).

One of Spain's most ardent defenders of the dehesa and the *via pecuaria*, Jesús Garzón Heydt (2001), brings a potent background in government service, ecological training, and pro-transhumance activism to his ground-breaking work on transhumance. A field ecologist by training, he notes a variety of deleterious effects associated with a cessation of transhumance by trail, a process that began with the arrival of movement of livestock by rail and later truck in the late nineteenth century. These ill-effects include overgrazing, since, when no alternate seasonal pastures are available local sites are grazed harder; the destruction of holm oak regeneration by longer grazing seasons; the pollution of water sources from livestock crowded in a smaller space; the destruction of shelter and food resources for wildlife; and disturbance of reproduction cycles for sensitive species.

A corruption of local community values, an endangerment of once-traditional products and practices; a loss of culture and history, might be added to the roster of undesirable results. As Garzón writes (2004, p. 263): "With the last transhumant shepherds much will be lost e.g. a wealth of knowledge, gastronomy, artisanal technology, vocabulary, songs, music, dressing traditions, and vernacular architecture, diversity of local plant varieties and hardy breeds. One of Europe's ancient and most interesting cultures will therefore be lost, unless something is done urgently to prevent it".

And that would be a loss for all – mountain peoples, lowland peoples, livestock, and the cultural patrimony.

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⇒ Eighty additional references and further sources are available upon request: stars@unr.edu ⇐

Transhumant GPS tracked sheep flocks from lowlands to highlands in Spain: grazing resources use and difficulties of walking/herding

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Abstract. The need for preserving walking/herding transhumance drove roads on the Iberian Peninsula has been widely recognized, as they provide a wide range of ecosystem services. In spite of the decline of walking transhumance in Spain, some drove roads are being reactivated due mainly to the high price of lorry transport and feeds for livestock. The objectives of this work were: (i) develop a method to track the transhumant flocks in order to know the route followed and detail the type of pastures that the sheep use during the trip; (ii) know the main difficulties of the activity, either technical, economic or social. Collars with GPS were installed around the neck of some animals of five transhumant flocks. The data provided by GPS were analyzed by a GIS and overlapped with pastures/vegetation maps. For each flock, interviews with the farmers provided data in terms of difficulties for the activity to be continued. The method provided highly accurate data of the routes. The main types of vegetation used by sheep and main difficulties perceived by the farmers to continue the activity are summarized.

Keywords. Drove roads – “Cañadas” – GPS tracking – Vegetation use.

Suivi par GPS des troupeaux ovins transhumants du plain à la montagne en Espagne: utilisation des ressources fourragères et difficultés du déplacement à pied

Résumé. La nécessité de préserver les drailles ou chemins de la transhumance à pied dans la péninsule Ibérique est largement reconnue, parce qu'elle fournit une grande diversité des services des écosystèmes. Malgré la diminution de la transhumance à pied en Espagne, quelques chemins de la transhumance sont une nouvelle fois utilisés à cause, surtout, de l'augmentation des prix des inputs dans les exploitations, comme le coût des camions et de l'alimentation. Les objectifs du travail sont: (i) développer un système de suivi des troupeaux pour connaître l'itinéraire suivi et les types de végétation pâturée par les troupeaux pendant leur déplacement; (ii) connaître les principales difficultés du point de vue technique, économique et social de cette pratique. On a mis des colliers de repérage GPS dans le cou des plusieurs brebis dans chacun des cinq troupeaux transhumants étudiés. Les données fournies par le GPS ont été analysé à travers du SIG et ont été superposé avec des cartes de végétation. On a aussi réalisé des enquêtes aux éleveurs pour obtenir information sur les défis pour la continuité de la transhumance à pied. La méthode utilisée a fourni des données très précises des itinéraires suivis. Les principaux types de végétation pâturée par les troupeaux ainsi que les principales difficultés ont été résumé.

Mots-clés. Drailles – « Cañadas » – Suivi par GPS – Utilisation végétation.

I – Introduction

Transhumance is a livestock production system that avoids the critical periods of plant production by means of seasonal moving of livestock, and follows the same routes (drove roads or ‘cañadas’ in Spain, ‘cabañeras’ in Aragon) every year.

Many studies have highlighted the wide range of ecosystem services provided by the walking/herding transhumance, including ecological connectivity, seed dispersion, soil fertility, fire prevention, maintenance of cultural landscapes, biodiversity conservation, and traditional ecological knowledge (e.g., Gómez Sal and Lorente, 2004; Oteros-Rozas *et al.*, 2013; Ferrer, 2016). The abandonment of drove roads and winter and summer grasslands leads to an increasing of fire risk, biodiversity losses and landscape homogenization.

In Spain, sheep transhumance by walking/herding had high relevance until the nineteenth century and almost disappeared in the 1970s-1980s. At present, some of the main roads are being re-activated by foot transhumances, mainly because of the increase of input prices such as fuel for transportation in lorries, and price feeds.

Difficulties and conflicts of the walking transhumances have been identified in some drove roads, such as intrusions of crops, paved roads, residential areas, golf courses, dumping sites, etc. (Pallaruelo, 1993; Oteros-Rozas *et al.*, 2013).

The objectives of the present study were: i) develop a method to track the transhumant flocks in order to know the exact route followed and detail the type of pastures that the sheep use during the trip and ii) assess the main difficulties of the activity, either technical, economic or social.

II – Materials and methods

Five sheep transhumant flocks and routes were studied in the Iberian Peninsula, from the Ebro Basin to the Pyrenees (routes 1 to 4) and from the Iberian Range to the southwest *dehesas*. The characteristics of the routes and transhumant animals are summarized in Table 1.

Table 1. Characteristics of the routes and sheep transhumant flocks

	Route 1	Route 2	Route 3	Route 4	Route 5
Main breeds	Churra Tensina	Crosses x Rasa Aragonesa, Talaverana, etc.	Chisqueta	Rasa Aragonesa	Merina de los Montes Universales
Livestock Units	185	186	168	325	416
Origin – Destination	Huesca – San Juan de Plan	Lascasas – Canfranc	Loscorrales – Zuriza	Loscorrales – Astún	Vilches – Guadalaviar
Lengh (km)/days	126/15	97/6	109/7	80/6	343/22
Biogeographical region			Mediterranean – Alpine		Mediterranean

Collars with GPS were installed around the neck of two animals of each flock, programmed to get positional and temporal information every 30 seconds with an accuracy of 2-5 m. GPS data were analyzed by means of Quantum GIS software and overlapped on a pastures map previously generated by Barrantes *et al.*, (2005) for routes 1 to 4, and on a vegetation map “Mapa Forestal de España” (Ruiz, 1994) for route 5. Proportion of the four major types of pastures in each route and percentage of time spent on each type were calculated for the five routes. Differences between the routes in terms of distribution of the time spent on each type were assessed by means of Chi-Square Tests. Differences between the use of vegetation and proportion of the types were assessed by means of G-tests. Ivlev’s electivity index E_j (Jacobs, 1974) was calculated for the five herds in relation to the four major pastures types. $E_j = (r_i - p_j) / (r_i + p_j)$, where r_i = fraction of time spent in vegetation type and p_j = fraction of area covered by vegetation type. E_j takes values between 1 (highly preferred) and -1 (completely avoided). Pastoral Value (PV) of each pastures types was obtained mainly from Reiné *et al.*, 2004 and Maestro *et al.*, 2004, where published phytosociological inventories of each pasture type

were used and PV was calculated using the Daget & Poissonet (1972) method. PV has been used extensively as a pasture quality index to identify potential livestock stocking rates (Loiseau *et al.*, 1998). Kendall's coefficient of rank correlation was used to explore the relationship between PV weighted by proportion of each pasture type and percentage of time spent on each type.

Farmers were interviewed, addressing economic, social and animal production aspects and main difficulties of the activity, only the last results are presented in this work.

III – Results and discussion

The distribution of time spent by the flocks on each type of vegetation (in percentage) was different for every route (Chi-Square Test, $P < 0.05$) except for routes 2 and 5, which showed similar distributions of time ($P > 0.05$). In routes 1, 3 and 4, the flocks spent clearly more time on natural pastures (grazeable forests, shrublands, and natural grasslands) than on arable land and meadows (Fig. 1a). The use of the four types of vegetation deviated significantly from the expected use in terms of proportion of each type (Fig. 1a versus 1b), ($P < 0.001$ in all routes).

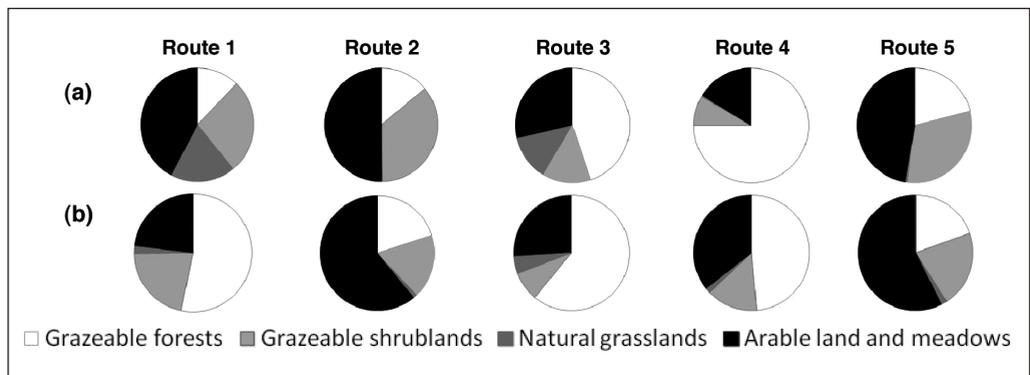


Fig. 1. (a) Percentage of time spent by five transhumant sheep flocks on different types of pastures. (b) Proportion of each type of pasture.

Flock of route 1 and 3 had preference by shrublands, natural grasslands, and crops and meadows, and avoided grazeable forests. Flock of route 2 preferred shrublands and avoided the rest of the types. Preferences of flock of route 4 were complementary to those of routes 1 and 3. Flock of route 5 preferred shrublands and avoided natural grasslands and crops (Fig. 2).

The percentage of time spent by the flocks on the types of vegetation was correlated with the Pastoral Value of the vegetation weighed by their availability ($t = 0.489$, $p < 0.001$). The value of t suggests that shepherders decisions about the timing of herding is driven also by factors other than quality of pastures like slope, availability of water, planned date of arriving at the destination, etc.

The farmer survey showed some difficulties of herding/walking transhumance that may hinder the continuity of the activity. The main difficulties were (percentage of farmers in brackets): **Physical/technical**: Interruptions of the drove roads (all farmers); shrub encroachment, poor state of conservation of the drove roads, narrowing of the drove roads (80%); tracks not sufficiently labelled (80%); lack of drinking troughs (all farmers). **Social**: lack of continuity linked to ageing of farmers and lack of an appropriate generational turnover (all farmers). **Economic**: no direct subsidies (all farmers). In terms of farmers' perception, animal welfare was not an issue of the walking/herding transhumance.

IV – Conclusions

Flocks used several natural and arable land resources along the routes. Most of the flocks studied spent more time on grazeable forests, shrublands and xerotropic natural grasslands than on arable land and meadows. There are relevant physical/technical, economic and social difficulties that may threaten the continuity of the activity. The method developed to track the flock was suitable for the objectives of the study, providing highly accurate data of the route.

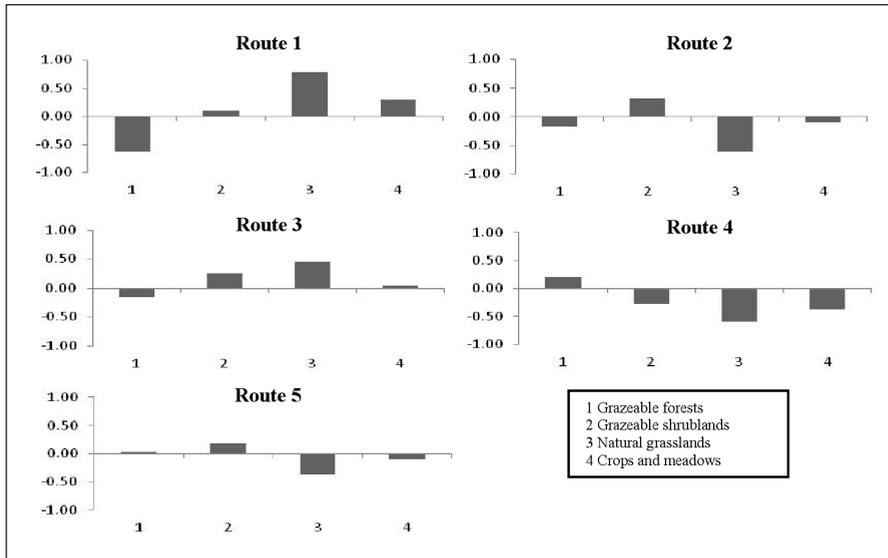


Fig. 2. Ivlev's electivity index for the five transhumant herds in relation to the four major vegetation types.

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Participatory research approach in mountain pasture management in Central Italy

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Abstract. Most mountain pastures in Italy are underutilized or even abandoned due to urbanization, low incomes, limited social opportunities for rural families. A three years research was done on the rehabilitation of some pastures in two farms of North-Western Tuscany, central Italy. During the first part of the trial some agronomic interventions were compared (new pasture fencing, potato cash crop sowing, sowing and oversowing a pasture mixture of grasses and legumes, chemical fertilization mainly nitrogen, planting scattered forage trees), at the end of the agronomic trial 20 more farmers of the area were invited to visit the trials and discuss the results in order to know the level of their appreciation of the interventions done and their further demands. The agronomic interventions more appreciated were the new fencing and shrubs clearing, and the one year cash crop. The farmers had less appreciation for fertilization and oversowing, and very little appreciation for the new planting of scattered forage trees. Under a general point of view however, social actions were demanded much more than agronomical. People asked better and faster links to the near towns, better possibilities to publicize and sell their produce straight to customers by internet, they asked the development of local small scale industries that can process milk for sale and to make cheese, less limitations in starting and managing agri-tourism activities.

Keywords. Pasture abandonment – Pasture rehabilitation – Rural people demands – Social and agronomic interventions – Integrated pastoral systems.

Approche participative dans la gestion des pâturages de montagne en Italie centrale

Résumé. De nombreuses pâturages de montagne en Italie sont sous-utilisés ou même abandonnés en raison de l'urbanisation, des faibles revenus et aussi du développement social fortement limité dans le milieu rural. Dans ce contexte, une recherche concernant la réhabilitation de certains pâturages a été menée chez deux fermes du nord-ouest de la Toscane. Au cours de la première phase expérimentale, certaines interventions agronomiques ont été réalisées (réalisation de clôtures des pâturages, plantation de pommes de terre, semis et sursemis d'un mélange de graminées et de légumineuses, fertilisation azotée, plantation d'arbres fourragers). Après la conclusion de l'essai, différents agriculteurs de la région ont été invités pour évaluer les résultats. Cela a permis de connaître le niveau d'appréciation sur les interventions effectuées et, en plus, leurs exigences supplémentaires. Les agriculteurs ont beaucoup apprécié le débroussaillage et les cultures de rente plutôt que la fertilisation, le sursemis et la plantation d'arbres fourragers. D'un point de vue général, les actions qui favorisent le développement social sont plus appréciées que les interventions agronomiques. Les agriculteurs ont demandé un lien plus efficace avec les villes, la possibilité de vendre leurs produits directement aux clients par internet, des industries locales à petite échelle pour la transformation du lait et moins de limitations dans la réalisation et la gestion de l'activité agro-touristique.

Mots-clés. Pâturages abandonnés – Amélioration des pâturages – Demandes des populations rurales – Interventions sociales et agronomiques – Systèmes pastoraux intégrés.

I – Introduction

Most mountain pastures in Europe and Italy are underutilized or even abandoned due to urbanization, low incomes, limited social opportunities (Skórka *et al.*, 2010). The most common causes are related to the difficult physical environment, characterized by very cold winters and hot summers,

steep slopes with enhanced soil erosion and shallow unfertile soils (Price *et al.*, 2015). All this has favored the move of rural families to towns. Marginal lands are now more useful for tourism than for agricultural production (Peeters, 2008), however pasture management supports tourist activities including visiting natural parks, summer trekking, winter skiing, overnights in agri-tourism farms, all this has brought farmers to develop a modern agriculture linked to services, starting Integrated Pastoral Systems (Pardini, 2005). In order to support these activities it is necessary to concentrate any management on the most suitable pastures and crops (Pardini *et al.*, 2008; Pardini and Nori, 2011).

A project run for three years was done in an area of Garfagnana (Apennines, in the North-Western Tuscany, central Italy) comparing agronomic practices (Natali *et al.*, 2005). At the end of the trial a group of farmers of the area visited the trials and discussed the results, and were interviewed to know their general opinions on interventions done and others possible, this article refers on these last part of the trial.

II – Materials and methods

At the beginning of an agronomic trial the following interventions were done in two farms: new fencing, shrubs clearing, sowing potato cash crops, sowing permanent pastures, sowing and oversowing, chemical fertilization, planting of scattered forage trees.

At the end of the agronomic trial that lasted three years, 20 farmers of the area were invited to visit the trials and to discuss the results, and encouraged to express their opinion on the real benefits of the interventions done or others possible. A total 22 farmers were interviewed (the two owners of the farms and other 20 visiting farm owners).

The interviewing had a Participatory Research Approach: a form was prepared with listed the interventions done, later other interventions suggested by local farmers were added with the percentage of people demanding them. The interviews concerned the following two aspects:

- efficacy of the agronomic interventions already done;
- demands of further interventions (further interventions asked directly by farmers).

Results were subjected to ANOVA performed by means of Sistas software, with interventions as fixed effect.

III – Results and discussion

1. Efficacy of the already done agronomic interventions

The farmers had higher appreciation (Table 1) for interventions whose effects were rapid and at the same time can persist several years (fencing, 100%; shrubs clearing, 100%; sowing permanent pasture 80%). In addition, interventions that have rapid results even if for short time were highly appreciated (potato cash crop, 98%). Oversowing was less appreciated (45%) than sowing (80%) because a small number of introduced plants survive. Tree planting was not much appreciated (15% only) because positive effects are visible only after several years.

Table 1. Appreciation of the interventions already done (% of appreciation in decreasing order)

Intervention	Appreciation (%)	Reason
New fencing	100 a	Improvement that lasts many years. Some wolves are seen in the area.
Shrubs clearing	100 a	Some pastures have been completely encroached and cannot be recovered else.
Sowing cash crop (1 year)	98 a	Allows better control on weeds when pasture is sown the following year. Rapid return of money to the investor.
Sowing permanent pasture	80 b	Useful, but not very much because productivity is little anyway due to physical constraints. Native pasture is cheaper and will do it anyway.
Oversowing permanent pasture	45 c	Oversowing is very sensible to competition with weeds, moreover this improvement lasts only 2-3 years.
Chemical fertilization	40 b	It has only effect for 2-3 years.
Planting of scattered forage trees	15 c	Trees take too long to be reintroduced, moreover the forage gap is in winter when livestock is in stable with hay.

Values in column with different letters are different at P = 0.05.

2. Demands of further interventions

Farmers have asked for several interventions *else* than agronomic, actually socio-economical (Table 2).

Table 2. Appreciation of the further interventions (% of appreciation in decreasing order)

Intervention demanded	Appreciation (%)	Reason
Economic contributions	100 a	Money can compensate the difficult life style and the poor incomes.
Better links to towns (improve roads, transports)	100 a	Need of nurseries, schools, ambulatories, administrative offices, social opportunities.
Develop local small scale industries to process and sale milk and cheese	100 a	This produce can be processed at home in very little amounts, if farmers can increase the number of livestock then need to bring the produce to large industries too far.
Develop internet produce sale straight to customers	100 a	The local market is rapidly saturated with the produce, even with organic and PDO certifications, that is all the certifications related to the geographical area and production methods that give an added value to the produce. Some farms have developed larger markets on line, each separately and spending their own money.
Starting agri-tourisms	89 b	Very useful, but complex. Bureaucracy and law limitations are important constraints. Finally, not all farms have structural characteristics to start an agri-tourism.
Cooperative organization in order to have days off.	75 c	Useful because livestock need daily work. However many farmers have relatives with nearby farms and can help each-other.
High school stages in farm for farmers' children	50 d	Only aged people is still working in mountain farms and they need to employ their children but young people have to study and return to farm when this is already in critical conditions. Periodical stages will help parents to manage the farm.

Values in column with different letters are significantly different at P = 0.05.

This points out that the agronomic interventions done have already hit the technical target, but they are not sufficient to keep the people on their land, and that the reasons of land abandonment are to be sought more in the gradual social changes than in the little productivity of the vegetation. Some possible actions are considered complex to be achieved (starting agro-tourism activities, co-operative organization, and less than all the others school stages) thus they are asked by a smaller number of rural people.

Actually all the most demanded interventions are related to better link with the rest of the society and the economy of the whole area (a part the simple financial contribution, people asked better connections to towns, develop small scale industries in the area, develop produce sale straight to customers by internet). Also the other interventions, less demanded, have social implications nonetheless.

IV – Conclusions

Pasture management in marginal areas is important for territory conservation and to develop a modern agriculture linked to services, the results of the current trial showed that good agronomic practices are useful, although rural people demand more services that, if implemented together, can bring to the organization of Integrated Pastoral Systems which link agricultural production and services offered in farm. Some agronomic interventions are possible to support these changes and they are appreciated by rural people especially if they can last for several years (new fencing, shrubs clearing). However farmers and their families demand mainly actions with a more immediate effect on social aspects and life style (improve connections to towns, develop small scale local industries, organize connections and trade also by internet). In general, it is clear anyway that agriculture in any marginal area of Italy shall not persist unless the traditional life style can be adapted to the whole regional economy and to a more modern lifestyle.

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Effects of climate warming and nitrogen deposition on species and community plasticity in grasslands in the French Pyrenees

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Abstract. Nitrogen deposition is the third cause of biodiversity loss on natural systems. Many experiments have studied responses of grassland ecosystems to nitrogen deposition, but only a few have addressed the interaction of such process with global warming. This work aims to understand the plastic response of species of a grassland community to the interaction of atmosphere warming and nitrogen deposition through responses in plant functional traits. The experiment was set up in 2012 in a typical subalpine grassland dominated by *Nardus stricta* L. The experimental design includes six randomized blocks with three nitrogen deposition treatments (0, 5 and 30 kg N ha⁻¹ year⁻¹ in a dose of 2/3 NH₄⁺ and 1/3 NO₃⁻) and two atmosphere warming treatments (ambient and warmed by top open chambers). A survey was performed during the peak biomass period on summer 2015. After completing field measurements, we collected samples from seven out of the 32 recorded species, to measure other plant functional traits. For the remaining species, we acquired the traits from trait databases, in order to calculate the community weighted mean. We want to know if: (1) the most abundant species show high plasticity in response to atmosphere warming and nitrogen deposition; and (2) there is a shift in plant functional traits at the community level in response to environmental changes.

Keywords. Nitrogen deposition – Global warming – Plant functional traits – Community plasticity.

Effets du réchauffement climatique et des dépôts d'azote sur la plasticité des espèces et des communautés des prairies des Pyrénées françaises

Résumé. Les dépôts d'azote sont la troisième cause de perte de biodiversité dans les systèmes naturels. De nombreuses expériences ont étudié les réponses des écosystèmes des prairies aux dépôts d'azote, mais seulement quelques-unes ont abordé l'interaction de ces processus avec le réchauffement climatique. Ce travail vise à comprendre la réponse plastique d'une communauté de prairie et l'interaction entre le réchauffement atmosphérique et les dépôts d'azote, à travers les traits fonctionnels des plantes. L'expérience a été mise en place en 2012 dans une communauté typique de l'étage subalpin, composée principalement par *Nardus stricta* L. Le dispositif expérimental comprend six blocs aléatoires avec trois traitements de dépôts d'azote (0, 5 et 30 kg N ha⁻¹ an⁻¹ à une dose de 2/3 NH₄⁺ et 1/3 NO₃⁻) et deux traitements de réchauffement atmosphérique (ambiant et réchauffé par chambres ouvertes). Un échantillonnage a été effectué en été 2015 au moment où la biomasse était à son maximum. Après les mesures sur le terrain, nous avons recueilli des échantillons provenant de sept des 32 espèces recensées, pour mesurer les traits fonctionnels des plantes supplémentaires. Pour les autres espèces, nous avons utilisé les valeurs consignées dans des bases de données de traits, afin de calculer la moyenne pondérée de la communauté. Nous voulons savoir si: (1) les espèces les plus abondantes montrent une grande plasticité en réponse au réchauffement atmosphérique et aux dépôts d'azote; et (2) il y a un changement dans les traits fonctionnels de plantes au niveau de la communauté en réponse aux changements environnementaux.

Mots-clés. Dépôts d'azote – Réchauffement global – Traits fonctionnels de plantes – Plasticité.

I – Introduction

Grasslands cover a very large portion of the Earth's surface (about 52 million km²) and play an important role as food source for livestock, habitat for wildlife, environmental protection and conservation of genetic resources (FAO, 2005). The reactive nitrogen (N) deposition has become a serious threat to survival of marine and terrestrial ecosystems. Forecasts indicate that this factor will be the third major cause of biodiversity loss by the year 2100. Moreover, global warming is one of the most important elements of climate change. Nevertheless, there are few studies that analyze the responses of grasslands to the combined effect of warming and N deposition. Measurements of N deposition in the Pyrenees show higher values than expected from model predictions, with amounts of about 8 kg ha⁻¹ yr⁻¹ of N currently recorded in the French Pyrenees (Boutin *et al.*, 2015). These values of N may be low when compared to the values of N in some intensive grasslands. Experimental studies show how warming is threatening the vegetation composition (Sebastia *et al.*, 2008), and plant (Sebastia, 2007) and functional (Debouk *et al.*, 2015) diversity of grassland ecosystems in the Catalan Eastern Pyrenees. In order to study the combined effect of N deposition and warming, an experiment was set up in a subalpine grassland in the French Eastern Pyrenees. Here an analysis of the responses of the vegetation to both factors after three years of experimentation is presented. In particular, we report the responses of functional traits of the most abundant plant species in the grassland. In this context, this study aims at analyzing the effects of three nitrogen deposition and two warming scenarios on the plasticity of subalpine grasslands in the Pyrenees.

II – Materials and methods

1. Location

The study site is located in the Ariège Region (42° 42' 51.1" N – 1° 42' 18.3" W; 1940 m.a.s.l.), in the French Pyrenees. The study area corresponds to a subalpine grassland mostly dominated by *Nardus stricta* L. and a pool of other species with lower abundance. Climate is characterized by mean annual temperature of 5.6 °C and mean annual precipitation of 1100 mm. The study area is moderately grazed by sheep, cattle and horses, but the site has been enclosed since the beginning of the experiment in June 2012 to exclude grazing.

2. Experimental design

We sampled 36 plots in the experimental area three years after the beginning of the experiment. The design includes six randomized blocks with three nitrogen deposition treatments (0, 5 and 30 Kg N ha⁻¹ year⁻¹ in a dose of 2/3 NH₄⁺ and 1/3 NO₃⁻) and two atmosphere warming treatments (ambient and warmed by top open chambers with mean increase of 1.3 °C).

3. Functional trait measurements

We selected ten plant functional traits to answer the objectives of this experiment. In a first stage, we carried out a visual inventory of species cover in the field, and measured plant height, taking the highest and smallest individuals per species and treatment, to evaluate responses related to competitive vigor and stress tolerance (Cornelissen *et al.*, 2003). We then selected 10 individuals of the most abundant species (three grasses, a sedge and a forb) for each treatment within each block, put them in a cooler to keep them fresh, and brought them to the laboratory where we measured additional plant functional traits. The traits measured in the laboratory were: leaf size (LS, one-side projected surface area), specific leaf area (SLA, the ratio between the leaf size and its oven-dry mass), and leaf dry matter content (LDMC, oven-dry leaf mass divided by its water-saturated fresh mass). Plant material for each species was then sent to the laboratory to determine leaf nitrogen content (LNC) and carbon content (LCC), corresponding to the total amount of nitrogen and

carbon per unit of dry leaf mass, but this data are not presented here. We used a microbalance to weigh fresh leaves. For leaf projected areas we used a digital scanner (Brother MFC-7860DW Printer) and Adobe Photoshop CS6 software to estimate the leaf surface area. We later dried the samples in an oven at 60°C for 72 hours and we calculated the dry mass. Based on these procedures, we calculated LS, SLA and LDMC. We acquired further traits from literature: growth form (associated with plant strategy, climatic factors and land use), life form (adaptation of plants to climate), vegetation spread and growth habit.

4. Data analysis

We performed regression analysis on each trait and for each species to determine their responses to the treatment factors. In the regression model we included the two treatment factors, warming and N deposition, and their interaction. We also included block as a factor.

III – Results and discussion

Our results show that the treatment factors warming and N deposition had a significant effect on the dynamics of traits, except for leaf dry matter content (LDMC), which was the least responsive trait to both factors (Table 1). WSFM was the most responsive trait to both treatment factors for practically all the species (Table 1). SLA was shown to be a highly responsive trait in front of warming by Debouk *et al.* (2015), however in our study only the SLA of *F. eskia*, and to a lesser effect of *C. caryophyllea*, were modified with warming. The interaction between N deposition and warming was significant for many species, particularly *F. nigrescens*, *C. caryophyllea* and *P. erecta*. Generally, these three species were the most affected by warming. Sebastià *et al.* (2008) showed that the first two species became more abundant in a warming experiment. On the other hand, of all the dominant species tested, *F. nigrescens* was the least responsive, particularly to warming. Sebastià *et al.* (2008) already showed how this species went from being dominant in subalpine grasslands in the Pyrenees to becoming scarce under strong warming conditions. However, *F. nigrescens*, together with *N. stricta*, were highly responsive to N deposition.

Table 1. Warming and N deposition effects on plant functional traits of the most abundant grassland species. WSFM: Water Saturated Fresh Mass; LDMC: Leaf Dry Matter Content; ODM: Oven Dry Mass; SLA: Specific Leaf Area (see section 3)

Species	Treatment	WSFM	ODM	Leaf Size	SLA	Height	LDMC
<i>Carex caryophyllea</i>	Warming	***	n.s.	n.s.	**	***	n.s.
	N	***	**	n.s.	n.s.	***	n.s.
	Warming x N	***	*	n.s.	*	n.s.	n.s.
<i>Festuca eskia</i>	Warming	***	***	n.s.	***	***	*
	N	n.s.	n.s.	***	***	***	n.s.
	Warming x N	***	n.s.	***	***	***	n.s.
<i>Festuca nigrescens</i>	Warming	**	n.s.	n.s.	n.s.	**	n.s.
	N	***	**	***	n.s.	n.s.	n.s.
	Warming x N	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
<i>Nardus stricta</i>	Warming	n.s.	n.s.	***	n.s.	n.s.	*
	N	***	***	**	***	***	***
	Warming x N	n.s.	*	n.s.	n.s.	*	n.s.
<i>Potentilla erecta</i>	Warming	***	n.s.	***	n.s.	***	*
	N	***	***	n.s.	n.s.	***	n.s.
	Warming x N	***	n.s.	**	n.s.	***	n.s.

n.s. non significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

IV – Conclusions

Overall, our results show that both N deposition and atmosphere warming have a strong effect on plant functional traits. As different species respond plastically to either one or both of these treatment factors in different ways, we expect that the combination of the two stresses will have in the long term a strong effect on the persistence of the species and the composition of the grassland.

Acknowledgments

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**Programme and
List of participants**

Meeting Programme

Tuesday 14 June 2016

09:00 – 10:00	<p>Welcome Lecture <i>Chair: Juan Busqué (CIFA-Cantabria, Spain)</i> S0-K: PROFITABILITY OF PERMANENT GRASSLAND: HOW TO MANAGE PERMANENT GRASSLAND IN A WAY THAT COMBINES PROFITABILITY, CARBON SEQUESTRATION AND BIODIVERSITY? A. Peeters, K. Osoro</p>
<p>SESSION 1: PATHWAYS TOWARDS MOUNTAIN FARMING SYSTEMS SUSTAINABILITY: ASSESSMENT METHODS AND CASE STUDIES <i>Chairs: Alberto Bernués (CITA-Aragón, Spain) and Massimiliano Probo (University of Torino, Italy)</i></p>	
10:00 – 10:30	<p>Keynote paper S1-K: BEEF CATTLE FARMS IN LESS-FAVOURLED AREAS: DRIVERS OF SUSTAINABILITY OVER THE LAST 24 YEARS. IMPLICATIONS FOR THE FUTURE. P. Veysset, C. Mosnier, M. Lherm</p>
11:30 – 12:30	<p>Oral presentations (I) S1-O-1: FIELD VALIDATION OF AN AUTOMATIC COEFFICIENT OF ELIGIBILITY OF PASTURES IN MOUNTAIN AREAS. J. Busqué, J.R. Rodríguez, G. Maestro S1-O-2: ADOPTING A RESILIENCE LENS TO ACCOMPANY ADAPTATION TO CLIMATE CHANGE ON SUMMER MOUNTAIN PASTURES. B. Nettièr, L. Dobremez, S. Lavorel, G. Brunschwig S1-O-3: INCREASED ARCTIC BEEF PRODUCTION. I. Hansen, G.M. Jørgensen, V. Lind S1-O-4: ASSESSING THE SUSTAINABILITY OF A COMBINED EXTENSIVE/INTENSIVE BEEF PRODUCTION SYSTEM: THE CASE OF FRENCH SUCKLER COW-CALF FARMS INTEGRATED WITH ITALIAN BEEF FATTENING HERDS. M. Berton, M. Lherm, J. Agabriel, L. Gallo, M. Ramanzin, E. Sturaro.</p>
13:30 – 14:00	<p>Oral presentations (II) S1-O-5: THE CURRENT STATUS OF TRANSHUMANCE SYSTEMS IN THE PROVINCE OF LEÓN (SPAIN), TOWARDS A MULTI-DIMENSIONAL EVALUATION. E. Velado Alonso, A. Gómez Sal S1-O-6: COMPARING TRANSHUMANCE IN XINJIANG, CHINA AND CALIFORNIA, USA. W.J. Li, S. Talinbayi, L. Huntsinger</p>
<p>SESSION 2. LIVESTOCK ON MOUNTAIN PASTURES: ANIMAL PERFORMANCE AND PRODUCT QUALITY <i>Chairs: René Baumont (INRA, France) and Joel Berard (ETHZ, Switzerland)</i></p>	
14:00 – 15:30	<p>Keynote paper + Oral presentations (I) S2-K: THE CONTRIBUTION OF MOUNTAIN PASTURES TO THE LINK TO TERROIR IN THE CASE OF MEAT AND DAIRY PRODUCTS. B. Martin, M. Coppa, I. Verdier-Metz, I. M.C. Montel, M. Blanco, I. Casasús, M. Joy S2-O-1: ALPINE GRASSLANDS: RELATION AMONG BOTANICAL AND CHEMICAL VARIABLES AFFECTING ANIMAL PRODUCT QUALITY. M. Renna, S. Ravetto Enri, M. Probo, C. Lussiana, V. Malfatto, L.M. Battaglini, M. Lonati, G. Lombardi. S2-O-2: CLUSTERING FORAGE TYPES ACCORDING TO THEIR FEED NUTRITIVE VALUE. D. Villalba, E. Molina, J. Alvarez-Rodriguez S2-O-3: EFFECTS OF FORAGE FEEDING AND THE INCLUSION OF QUEBRACHO IN EWES' DIET ON SUCKLING LAMB'S MEAT QUALITY. S. Lobón, A. Sanz, G. Ripoll, M. Blanco, J. Ferrer, A. Sedeño, M. Joy</p>

16:30 – 17:30	<p>Oral presentations (II)</p> <p>S2-O-4: DIFFERENCES IN NUTRITIONAL QUALITY OF MILK PRODUCED FROM EWES REARED IN MOUNTAIN VERSUS VALLEY AREAS. L. Bravo-Lamas, N. Aldai, J. K. G. Kramer, L. J. R. Barron.</p> <p>S2-O-6: ARE THE SPECIFIC SENSORY PROPERTIES OF PASTURE CHEESES LINKED TO MILK FAT COMPOSITION AND BACTERIAL DYNAMICS?. M. Frétin, B. Martin, C. Bord, D. Pereira, M.C. Montel, C. Cirié, F. Fournier, C. Delbès, A. Ferlay.</p> <p>S2-O-7: THE INTEREST OF A MOUNTAIN DAIRY COW BREED TO COPE WITH MEDITERRANEAN SUMMER HEAT STRESS. R. Bellagi, D. Pomies, B. Martin, T. Najar.</p> <p>S2-O-8: GRAZING BEHAVIOUR AND BODY-WEIGHT GAINS OF STEERS GRAZING AT CANTABRIAN MOUNTAIN PASTURES. A. Román-Trufero, A. Martínez, V. García-Prieto, R. Rosa-García, K. Osoro, R. Celaya.</p>
18:30 – 21:00	<i>Social Evening at Palacio de la Aljafería</i>

Wednesday 15 June 2016

<p>MID-CONGRESS TOUR: MOUNTAIN PASTURES AND ASSOCIATED LIVESTOCK PRODUCTION SYSTEMS IN THE PYRENEES</p>
<p>LIVESTOCK FARM & ARTISAN CHEESE FACTORY "FLOR DEL ASPE" – www.flordelaspe.com/</p> <p>MOUNTAIN PASTURES IN AISA VALLEY – Grazing Ecology Research in "Puerto De Aisa" – www.ipe.csic.es</p> <p>LA GARCIPOLLERA Research station – www.cita-aragon.es</p>

Thursday 16 June 2016

SESSION 3: ANIMAL-PASTURE INTERACTIONS IN MOUNTAIN AREAS: BOTTLENECKS AND OPPORTUNITIES IN BIODIVERSITY MANAGEMENT AND FORAGE PRODUCTION <i>Chairs: Eric Mosimann (Agroscope, Switzerland), Manuel Schneider (Agroscope, Switzerland) and Daniel Villalba (Univ. Lleida, Spain, Spain)</i>	
09:00 – 10:30	Keynote paper + Oral presentations (I) S3-K: GRAZING AND BIODIVERSITY: FROM SELECTIVE FORAGING TO WILDLIFE HABITATS. M. Wallis de Vries S3-O-1: FLOWER-FORAGING INSECTS AND THEIR POLLEN LOADS IN MOUNTAIN PERMANENT GRASSLANDS. J.N Galliot, A. Farruggia, A. Bérard, A. Chauveau, A. Blanchetête, D. Genoud, D. Brunel S3-O-2: WILD HERBACEOUS LEGUMES FOR PASTURES RESTORATION IN SIERRA NEVADA NATURAL PARK: FORAGE AND SEED YIELDS. M.E. Ramos-Font, M.J. Tognetti-Barbieri, J.L. González-Rebollar, A.B. Robles-Cruz S3-O-3: IMMEDIATE EFFECTS OF PRESCRIBED BURNING ON C-RELATED TOPSOIL PROPERTIES IN CENTRAL PYRENEES. C.M. Armas-Herrera, D. Badia-Villas, C. Martí-Dalmau, J.O. Ortiz Perpiñá, A. Girona-García, J.L. Mora. S3-O-4: TO WHAT EXTENT ARE MOUNTAIN PERMANENT GRASSLANDS DIFFERENT FROM LOWLANDS PERMANENT GRASSLANDS? RESULTS FROM A STUDY CONDUCTED IN FRANCE. R. Baumont, A. Michaud, E. Pottier, S. Pantureux
11:15 – 12:30	Oral presentations (II) S3-O-6: GRASSLAND ODORScape: A NEW TOOL TO EXPLORE THE ECOSYSTEMIC SERVICES. A. Cornu, A. Farruggia, E. Leppik, C. Pinier, F. Fournier, B. Meunier, D. Genoud, S. Toillon, F. Farruggia, B. Frérot S3-O-7: TARGETED AND UNTARGETED ALKALOIDS CHARACTERISATION OF PASTURE HERBS IN EASTERN ITALIAN ALPS USING HIGH RESOLUTION MASS SPECTROMETRY. T. Nardin, E. Piasentier, C. Barnaba, A. Romanzin, R. Larcher. S3-O-8: HABITAT SELECTION OF DAIRY-SHEEP IN ATLANTIC MOUNTAIN GRASSLANDS. M. Arzak, I. Odriozola, G. García-Baquero, L.J.R. Barron, A. Aldezabal. S3-O-9: RECONCILING MEAT PRODUCTION AND BIODIVERSITY CONSERVATION ON MARGINAL PASTURES. T. Zehnder, M.K. Schneider, J. Berard, M. Kreuzer, A. Lüscher S3-O-11: RESPONSE OF VEGETATION TO EXCLUSION AND GRAZING IN THE MEDITERRANEAN WET MOUNTAIN PASTURES (SIERRA NEVADA, GRANADA, SPAIN). A.B. Robles-Cruz, M.E. Ramos-Font, C. Salazar, J.L. González-Rebollar
13:30 – 14:30	Oral presentations (III) S3-O-5: HOW TO OPTIMIZE THE CARRYING CAPACITY OF JURA SUMMER PASTURES ?. E. Mosimann, M. Meisser, J.B. Wettstein. S3-O-10: TEMPORARY NIGHT CAMP AREAS: AN EFFECTIVE WAY TO RESTORE SUB-ALPINE SHRUB-ENCROACHED GRASSLANDS USING LIVESTOCK. M. Probo, M. Pittarello, S. Ravetto Enri, E. Perotti, M. Lonati, G. Lombardi S3-O-12: TRANSHUMANCE OF DAIRY COWS ON ALPINE SUMMER PASTURES: RELATIONSHIPS BETWEEN MILK PRODUCTION, PASTURE MANAGEMENT, AND INSECT BIODIVERSITY. G. Faccioni, M. Ramanzin, G. Bittante, L. Marini, E. Sturaro. S3-O-13: ADAPTATION OF AN ECOLOGICAL AND PASTORAL DIAGNOSIS TO THE ALBANIAN CONTEXT: CHALLENGES AND LESSONS LEARNED. A. Garnier, C. Bernard, P. Dobi, S. Girardin, F. Launay, F. Lerin, J. Marie, B. Medolli, B. Sirot

SESSION 4: MOUNTAIN PASTURES AND SOCIETY: BIOPHYSICAL, ECONOMIC AND SOCIO-CULTURAL VALUATION OF ECOSYSTEM SERVICES

Chairs: Tzach Glasser (Ramat Hanadiv Nature Park, Israel)

14:30 – 15:00	Keynote paper S4-K: ENABLING SUSTAINABLE PASTORAL LANDSCAPES: BUILDING SOCIAL CAPITAL TO RESTORE NATURAL CAPITAL. L. Huntsinger
15:30 – 16:45	Oral presentations S4-O-1: EXPERT VIEWS ABOUT FARMING PRACTICES DELIVERING CARBON SEQUESTRATION IN MEDITERRANEAN AGRO-ECOSYSTEMS. T. Rodríguez-Ortega, A. Bernués, A.M. Olaizola S4-O-2: FIREBREAK MAINTENANCE WITH EQUINES IN SERRA DE TRAMUNTANA MOUNTAINS (MALLORCA, UNESCO WORLD HERITAGE). J. Gulías, A. Mairata, J. Frontera, I. Janer, J. Jaume, J. Cifre S4-O-3: ANIMAL WELFARE AND ECOSYSTEM SERVICES IN MOUNTAIN AREAS. A. Zuliani, A. Romanzin, S. Bovolenta S4-O-4: BALANCING ON THE TRANSHUMANT ROAD: AN UPDATED POLITICAL ECOLOGY OF LIVESTOCK DRIVEWAYS. P. Starrs

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Mountain pastures and livestock farming facing uncertainty: environmental, technical and socio-economic challenges

Edited by:
I. Casasús, G. Lombardi

Livestock farming is facing major challenges at a global level due to increasing uncertainty in markets, policies, socio-cultural trends, and the environment. One of the hot topics in research and policy design is to reconcile the sometimes conflicting objectives of delivering both animal products and environmental services. On mountain pastures in particular, adequately conducted livestock can be a tool for the efficient management of large areas of high natural value. At the same time, it can sustain a viable economic activity and provide differentiated products that fulfill societal demands for quality and environmentally-friendly production. Optimizing these aspects requires a multidisciplinary approach, combining research and development on ecology, animal, plant, social and environmental issues.

This publication compiles 60 articles of the contributions presented at the **19th Meeting of the FAO-CIHEAM Mountain Pastures Subnetwork**, held in Zaragoza (Spain) in 2016: **“Mountain pastures and livestock farming facing uncertainty: environmental, technical and socio-economic challenges”**.

Over 90 researchers and technicians involved in research and development activities on mountain pastures participated in the Meeting, structured around four specific scientific topics:

- Pathways towards mountain farming system sustainability: assessment methods and case studies.
- Livestock on mountain pastures: animal performance and quality products.
- Animal-Pasture interactions in mountain areas: bottlenecks and opportunities in biodiversity management and forage production.
- Mountain pastures and society: biophysical, economic and socio-cultural valuation of ecosystem services.

The Meeting was co-organized by the Agrifood Research and Technology Centre of Aragon (CITA) and the Mediterranean Agronomic Institute of Zaragoza (IAMZ-CIHEAM), with collaboration from the University of Lleida and the Pyrenean Institute of Ecology (IPE-CSIC). The organization received financial support from the National Institute for Agricultural and Food Research and Technology (INIA) of the Spanish Ministry of Economy and Competitiveness.



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