# Book of Abstracts

## of the Mountain Grassland and Livestock Joint Conference
## New perspectives for mountains farming

EAAP · EUROPA · FEZ · EVT · EAX

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**Plantahof, Landquart, Switzerland**
**15-17 June, 2026**

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## Summary

# The European Federation of Animal Science (EAAP)

The main aims of the EAAP are to promote, by means of active co-operation between its members and other relevant international and national organisations, the advancement of scientific research, sustainable development and production systems; experimentation, application and extension; to improve the technical and economic conditions of the livestock sector; to promote the welfare of farm animals and the conservation of the rural environment; to control and optimise the use of natural resources in general and animal genetic resources in particular; to encourage the involvement of young scientists and technicians. More information on the organisation and its activities can be found at www.eaap.org.

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The European Federation of Animal Science (EAAP) has close established links with its sister organizations of American Society of Animal Science (ASAS), American Dairy Science Association (ADSAS), Canadian Society of Animal Science (CSAS) and Asociación Latinoamericana de Producción Animal (ALPA) and is also member of the World Association for Animal Production (WAAP).

# Welcome to the Mountain Grassland and Livestock Joint Conference

On behalf of Agroscope, the Swiss Confederation's Centre of Excellence for Agricultural Research, the European Association of Animal Production (EAAP), and the FAO–CIHEAM Mountain Pasture Subnetwork, we are pleased to welcome you to the Mountain Grassland and Livestock Joint Conference.

This conference provides a platform for exchange on mountain farming systems, bringing together researchers working in the fields of mountain grasslands and livestock. It offers the opportunity to share knowledge, discuss current challenges, and develop new ideas alongside both well established and emerging colleagues.

The program includes engaging scientific presentations and a special session dedicated to the UN Year of Pastoralism. This special session will encourage participants to look beyond their usual perspectives, with impressions of pastoralism from Africa, Central Asia, New Zealand, and South America.

Participants can also look forward to experiencing Swiss hospitality, including regional culinary specialties and a convivial social dinner. The conference excursions will lead into the surrounding alpine landscapes, with visits to alpine summer farms with on site cheese making, a traditional mountain restaurant, areas of special alpine vegetation, and sites illustrating shrub management practices.

We gratefully acknowledge the support of the Swiss Grassland Association, the Canton of Grisons, and Plantahof, whose help make this event possible.

We are pleased to welcome your participation in this conference and to share with you an exchange of ideas and experiences that supports the sustainable future of mountain grassland and livestock systems.

## Joint organizers

EAAP
European Federation of Animal Science

CIHEAM International Center for Advanced Mediterranean Agronomic Studies
*Sharing Knowledge, Feeding the Future*

Schweizerische Eidgenossenschaft
Confédération suisse
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**Agroscope**

## Sponsors

# FAO-CIHEAM Network

The FAO-CIHEAM Network on Pasture and Forage Crops is an international scientific and technical cooperation platform established in 1978 and incorporated into the ESCORENA framework in 1995 through collaboration between FAO and CIHEAM. The network was created to promote the exchange of scientific knowledge, the development of shared methodologies, the implementation of collaborative research projects, the dissemination of results through publications, and the training of researchers in the field of pasture and forage crop systems. It is structured into two complementary sub-networks: the Mediterranean Forage Resources sub-network, focused on Mediterranean environments, and the Mountain Pastures sub-network, devoted to temperate mountain regions. The network is currently coordinated by Dr. Claudio Porqueddu of the National Research Council of Italy (CNR), based in Sassari.

The Mountain Pastures sub-network, initially established as a working group in 1962 and formally integrated into the wider network in 1978, has developed into a major international forum for research on mountain grasslands, pastoral systems, forage resources, and their ecological and socio-economic functions. With approximately 400 members from numerous countries across Europe and beyond, it represents a broad scientific community. Its principal activities include the organization of biennial meetings and thematic workshops, the promotion of research and development initiatives, the publication of proceedings and scientific reports, and the support of training opportunities for early-career researchers.

Over the decades, the sub-network has made a substantial contribution to advancing knowledge on mountain pastures, particularly in relation to sustainability, livestock systems, biodiversity, ecosystem services, and environmental conservation. Its meetings and collaborative activities have fostered durable links among research institutions, encouraged international mobility, and supported the scientific education of younger generations of scholars. More broadly, the network has played a significant role in strengthening transnational cooperation and in consolidating a shared scientific framework for the study and management of pasture and forage systems in mountain areas.

# Agroscope

Agroscope is the Swiss Confederation's center of excellence for agricultural research and a key partner in advancing sustainable food systems. As a national research institute, Agroscope develops science-based solutions that support productive, resilient, and environmentally responsible agriculture across Switzerland's diverse landscapes—from lowland arable systems to alpine grasslands.

Agroscope conducts interdisciplinary research on forage production, grazing management, ruminant nutrition, animal health and welfare, biodiversity, and climate adaptation. Its work integrates ecology, agronomy, animal science, and socio-economic perspectives – including the specific challenges of high-altitude and marginal regions.

Agroscope collaborates closely with farmers, advisory services, universities, and public authorities to ensure that research outcomes are practical and impact-oriented. Through long-term field experiments, on-farm trials, and innovative monitoring approaches, the institute contributes to maintaining productive agriculture while safeguarding ecosystem services.

# About Landquart and Plantahof

The conference will take place in **Landquart**, a small town situated at 520 m a.s.l., surrounded by the scenic mountains of the Eastern Swiss Alps. The region offers a wide range of recreational and cultural landscapes, from high alpine areas shaped by a long tradition of mountain farming to vineyards producing excellent wines, as well as attractive hiking trails. Thanks to excellent transport connections, the region's internationally renowned spa and sports resorts are also easily accessible.

The venue, **Plantahof**, is a newly renovated stately building from the early 19th century. Today, it serves not only as the agricultural school of the Canton of Grisons, but also as the cantonal agricultural advisory centre, supporting all aspects of farming and rural life through regional offices across the canton. Plantahof offers a broad programme of continuing education for farmers and acts as a "*showcase of the farming profession*". To this end, it operates a large and diverse agricultural enterprise with several sites, ranging from valley farms to alpine summer farms, and includes an on site farm shop.

# Industry members

EAAP started in 2023 a new initiative to create closer connections between European livestock industries and the animal science network. Therefore, the “EAAP Industry Club” was shaped with the specific aim of bringing together the important industries of the livestock sector with our European Federation of Animal Sciences. All companies dealing with animal production (nutrition, genetic, applied technologies, etc.) are invited to join the “EAAP Industry Club” because industries will have opportunity to increase their visibility, to be actively involved in European animal science activities, and to receive news and services necessary to industries. In addition, through the Club, industries will enlarge their scientific network and will receive specific discounts on sponsoring activities.

The Industries that already joined the “EAAP Industry Club” are:

## The Club gives:

Visibility • Company name and logo at EAAP website and all relevant documents • Slides with name and logo at Official Events • Priority links with EAAP Socials • Invite, through EAAP dissemination tools and socials, people to events organized by your company • Information disseminated through a brand new Industry Newsletter • Networking • Joining the Study Commissions and Working Groups • Suggest topics to be considered for Annual Meetings Scientific Sessions • Organize Professional Panel through the EAAP platforms • One free registration to each Annual Meeting and at every meeting organized by EAAP • Five individual memberships at no cost • Many possible discounts (-30%) to sponsor and to increase company visibility through: EAAP Newsletter, EAAP website, EAAP Annual Meetings and workshops • Support young scientist by sponsoring scholarships named by the company • Co-Organize and sponsor webinars

Make yourself more visible within the livestock industry via the animal science network!

For more information, please contact eaap@eaap.org.

# Scientific programme

## Session 1. Mountain grasslands and livestock in the context of climate change

Date: Monday 15 June 2026; 11:00 - 14:45
Chair: Zanon / Klingler

### Theatre Session 1

## Coffee break and Poster session 1

Date: Monday 15 June 2026; 15:25 - 15:25:00
Chair:

## Session 2. Site-adapted animals and management to enhance ecosystem services

Date: Monday 15 June 2026; 16:30 - 17:30
Chair: Zanon / Lombardi

### Theatre Session 2



## Session 3. Pastoralism worldwide

Date: Monday 15 June 2026; 17:30 - 18:30
Chair: Pauler / Peratoner

### Theatre Session 3

## Session 4. You never walk alone: land-use conflicts or coexistence?

Date: Tuesday 16 June 2026; 8:30 - 9:45
Chair: Bernués / Sturaro

### Theatre Session 4



## Coffee break and Poster session 2

Date: Tuesday 16 June 2026; 10:45 - 10:45:00
Chair:

## Session 5. Feeding livestock by mountain grassland

Date: Tuesday 16 June 2026; 12:00 - 13:00
Chair: Cozzi / Eppenstein

### Theatre Session 5



## Session 6. Economy and social context of grassland-based livestock production

Date: Wednesday 17 June 2026; 8:30 - 10:00
Chair: Cozzi / Tesnière

### Theatre Session 6

## Session 7. New ways to maintain the heritage of grassland and livestock

Date: Wednesday 17 June 2026; 9:00 - 10:00
Chair: Grøva / Pittarello

### Theatre Session 7



## Session 8. From pasture to plate: product quality along the production chain

Date: Wednesday 17 June 2026; 10:30 - 12:00
Chair: Coppa / Dovc

## Session 9. Bits and pixels: software and sensors for grassland-based livestock systems

Date: Wednesday 17 June 2026; 10:30 - 12:00
Chair: Morgan-Davies / Klingler

### Theatre Session 9



## Session 10. Shrubs and trees: friends or foes of mountain grasslands?

Date: Wednesday 17 June 2026; 13:30 - 14:15
Chair: Ravetto Enri

### Theatre Session 10

**Challenges of grassland farming in mountain areas**

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Mountain grasslands are the main forage source for livestock in alpine and northern regions. Their functioning depends on topography, climate and soil, creating highly heterogeneous conditions which require site-adapted management strategies. Short growing seasons, steep slopes and shallow soils limit forage production, while demanding flexible management and high labour inputs. Climate change is affecting these systems, altering phenology and increasing weather extremes. Socioeconomic dynamics further intensify these pressures. Structural changes, declining labour availability and the concentration of production on favourable sites drive a mismatch between site potential and management intensity, resulting either in intensification or abandonment. Both trends reduce the multifunctionality of mountain grasslands. The trade-offs between ecosystem services along a gradient of management intensity requires a context-dependent prioritisation of aims and a mosaic of management intensities to provide different ecosystem services. Livestock production remains central but must adapt to shifting forage resources, predator pressure and societal expectations. While transhumance and local breeds enable the use of steep and remote areas, modern high-yield systems increase reliance on imported feeds and decrease the utilisation of Alpine summer pastures. Emerging technologies like remote sensing and digital tools offer promising options to improve monitoring, decision-making and resource efficiency. Further key elements are the continuous selection and adaptation of genetic resources suited to the mountain environment, and a targeted exploitation of synergistic effects of functional diversity. Future research must address climate adaptation, digitalisation, conflict mitigation and the development of sustainable mountain farming systems. An enhanced facts-based dialog with stakeholders and society is pivotal to develop shared and effective policies.



**Risk management dynamics and adaptive capacities of Andean and Alpine pastoral systems: insights from temporal and spatial comparisons**

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Analysis of livestock pastoral farming systems in the central Peruvian Andes conducted in 1985 showed that farmers favoured secure production over quantitative maximisation, relying on practices designed to limit the risks and vulnerability. Their practices were thus spread out over time, favouring short supply chains, capital preservation and savings in products rather than money. They formed a stable strategy based mainly on the inherent capabilities of livestock systems in a context without support structures (banks, insurance, technical advice). Forty years later, an analysis of multiple risk management practices in pastoral sheep systems in the central Alps conducted by Virapin in 2025 highlights multiple strategies for taking risks into account, particularly those related to the interface between wildlife and livestock farming systems. These practices reflect a logic of vulnerability reduction based on "doing with nature", favouring the absorption of hazards rather than their control and strengthening the autonomy of systems in the face of the uncertainty of the various risks, in particular by using short supply chains and adopting specific practices to face predation, climate change and their uncertainties. The similarities in practices and objectives between these livestock farming systems, distant in time and space, highlight, the relationship to risks and the use of internal solutions within farming systems rather than external aid or support, and the intrinsic resilience of pastoral systems to endure in mountain areas. This diachronic and geographical comparison illustrates the importance of comparative methods for analysing complex livestock systems. It also highlights the central role of risk management in pastoral systems that are structurally confronted to a degree of uncertainty with which they must cope. Their ability to take their vulnerabilities into account and work to mitigate hazards is an essential component that allows them to maintain margins for manoeuvre in the short and long term. Understanding this ability is therefore a prerequisite for analysing the resilience of pastoral systems in a context of global change.

**Long-term impact of climate change and grazing management on vegetation dynamics of Alpine pastures**

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Alpine grasslands are undergoing pronounced transformations as a result of both ongoing climate change and grazing management, yet their joint effects on vegetation dynamics are still poorly understood. By revisiting historical vegetation surveys, this study examined long-term dynamics in plant community composition, plant diversity, and pastoral value in five alpine pastures of the Western Italian Alps over a 20-year period (2003–22), combining vegetation data with climatic and grazing management data. Over the study period, temperatures rapidly increased, while precipitation showed high variability, with more concentrated rainfall patterns and longer dry spells. Pastures were regularly grazed, with stocking rates showing slight increases or decreases. The cover of lower-elevation species increased in the subalpine belt, with species of meso-eutrophic grasslands (+36%) and montane oligotrophic swards (+8%) expanding, indicating an ongoing thermophilization process. Species richness and pastoral value remained stable, while community evenness increased. Such vegetation dynamics were driven by the combined effects of grazing management and climatic variations, with neither factor clearly prevailing over the other. Site-use intensity was the main driver: intermediate intensity produced the largest increases in the cover of species typical of meso-eutrophic grasslands and montane oligotrophic swards, and also maximized community evenness. In contrast, high grazing pressure or rapid climatic shifts reduced both species cover and evenness. Climate played a key role as well, with species of meso-eutrophic grasslands favored by rapid warming and increasing precipitation, while those of montane oligotrophic swards expanded only under moderate warming and sufficient moisture. Conversely, accelerated warming and increasing drought determined a reduction in cover of both species groups. Results suggest that Alpine pastures can remain resilient to climate change under balanced grazing, although this buffering capacity may weaken with accelerated warming and increasing aridity.



**Estimating dairy cows' drinking water intake during alpine grazing using smaXtec bolus data: validation of estimated intake**

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*[1] BFH, HAFL, Länggasse 85, 3052 Zollikofen, Switzerland, [2] Agroscope, Forage production and grassland systems, Reckenholzstrasse 191, 8046 Zürich, Switzerland*

Increasing climatic changes are substantially affecting water availability in mountain regions and have increasingly led to water shortages on alpine summer farms in recent years. Where insufficient water is available in the mountains, alpine grazing during the summer season becomes difficult—if not impossible. Addressing this challenge requires solid knowledge of both the available water resources and the water demand of an alpine farm. Based on this information, the need for infrastructure improvements can be assessed and water-use efficiency can be increased. Within the project Water balance on alpine farms – improving water management in alpine summer grazing areas, a tool was developed to compare demand and supply of water. A relevant share of total demand is animals' drinking water intake. Available intake data largely originate from indoor housing systems (e.g., total mixed ration) and are only partly transferable to alpine conditions, where milk yield, temperature, altitude, grazing system and feed basis differ substantially and may therefore affect drinking behaviour and water requirements. SmaXtec sensors, which monitor reticulorumen temperature, allow an estimation of ingested water. In summer 2025, cows on Alp Weissenstein were equipped with smaXtec boluses; in parallel, a water meter was installed at the troughs to record the actual water withdrawal. The objectives are (i) to verify the bolus-based estimates against the water-meter measurements and (ii) to compare the results with the drinking-water assumptions currently used in the water-balance tool for the alpine summer season. Initial analyses indicate that observed drinking water intake (litres per day) is in some cases less than half of the values previously calculated in the tool. Moreover, a relationship between water intake and precipitation is emerging. This provides the first data-driven basis for dairy cows' drinking water intake under alpine conditions, which can improve the parameterisation of water-balance models and the sizing of water infrastructure in mountain regions.

**Exploring wildlife–livestock interfaces in alpine pastoral systems**

*M. Virapin[1,2], E. Sturaro[2], G. Brunschwig[1]*
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Mountain livestock systems operate within complex socioecological environments where farming activities, wildlife and human uses coexist. Climate change, land-use dynamics and evolving conservation policies intensify these interactions and transform pastoral practices. While wildlife–livestock relations are often approached through a conflict-based lens (predation, disease transmission or competition for resources), such perspectives obscure the diversity and context-dependence of situations. This work documents the diversity of interfaces, interactions and risks between wildlife and pastoral livestock systems, while proposing a conceptual framework for the wildlife–livestock interface. The interface is understood not merely as a spatial zone of contact, but as a dynamic and relational configuration shaped by multiple dimensions (ecological, social, economic and institutional). We carried out bibliographic analysis of 150 case studies using clustering methods and cross-thematic analyses and conducted one hundred interviews with breeders in France and Italy. This combined approach articulates a global perspective from literature with a detailed analysis of local situations. Results show that the wildlife–livestock interface remains a marginal concept in risk management, despite its central role in understanding risks affecting pastoral systems and reveal a diversity of risk management practices implemented at this interface. Often reduced to a spatial or temporal dimension, it emerges as a multidimensional and context-dependent socio-ecological configuration. Beyond constraints, the interface also appears as a space of negotiation and adaptation, where coexistence is constructed through interactions and mutual adjustments. Far from being a fixed zone of confrontation, it should be understood as a dynamic of tensions and opportunities, essential for thinking about the resilience of pastoral systems in the context of global change. By moving beyond conflict interpretations, this work opens new perspectives for understanding mountain livestock systems, dynamics of risk and coexistence and provides a conceptual basis for further research on resilience and adaptation of alpine pastoral systems.



**How French suckler cattle farms in mountainous areas can achieve a balance between economic, environmental, and animal welfare performance**

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Practices aimed at improving animal welfare or reducing environmental impacts can lead to a decrease in the global economic efficiency of the production system. Due to these antagonistic relationships related to farming practices, economic, environmental and animal welfare performance objectives are often not achieved simultaneously. Our aim here is twofold: first, to understand which performance objectives are in conflict on suckler cattle farms in mountainous areas; and second, to examine how these conflicts can be managed. First, we determine the relationships between the different performance indicators using a bioeconomic model that focuses on variables impacting feeding. The focus on animal feeding was chosen because of its central role in livestock systems and its pivotal role in the relationship between farm economics, environmental impacts and animal welfare. Then, we analyse the conflicts between performance indicators. For the economic dimension, we use the profitability indicators farm income in Euros and farm income ratioed to revenues, where farm income is defined as a feed margin, i.e., revenues from livestock sales minus feed costs. For the environmental dimension, we examine the climate change impact and eutrophication using two different functional units – kilogram carcass of sold animals and hectare of land used. For animal welfare dimension, we choose a proxy representing grazing time. Finally, we examine how these trade-offs can be managed using a compromise programming approach. This method consists in minimising a distance metric between feasible solutions and a utopian point where all objectives would be optimal. The compromise solutions obtained show that environmental and animal welfare performance can be substantially enhanced compared with profit-driven optimisation, with foregone profits of approximately 15% of optimum values. These improvements can be achieved by reducing herd size and focusing on non-fattened animals, increasing the proportion of grassland in farmland, and reducing concentrate feed purchases.

**French mountain pastoral regions facing climate change**

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Anticipating the consequences of climate change on water resources, plant resources, and livestock requires projections and indicators at a relevant spatial scale. From a set of contrasting projections that reflect the current state of scientific knowledge on climate change, it appears that by mid-century (2050), assuming high emissions (RCP8.5): i) the average warming projected for France is more pronounced in the southeast and in the mountains than in the northwest, and is also stronger in summer than in winter, ii) changes in annual precipitation totals are subject to significant uncertainty, with a tendency for precipitation to increase in winter and decrease in summer, iii) one of the consequences of rising temperatures is an increase in reference evapotranspiration across the entire territory. In mountain areas (altitude > 800 m asl), with rising average temperatures, the average annual number of frost days will decrease significantly (-32 to -45 days per year according to projections). The start date for grassland vegetation is expected to be brought forward by an average of 21 to 28 days. This means that the possible turnout date to grass would be brought forward by around 20 days. The water supply to grasslands will be a determining factor, particularly at the end of summer, in ensuring autumn growth and thus extending the grazing period to take advantage of the later date of the first frosts. Summer river flows could fall by up to 40% in the foothills of the Southern Alps and the Pyrenees. The availability of water for watering animals may become a problem in some areas, particularly in karstic pastoral areas. In dairy mountain pastures, the summer decline in water flow could also become a problem for cleaning milking and cheese-making facilities, as well as for the drinking water supply for shepherds. In mountain areas, the number of very hot days (maximum temperature > 30°C) will remain relatively low, with little or no impact on the thermal comfort of animals. Provided that the grasslands have sufficient water at the end of summer (uncertainty about rainfall), climate change may create opportunities by extending the period during which animals can graze. The main risk may be water management for drinking and other uses in summer.



**Climate neutral agriculture Grison – emissions and reduction potentials in the alpine canton of Switzerland**

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The canton of Grisons is the largest canton of Switzerland by area and is strongly characterized by alpine topography. Since 2020, the canton has pursued a climate strategy aiming at net-zero greenhouse gas (GHG) emissions by 2050, to which agriculture is expected to contribute. This represents a particular challenge, as roughly 90 % of the agricultural area consists of grassland used for ruminant livestock. During the pilot phase of the project "Klimaneutrale Landwirtschaft Graubünden" (2020–2025), 52 farms tested various mitigation measures. GHG accounting using the ACCT-Tool showed that the implemented measures did not lead to an overall reduction in emissions across participating farms. However, year-to-year fluctuations in for example herd size or forage production can mask mitigation effects. A closer analysis of individual farm trajectories is thus needed to reveal relevant patterns and explanatory factors for the observed developments. To assess the broader relevance of the pilot phase, tested measures were scaled up to the cantonal level based on the cantonal emissions inventory, resulting in an overall mitigation potential of approximately 10 % of current cantonal agricultural GHG emissions. For example, methane-mitigating feed additives such as 3-NOP could reduce emissions by around 2 %, but their applicability is limited by grass-based feeding systems, long grazing periods and the high share of organic farms. Optimisation of grass-based rations mainly improves production efficiency, whereas increasing dairy cow longevity could contribute to absolute emission reductions but requires changes in herd structure. Biochar application represents a technically feasible long-term carbon sequestration option, although production capacities and high costs currently restrict its mitigation potential to about 1 %. Overall, achieving a 10 % emission reduction already represents a very ambitious target for agriculture in Grisons. Additional measures will be required to reach net-zero emissions. In the next project phase, selected measures will be scaled up to reach around 500 farms through implementation programmes as well as education and training activities.

**Modeling energy use and greenhouse gases for organic dairy farms in Bavaria**

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Livestock farming is one of the main sources of greenhouse gas (GHG) emissions in agriculture. Dairy farming in particular is considered a significant contributor to environmental and climate impacts, mainly due to methane emissions. Despite numerous studies on GHG emissions in milk production and mitigation strategies, there are currently only a few results available for Bavaria, particularly for grassland-dominated production systems. The present study investigates the energy consumption and GHG emissions of 22 organic dairy farms in the Bavarian Alpine foothills. Additionally, specific optimization strategies for milk production systems are analysed for their GHG-reduction potential. The environmental management program REPRO is utilized to calculate energy and GHG balances in crop and feed production, soil humus dynamics, and farm nutrient cycles. The subsequent process analysis of dairy farming incorporates the following steps: (1) feed production and feed purchases, (2) feed storage, (3) housing system, (4) enteric fermentation, (5) milking system, (6) manure management, and (7) heifer production. The model is sufficiently sensitive to analyze and evaluate management changes in terms of their potential to mitigate greenhouse gas emissions. The emission of GHG is contingent on a number of management and spatial factors. It is evident that increased milk yield is associated with lower emissions. However, this effect is diminished and superseded by other factors, including lifetime performance. It is estimated that approximately half of all GHG emissions are methane. However, the potential for reduction through optimization of feeding is limited in ruminants. Furthermore, emissions from the use of fossil fuels constitute a substantial proportion of overall GHG emissions. The use of renewable energies results in a substantial reduction in the energy balance, particularly within milk production, yet has only a minor impact on the overall GHG gas balance. A systemic approach is required to reduce GHG emissions in dairy farming. To effectively reduce GHG emissions in dairy farming, all areas and processes must be integrated.



**Contrasting feeding strategies in Swiss dairy farming on milk production, GHG emissions, land use and cow health**

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The intensification of dairy production creates a shift from pasture-based (PB) to confinement-based (CB) feeding strategies where meadow forage is often readily exchanged for whole-crop maize and concentrates. This phenomenon also affects dairy production in the foothills of the Alps, where topographical and climatic conditions limit arable farming. Concomitantly, there is an increasing demand for grassland-based milk production systems, which are often considered sustainable, require less resources and have high animal welfare standards. The impact of each feeding strategy on milk production, cow health, GHG emissions and land use was assessed on 15 CB and 15 PB dairy herds in Switzerland, all off which had access to pasture. The feeding strategy of each production system was aligned with the land use (crop rotation vs. grassland) and breeding strategy (high performance vs. pasture adaptation) of the farm. The higher production intensity of CB farms compared to PB farms (140 vs. 20.0 g dry matter concentrated feed/kg Energy Corrected Milk (ECM); $p < 0.001$) led to a higher milk yield per cow (9,901 ± 1,052 vs. 5,806 ± 986 kg ECM/cow; $p < 0.001$) and per hectare (incl. external farmland) (11,724 ±1,774 vs. 7,655 ± 1,457 kg ECM/ha; $p < 0.001$). Nevertheless, GHG emissions allocated to milk (810 ± 73.8 vs. 821 ± 71.5g $CO_2$ eq/kg ECM; $p = 0.69$) and the land-use ratio (1.51 ± 0.41 vs. 1.24 ± 0.66; $p = 0.20$) were similar in both systems. Clinical health assessments conducted over four visits revealed higher prevalences for hairless patches (17.2 ± 3.48% vs.7.95 ± 1.86%; $p < 0.001$), lesions (5.49 ± 1.41% vs. 1.22 ± 0.39%; $p < 0.0001$), hindleg swellings (1.39 ± 0.01% vs. 0.09 ± 0.01%; $p < 0.0001$) and lameness (11.4 ± 2.19% vs. 1.07 ± 0.33%; $p < 0.0001$) than PB farms. However, both systems demonstrated high levels of animal welfare. In conclusion, the productivity and sustainability of low-lying alpine dairy farms may be more comprehensively reflected by the inclusion of additional indicators for land use competition.

**Relationship between soil microbial and floristic biodiversity of hay meadows in the Dolomite areas**

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Mountain meadows are a valuable resource, especially for animal feed, but they also play an important role in supporting ecosystem services. Within these services soil biodiversity plays a fundamental role linked to forage productivity. There is currently limited information on the influence of plant community on soil microbial communities of meadows. The aim of this study was to investigate how plant biodiversity in mountain meadows influences soil microbial diversity and conversely. In 2025, 12 permanent meadows in the Italian Dolomites (Belluno, Italy), having a slopes ranging from 0 to 15% and an altitude from 950 and 1400 m a.s.l., were investigated. Botanical surveys were carried out before each mowing, using the Braun-Blanquet method in a 100m2 area. After each cut, seven soil samples were collected for each area and analyzed for soil microbial diversity, assessed by phospholipid fatty acid (PLFA) analysis using gas chromatography (GC), to characterize microbial community composition and estimate the biomass of the main microbial groups. On the other hand, microbial activity was evaluated through bacterial growth rate using the tritiated leucine incorporation technique. Analyzing changes in the soil microbiota can provide valuable insights into the dynamics of the entire meadow ecosystem. The results showed that microbial diversity was higher in meadows at higher elevations compared to those at lower elevations, while microbial diversity and community composition varied in relation to plant species richness, legume presence, and plant species composition. Although these findings are preliminary, they suggest interactions between aboveground and belowground biodiversity with implications for the long-term stability of meadow ecosystems.



**Microbiological Air Emissions from a Cattle Barn**

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The intensification of animal production is associated with the concentration of large numbers of animals in limited areas. Intensive livestock farming may pose a threat to the natural environment and cause inconvenience to local residents and tourists. The aim of this study was to assess the level of microbiological contamination in the environment of a dairy cattle farm. The study was conducted on a dairy farm located in a tourist area within the ecologically clean region of the Beskidy Mountains. Investigations were carried out during the winter and spring seasons. During the study period, the cowshed housed 240 animal units of Red-and-White Lowland cattle. The research included an assessment of microclimatic conditions inside the cowshed and in its surroundings, as well as a microbiological analysis of air samples. Air samples were collected inside the cowshed and along a designated transect to determine the distance at which airborne microorganisms disappeared. Sampling points were located at 5 m, 25 m, and 75 m from the cowshed on the downwind side, and approximately 25 m from the building on the upwind side. Samples were collected by aspiration using forced airflow, which deposited microorganisms directly onto microbiological culture media. Microclimatic parameters were measured during each sampling event at five fixed points inside the cowshed and at one point 25 m outside the building. The recorded parameters included temperature, relative humidity, cooling power, air movement rate, and concentrations of ammonia, carbon dioxide, and ozone. Analysis of the results showed that the concentration of airborne microorganisms was correlated with temperature and humidity. Microbial counts decreased with increasing distance from the cowshed, indicating that the source of ambient air contamination was the building itself. Microbiological contamination levels comparable to the control point were observed only at a distance of 75 m from the cowshed.

**When the temperature goes up, do the animals go up?**

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Effects of global warming on Alpine vegetation can manifest themselves on decadal scales. Whatever the local vegetation, ground-truth implications in mountain grassland systems are, the practical management adaptation at large may also respond to administrative steering, an evolution of best practices and insights, as well as economic and labour constraints. We report and analyse occupancy numbers for all Swiss summering pastures from the national animal movement database since its renewal in 2010, in hitherto unreported time and spatial resolution. While the general trend to a prolonged summering season is readily visible over the sub-climatic period of 15 years, inter-year variations are remarkable and can be correlated to intra-year environmental variability: for cattle, the increase amounts to ca. 10 additional days over the given period on a per-head basis. We present further analyses on accentuated effects over geography, elevation, and essential production type.



**Influence of site conditions on provisioning and non-provisioning ecosystem services of Swiss mountain summer pastures**

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Mountain summer pastures provide numerous provisioning and non-provisioning ecosystem services. Site-specific conditions play a central role for their magnitude and temporal variability. Understanding how biophysical site factors shape ecosystem services provision is essential for developing site-adapted grazing management and livestock systems that avoid under- or overutilisation. Therefore, we quantified key ecosystem service indicators across 125 plots in 14 representative Swiss summer pasture areas in 2022-2025. Non-provisioning services included biodiversity (species diversity of vascular plants and grasshoppers), pollinator resources (such as nectar amount and the diversity of pollinator groups), and aesthetic value (via photo survey and floral traits). Provisioning services were represented by biomass yield and forage quality (as digestible organic matter). We assessed the effects of site factors, including topography (elevation, slope and aspect), climate (temperature and precipitation), and soil characteristics (pH, organic matter content and phosphorus content). Ongoing analyses aim to quantify the relative contributions of these site factors to patterns of ecosystem service provision. Preliminary results reveal pronounced differences in ecosystem service provision among mountain summer pastures, with strong variation in key indicators such as vegetation diversity (14–72 species) and biomass productivity (0.23–7.44 t DM $ha^{-1}$ $yr^{-1}$). While pasture and vegetation types differ in ecosystem service provision, pronounced differences are also observed within these pasture and vegetation types, indicating substantial fine-scale heterogeneity. These patterns suggest that variability is driven not only by broad pasture classifications but also by local site conditions.

**Sustaining the Thônes and Marthod sheep breed by promoting its strengths.**

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The Thônes and Marthod sheep breed is a small size population, dual-purpose breed endemic to the French Alps, raised in grass-based mountain farming systems. Breeders committed to preserving the breed have joined forces within the Thônes and Marthod Breeders'Union (UTM), as breeding organization. The breed is primarily recognized for its morphological qualities and its adaptation to alpine environments, (altitudes exceeding 2600m). Breeders aim to improve the breed's milk production potential while maintaining its key traits of hardiness and adaptation to mountain conditions. It is therefore necessary not only to improve knowledge of ewe milk performance (by attempting to disentangle the genetic component from environmental and management effects), but above all, to better characterize the breed's genetic diversity. This is essential to enable genetic improvement within its specific farming context, which is increasingly exposed to environmental changes and health risks. To support this initiative, the livestock farmers' cooperative Éleveurs des Savoie (EDS), with the support of the French Livestock Institute (IDELE), has implemented a milk performance recording system combined with pedigree data collection. Based on the data collected—milk yield per ewe, milk quality (fat and protein contents), and lactation length—from approximately 350 ewes, with an average of 25 records per animal and known pedigree links over three generations, we investigate the relationship between milk performance and the genetic "lines" within the different flocks. These data also allow characterization of genetic diversity within the population. For the year 2025, the average annual milk production was 204.7 L per ewe over 210.8 days, with a standard deviation of 66.9 L and 39.1 days, respectively. Pedigree analyses make it possible to estimate levels of relatedness and inbreeding within flocks, with a view to future correlations between milk performance and genetic lineages. Despite the limited size of the population, the challenge is to propose management tools— making the greatest possible use of existing tools while adapting them to this original population, supported by a motivated collective of breeders.



**Adapting the SEGAE Serious Game to Simulate Sustainable Mountain Farming**

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The serious game SEGAE, developed by an international team, is designed to teach students in agricultural schools and universities how to implement agro-ecological practices on mixed crop-dairy farms to ensure sustainable development. Educational games are an effective teaching tool, engaging students' attention far more than traditional methods. The game's basic scenarios simulate typical lowland farms from the authors' countries (France, Poland, Belgium, Italy). However, the application is to support extensions, including those that may reflect the unique designed features of mountain farming. The aim of the research was to analyze the possibilities of extending a serious SEGAE game to the conditions of mountain farming. While adding this functionality does not require changes to the core algorithms, the following tasks should be carried out.1. Adjust parameters and indicators. Mountain farming conditions differ from lowlands, requiring new parameters that reflect these specifics.2. Include local breeds and crops. Incorporate cattle, plants, and cultivation practices typical of mountainous areas.3. Develop mountain scenarios. Reflect the unique environmental, economic, and management challenges of high-altitude farming.4. Enhance visuals. Use mountain landscape graphics to increase realism and player engagement.The most challenging task is to develop a table of indicators and input parameters specific to mountain farms, as they differ substantially from lowland systems. In mountainous mixed dairy farming, the model should include local cattle breeds adapted to steep pastures and cooler climates, with lower milk yields but greater resilience. Grazing is typically extensive and seasonal, while fodder production relies on permanent grasslands, with limited arable crops. Developing scenarios is relatively simple and can be performed using the scenario manager. Incorporating these elements would make the game a highly effective tool for teaching sustainable mountain mixed crop-dairy farming.

**Informing management of traditional wood pastures as key habitat for an endangered bird species in the Jura mountains**

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Sylvopastoral systems have the potential to be valuable habitats for a number of declining bird species associated with semi-open habitats. In the Swiss Jura mountains, wood pastures, consisting of cattle-grazed pastures and scattered trees or shrubs, are a traditional form of a sylvopastoral system that vary in terms of trees and shrub cover. Like many mountain agricultural areas, wood pastures host a unique biodiversity but are threatened by land use intensification or land abandonment. Wood pastures host a significant part of the Swiss Woodlark (Lullula arborea) population, an endangered insectivorous bird that feeds and breeds on the ground. To preserve the species, it is therefore crucial to understand which environmental parameters Woodlarks rely on, to better inform management strategies in wood pastures. In this study, we modeled Woodlark habitat selection based on observations of singing individuals during the early reproductive period. During three years of monitoring, 96 presence data points related to 38 individuals were recorded. Using a multiple-scale approach with a resource selection function, we assessed Woodlark response to various environmental parameters, reflecting tree, shrub and ground cover, fertilization, and microtopography. Woodlark selected habitats at scales between 50 m and 100 m. Areas with a tree cover under approximately 15% and at least 1,5 % of rocky outcrop cover were preferred by the birds. Terrain ruggedness was negatively linked with Woodlark occurrence probability and areas with more than 30% of fertilization were avoided. These findings provide a basis for developing evidence-based management guidelines aimed at enhancing Woodlark conservation in sylvopastoral systems. Comparable management measures have already been effectively implemented in the canton of Neuchâtel. Moreover, such detailed insights into species-specific habitat requirements allow the production of integrated distribution maps, thereby supporting spatial conservation planning.



**Sustainable forage systems in mountain areas: a case study LIFE18 CCM/IT/001093 – LIFE agriCOlture**

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LIFE18 CCM/IT/001093 – LIFE agriCOlture project was carried out in a mountainous area deeply defined, both landscape and socially, by the production of milk for Parmigiano Reggiano P.D.O. cheese. In recent years, farmers have adopted agricultural practices to increase forage production, which has led to the loss of biodiversity and fertile soil. To this end, a project was set up to map the biodiversity, productivity and conservation status of meadows, soil and soil organic matter (SOC). The project aimed to restore and enhance fodder production in Apennine areas. This was achieved within LIFE agriCOlture, which worked on 10 case studies on dairy farms with the aim of developing and implementing adaptation and mitigation plans (AMP), aimed at improving productivity and reducing environmental footprints. The medium value of carbon footprint of the milk produced by the 10 cow farms averaged from 1,51 kg CO2eq/kg Fat Protein Corrected Milk before Best Practices application to 1. Enteric emissions, averaging 40% of the total, accounted for the largest share of total emissions, followed by emissions associated with the production of purchased feed (averaging 31,43% in ex-ante and 29,73% in ex post, in both cases a very high value) and methane and nitrous oxide emissions from effluents (about 18%). The Best practices regarding the production and use of forages were the most applied and led in some cases to an increase in milk production and always to a reduction in the purchased forages and feed.

**Emergency supplementary irrigation in an Alpine grassland: three-year effects on herbage yield and quality (PNGP, NW Alps)**

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Alpine grasslands are increasingly exposed to summer droughts, with consequences for forage supply and quality for mountain grazing animals. We assessed the effectiveness of "emergency" supplementary irrigation in an Alpine grassland within Gran Paradiso National Park (NW Italian Alps), comparing an irrigated area with a control. The site was a nutrient-poor dry pasture dominated by Sesleria varia, Festuca ovina aggr. and Plantago alpina at 2400 m a.s.l. Plant community composition was surveyed in the summer at the beginning of the experiment in ten fixed transects (five per treatment). Above-ground biomass was sampled monthly in 2023, 24 and 25, four times per summer, and analysed by NIR spectroscopy to estimate crude protein (CP) and fibre fractions (NDF, ADF, ADL). Irrigated plots were paired with the most similar controls based on a PCoA ordination, and treatment differences were tested at each sampling date using paired t-tests. In June, no significant differences emerged. By July, irrigated forage showed higher yield (+0.7 t/ha) and ADF (+2.4%), likely due to more flowering stems under reduced resource limitation. In August, during peak summer heat, the yield advantage persisted (+0.8 t/ha) and was accompanied by a marked CP increase (+2.1%), while fibre fractions no longer differed. By September, the two forages did not differ significantly, probably due to the mitigating effect of late-summer rainfall typical of this Alpine area. Overall, supplementary irrigation provided modest agronomic benefits. Longer monitoring is needed to disentangle treatment effects from interannual climatic variability and to assess potential cumulative changes in sward structure. From an animal perspective, the late-season CP increase may help counteract the seasonal decline in forage quality. Future work should also integrate water efficiency, logistic constraints and animal-level outcomes to support adaptation strategies.



**Nutritional value and digestibility of Alpine herbs in Switzerland**

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Mountain regions and alpine pastures account for a large proportion of Switzerland's agricultural land. However, existing data primarily address basic roughages, and knowledge of alpine forage herbs remains limited. This ongoing study aims to determine and compile the nutritional value and digestibility of alpine herbs. As further species will be analyzed, the results presented here are preliminary. Forty-eight species of mountain and alpine herbs were collected in Switzerland in the cantons of Uri, Ticino, Obwalden, Fribourg and Bern. For each species, 500 grams of fresh plant material was sampled. Dry matter (DM) and ash contents were determined by thermogravimetric analysis. Crude protein and crude lipid contents were analyzed chemically. In vitro organic matter digestibility (IVOMD) and net energy for lactation (NEL) were estimated using the Hohenheim gas test. Crude protein concentrations ranged from 66 to 308 g/kg DM, with the lowest values found in Leucanthemum vulgare and the highest in Peucedanum ostruthium. IVOMD ranged from 41.9 to 75.4%, with the lowest values observed in Rubus idaeus and the highest in Chenopodium bonus-henricus. NEL ranged from 3.66 to 6.71 MJ/kg DM, with the highest values observed in Ranunculus aconitifolius and Peucedanum ostruthium. Several alpine species exhibited high forage value, particularly Centaurea montana, Prunella vulgaris, Campanula barbata, Plantago alpina and Urtica dioica, due to high nutrient and energy contents combined with good digestibility. However, Prunella vulgaris and Urtica dioica are nutritionally valuable only when included in small proportions. Most species showed moderate to low digestibility and energy values, likely due to advanced developmental stages at the time of harvest. Comparison of results is limited by the scarcity of data on alpine herbs and differences in developmental stage between alpine plants and those from lowland regions. Nutritional value and digestibility are influenced by factors such as climate, altitude, soil type, harvest stage and chemical composition. In addition, palatability represents an important aspect of forage evaluation but was not assessed in the present study.

**Alpine Pig Production – Improving Advisory Services through a Practical Guide**

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Using whey, a by-product of cheese production, to fatten pigs on Swiss alpine farms has a long tradition and is an important element of the circular economy. Knowledge about alpine pig husbandry was historically passed on informally, but increasing staff turnover has created significant gaps. Training for alpine staff still concentrates on cattle and cheese-making, while pig management receives little attention. This often leads to missing production knowledge and delayed detection of management problems. This study aimed to develop a practical guide that supports alpine staff and advisors in managing pigs during the summer season. The guide covers key topics relevant for both newcomers and experienced operators. The work was based on a literature review, written inquiries to feed suppliers, and two expert workshops using focus group methodology. The literature review showed that research on alpine pig production is very limited and that staff often lack access to reliable information. The resulting German-language guideline is divided into two main parts. Part 1 covers preparations before pigs are moved to the alp, including legal requirements, infrastructure, schedules, and market aspects. Ration planning with complementary feed and whey treatment plays a central role. Transport, documentation, vaccinations, deworming, and medication management are also addressed. Part 2 focuses on herd management on the alp. It offers practical recommendations on feeding, starting with adaptation to whey-based diets and adjusting rations as needed. A core element is a daily checklist that supports systematic observation of herd and individual animal status. As information on alpine pig farming remains scarce, the developed guideline should now be tested in practice. Distribution to selected alpine farms for one season, followed by a user survey, would allow evaluation and refinement of the guide.



**The Black Alpine Pig in Extensive Mountain Farming Systems**

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In the past, every Alpine region had its own variety of pig (no classification of breeds at that time). In 1827, J.R. Steinmüller divided these varieties in two main types: the large, heavy lowland types (white or pink) and the smaller mountain pigs, which were more agile thanks to shorter backs and longer legs. He grouped the latter under the umbrella term ‘black Alpine pigs’ because most of them were black. At the end of the 19th century, British high-performance breeds came to Europe. Large white and improved Landrace pigs almost completely replaced the old breeds. A sensational discovery in Italy in 2013: veterinarians from University of Parma discovered remains of the ancient Valtellina/Grison type. Later, remains of Samolaco (Chiavenna) and Ultner Schecken (South Tyrol) are added. Each relic population individually was not viable. They were grouped together as ‘Black Alpine Pig’ (Schwarzes Alpenschwein SAS). The Alpine Network Pro Patrimonio Montano took over the breeding programme (with herd book) with 3 male and 7 female breeding lines. That the genetics are independent of other breeds was subsequently confirmed by genotyping at LMU University Munich. By end of 2025, there are again 51 small breeding groups, 24 in Switzerland, 14 in Italy and 13 in Austria, with some 160 breeding animals. In addition, fattening farms are relieving the breeding farms. The animals are only placed in mountainous areas so they retain their high level of mobility. Thanks to their undemanding nature, robustness and winter hardiness, they are predestined for extensive free-range farming. Studies by FiBL show, they help prevent degradation of alpine pastures. Their constant movement and eating numerous mountain grasses and herbs results in excellent product quality. Products from extensive farming with above-average taste have a bright future. Customers no longer want products that grow to slaughter weight in record time, but rather slowly developed meat that has already matured in the body. Alpine pigs can deliver this and also command the necessary price. A Europe-wide protected label helps with marketing.

**Controlling bracken fern through grazing with Black Alpine Pigs – a case study**

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The invasive spread of bracken fern (Pteridium aquilinum) is a major problem on extensively used pastures at higher altitudes. The fern, which is poisonous to many animals, outcompetes forage plants suitable for grazing, leading to a loss of pasture areas and a decline in biodiversity in mountain and alpine areas. As mechanical control of bracken is very labour-intensive, these overgrown pasture areas are increasingly being abandoned. There are anecdotal reports that pigs of the traditional breed Black Alpine Pig foraged on bracken without showing any adverse health effects. Based on these observations, a small on-farm case study was conducted as part of the Farmer Science project over a three-year period from 2022 to 2024: SAS pigs (n = 14) grazed on areas that were overgrown with bracken on the Soladino Alpine pasture in Vallemaggia (Someo), Ticino, each year from May to October. The grazing area per pig ranged from 234 m² to 503 m². The development of the bracken plant population during the grazing season was recorded using GPS measures. The health status of the animals was documented and the content of the plant toxin ptaquiloside was determined by laboratory analysis of muscle meat, liver and kidneys after slaughter. The pigs were slaughtered at different times after the last day on pasture: after 2 days, 4 weeks, 8 weeks and 14 weeks. The bracken population on the trial areas was reduced by 80 to 100% by the grazing SAS pigs during one Alpine season. However, grazing for only one year did not have a lasting effect. Repeated grazing as well as subsequent sowing of fast-growing pasture mixtures proved to be beneficial. In all muscle meat, liver and kidney samples of the slaughtered pigs, the ptaquiloside content was below the measurable value of 0.2 mg/kg. The time of slaughter therefore did not influence the ptaquiloside content. The animals showed no signs of discomfort or poisoning at any time. Daily weight gains during fattening were within the expected range for the breed. The results of this case study suggest that controlling bracken through grazing with Black Alpine Pigs is promising when combined with appropriate management. Further research to optimise the approach could provide additional practical support.



**The role of Polish Red cattle in sustainable development of mountainous regions in Poland**

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Extensive breeding of indigenous cattle is an important component of sustainable agriculture and rural development. Ecological livestock systems based on natural grasslands help maintain managed landscapes, prevent land abandonment, and support environmental policy objectives, while contributing to animal health, biodiversity, and the nutritional quality of animal products. The aim of this study was to present the advantages of ecological milk production based on Polish Red cattle, an indigenous breed maintained in the mountainous region of southern Poland. This breed is well adapted to harsh environmental conditions and is characterized by efficient utilization of low-cost forage, high disease resistance, good fertility and longevity, ease of calving, high calf survival rates, and strong legs and hooves. The studied animals originated from two herds: a conservation herd (A; 27 cows) and a genetically improved herd (B; 30 cows). Cows were kept in a loose housing system and fed exclusively on grass-based diets, with grazing in summer and wilted grass silage and hay in winter, without concentrate supplementation. Pastures were fertilized only with manure. Milk yield and protein content were similar in both herds (approx. 3,500 kg and 3.3%, respectively), while fat content was higher in the improved herd (4.8%). Milk from grazing cows showed markedly higher levels of PUFAs, particularly CLA, linoleic, and α-linolenic acids. Despite relatively low milk yield, the milk of Polish Red cows is distinguished by high biological quality and a high casein content, making it particularly suitable for cheese production. However, due to relatively low milkability, even with existing subsidies supporting the conservation of genetic resources, the economic viability of farms based on this breed often requires the undertaking of additional activities, such as agro-tourism and on-farm cheese production. Polish Red cattle, despite their relatively small population, continue to play an important role in preserving local biodiversity, protecting mountain ecosystems, and maintaining traditional farming practices and cultural heritage.

**Animal Welfare and Cultural Heritage in Alpine Transhumant Dairy Systems of Valtellina (Italy)**

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Alpine dairy farming in Valtellina (Italy) reflects a long cultural continuity shaped by transhumance and the communal management of high-altitude pastures. Of the 68 alpine pastures historically documented in Valmalenco, only 27 remain active today, illustrating both resilience and vulnerability of this pastoral system. During the 2022 summer season, as part of an international research project led by the Faculty of Agricultural and Forest Sciences (UNLP, Argentina) an adapted Welfare Quality® protocol was applied in three dairy farms operating on alpine pastures in Lanzada, Sondrio: Alpe Gembrè, Alpe Campagneda and Alpe Prabello. Data collection combined animal-based indicators (behaviour, ease of handling, clinical signs) with management information (pasture rotation, water access, supplementation, sanitary records). This was complemented by surveys exploring producers' perceptions of tradition, innovation and future challenges. Results show strong family-based organization, rapid response to animal health issues, and nutritional strategies finely tuned to mountain conditions. Notably, cows displayed high levels of trust toward familiar handlers, highlighting individualized human–animal relationships in these systems. While producers identified sensory superiorities in alpine milk, they expressed significant concerns for the next decade regarding labor availability, generational turnover, and economic viability of maintaining traditional transhumant systems. Findings suggest that integrating traditional ecological knowledge with welfare-oriented monitoring serves as a dual strategy: ensuring animal health while reinforcing the sustainability and preservation of alpine pastoral heritage.



**Population structure and genomic inbreeding in Spectacled Eye Sheep from Europe**

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Spectacled Eye sheep breeds of the Alpine region are regarded as rare livestock populations. Although close to extinction in several countries in the early 20th century, sustained breeding efforts by individual breeders ensured their survival. Today, populations of Spectacled Eye sheep breeds exist in Austria (Kärntner Brillenschaf), Italy (Villnösser Brillenschaf), Germany (Brillenschaf), Slovenia (Jezersko-Solčava sheep) and Switzerland (Spiegelschaf), with 500 to 8,000 animals per country. These breeds share a characteristic coat color pattern with pigmented markings around the eyes and a depigmented white fleece. A phenotypically similar breed, the Causse du Lot (CDL) from southwestern France, comprises approximately 100,000 animals. To our knowledge, the genetic relationship between these phenotypically similar breeds has not previously been investigated. We therefore analyzed population structure and genomic inbreeding in Spectacled Eye sheep populations. The 50k SNP genotyping data were generated using genomic DNA samples from newly collected samples from Spectacled Eye sheep breeds from Austria (48, AT), Italy (5, IT) and Switzerland (18, CH). This data was merged with available SNP genotyping data from sheep from Slovenia (23, SLO), Switzerland (53, CH), and France (20, CDL). A total of 167 animals were analyzed for approximately 32,000 SNP markers. MDS analysis showed a clear genetic differentiation between the cohorts analyzed, depending on their origin. The sheep populations from IT and SLO clustered closely together. Accordingly, the smallest pairwise Fst values were observed between IT and SLO (0.047), and the highest between AT and CDL (0.094). Some small pairwise relationships of ≤ 5% were observed between AT and SLO animals. Genomic inbreeding (FROH) was the lowest for SLO animals (3.5%) and the highest for CH animals (7.3%). Overall, our findings indicate genetic differentiation among Spectacled Eye sheep populations and limited past gene flow.

**Ecosystem Services of Sheep Farming in Mountain Regions of Europe**

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Sheep farming systems in mountain regions provide Provisioning, Regulating and Maintenance, and Cultural services to society. In Europe, these mountain regions are growing in importance due to their potential benefits related to resilience, food security and landscape conservation. Sheep remain an important part of these mountain agroecosystems and can therefore contribute to deliver Ecosystem Services to local and non-local communities. We explored the multifaceted contributions of mountain sheep farming in different regions of Europe through a review of scientific, international literature on Web of Science and some local literature available. We found that past research focused on Regulating and Maintenance services, whereas Provisioning and Cultural services were less observed. When comparing country contributions, Spain is the main producer of research papers, followed by Italy and Switzerland. Most of the reviewed studies focused on a single ecosystem service, whereas fewer studies adopted a more integrative approach by addressing multiple Ecosystem Services. The most studied aspect was the effect of grazing on habitat maintenance, followed by land use change, food quality and grazing as a management tool for natural protected areas. Our findings suggest that sheep farming can support the maintenance of mountain ecosystems under well-managed, intermittent grazing regimes, while its absence may also drive spatiotemporal land-use changes with potential negative effects on ecosystem service delivery.



**Evolution of ecosystem services in the Spanish Central Pyrenees**

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Many European mountain communities have experienced an economic shift from agricultural to tourism-based activities, largely influenced by agricultural modernization and wider socioeconomic and political factors. This has led to widespread agricultural abandonment in remote areas, and intensification in the valleys. Here, we aim to explore the implications of such transitions in mountain ecosystem services (ES) across three valleys of the Spanish Pyrenees. These are characterised by different trajectories of evolution between 1990 and 2018. Broto presents a constant population, decreasing agriculture, and increasing tourism centred in the Ordesa and Monte Perdido Natural Park. Benasque experiences increasing populations, decreasing agriculture and increasing winter ski tourism. Finally, Baliera shows a decreasing population trend, stable agriculture and limited tourism development. To assess changes and trade-offs between ES, we used the ARIES platform (Artificial Intelligence for Ecosystems and Sustainability) to estimate cultural (tourism recreation), provisioning (biomass grazed in pastures) and regulating (organic carbon stored in soil and vegetation) ES. Preliminary results show that cultural ES increased in Broto (2.2%) and decreased in Benasque (-0.7%) and Baliera (-3.5). Regulating ES remained constant in Broto and Benasque while drastically decreasing in Baliera (-89.1%). Provisioning ES decreased in all valleys, with more drastic reduction in Broto (-25.2%) and Benasque (-28.1%) than in Baliera (-13.5). These trends show trade-offs between ES and their beneficiaries. For instance, cultural ES increased in Broto, which is often enjoyed by visitors, while provisioning ES, linked to livestock activity and local employment, decreased. Land abandonment is perceived as a problem by local populations but benefits the wider population in the mid to long term through carbon storage and climate change mitigation. We observed a decrease in both regulating and provisioning ES in Baliera. Further analysis will fine tune ARIES global models to suit the area and to explore who benefits from land use changes.

**Effect of origin and experience on cattle habitat selection in mountainous rangelands**

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The choice of breed is a key management decision in heterogeneous ecosystems, such as mountainous rangelands. However, breed alone does not fully explain how animals use grazing areas. Among others, learning processes play an important role in shaping habitat selection. This study evaluated habitat selection behaviour in a herd of 50 Berrenda cows grazing a 4000-ha mountainous rangeland farm located in Granada, Spain. Part of the animals were born and raised on the farm, whereas other were introduced from another farms as adults. Over three grazing seasons, 27 cows were equipped with GNSS tracking collars to collect their location at 30-min intervals. Digital elevation models (DEM), and vegetation cover and topography maps were obtained from public repositories of the Spanish Government. Slope, aspect and elevation maps were calculated from the 5-m resolution DEM. Distances to water from each GNSS position were calculated. Spatial data processing was performed using QGIS and RStudio. Differences in habitat selection between farm-born and introduced cows were analysed using a Resource Selection Function (RSF) with a binomial function based on cow origin. Slope, aspect, elevation, vegetation type and distance to water of each cow location were used as explanatory variables, together with their interactions. Season was included as a fixed effect while year was considered a random variable. Results of the RSF showed that season has a significant effect on the selection behaviour of cows depending on their origin. However, geomorphological variables did not show a significant effect, except for the interaction between slope and elevation, for which farm-born cows showed a negative trend (-0.07; SD = 0.01). Regarding vegetation, forested areas exhibited the strongest negative association with the selection of farm-born cows, both as a main effect (-4.61; SD = 1.81) and through the interactions with distance to water, elevation and aspect. Habitat selection differs between cows born and raised on the farm conditions and those introduced from external environments. Further research should assess additional spatial patterns, such as daily movement trajectories and home-range characteristics.



**Animal genetic resources and summering – a closer look**

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We present data of livestock holdings and of livestock populations in Switzerland over a 16-year period in the case of cattle and a 6-year period in the case of small ruminants. The data is retrieved from the national animal movement database. We show the geographical presence of livestock herds at the end of each month, and on July 25th, the official census date for the calculation of the number of livestock kept in the summering zone. We dive into the seasonal dynamics of the geographical distribution of livestock production types such as dairy, beef, rearing and fattening, and shift this topic also to the breed level. Thereby, we decipher the evolution and involvement over time of the mentioned production types and breeds in transhumance and summer mountain grazing. We put a particular focus on breed populations designated as Swiss animal genetic resources. We discuss, quantitatively, the current role of those local, site-adapted breeds within the entire Swiss livestock system and show their relative importance in the field of summer pasture grazing, biodiversity and ecosystem services.

**Pastoralism in arid and semi-arid zones of Africa**

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Pastoralism is the dominant ruminant livestock production system in Africa, particularly in arid and semi-arid regions where environmental constraints limit crop production. These systems efficiently exploit marginal resources and rely on livestock mobility and adaptive management strategies to cope with the strong spatial and temporal variability of natural resources. Beyond food production, pastoral systems provide important ecosystem and socio-economic services. Livestock represents a major form of capital for rural populations, contributes to soil fertility through organic fertilization, supports biodiversity in rangelands, and plays a central role in the cultural and social organization of pastoral societies. However, pastoral systems are increasingly facing multiple and interconnected challenges. Climate change is leading to rising temperatures, shifts in rainfall patterns, and more frequent droughts, which affect rangelands by altering biomass production, plant species composition, pasture quality, and seasonal forage availability. These changes reduce rangeland productivity and resilience, placing additional pressure on pastoral livelihoods. At the same time, pastoral lands are progressively shrinking due to agricultural expansion and the development of protected areas, which may restrict access to key grazing resources and transhumance corridors. These processes contribute to the fragmentation of pastoral landscapes and limit herd mobility, a key component of pastoral sustainability. In this context, research efforts should focus on improving the monitoring of rangeland dynamics under climate variability, analysing livestock feeding behaviour and adaptation to heterogeneous grazing resources, and identifying pathways that strengthen the resilience of pastoral systems while improving land-use coexistence between pastoralism, agriculture and conservation.



**Austral rangelands: Challenges in Patagonian Ranching and a Behavioral Approach to Grazing Heterogeneity Inspired by New Zealand hill and high country Livestock Systems**

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We present a snapshot of rangeland farming in Patagonia, a region of South America, sometimes referred to as "the end of the world". We describe its heterogeneity, provide historical context and present some of the factors that have led to abandonment of these extensive farming practices. Specific features of the Patagonian landscape make livestock distribution and grazing management a challenge, with the need to manage access to winter pastures with their scattered and scarsed yet rich temporal and permanent wetlands meadows called "mallines", as well as in the summer high land pastures called "veranadas" where steep and rugged terrain remains mostly ungrazed. We then describe a "grazing personality model" (GP-model) formulated in the hill- and high-country grasslands of New Zealand, which was aimed at identifying individuals with more explorative behaviors using gene markers. Grazing personality genetics may provide a cost-effective approach to tackling grazing heterogeneity challenges in rangelands of the Southern Hemisphere.

**Pastoralism in the Asian steppe: High livestock numbers and climate change threaten the health of pastures and the livelihoods of local populations**

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Rangelands cover over 50% of the global land area and provide natural resources for herders and their livestock, mainly in desert areas. The largest contiguous arid region on Earth is the steppes of Central Asia and Mongolia. In Mongolia, about 1/3 of the population is engaged in pastoralism. Due to extreme climate and limited natural resources, nomadic herders there practice a very mobile and flexible form of pastoralism, frequently changing their camp sites throughout the year. For millennia, pastoralism in Mongolia was practiced at a subsistence level. During the Soviet era from the 1920s to 1991, herders belonged to collective cooperatives. With the fall of the Soviet Union, Mongolia transitioned to a market economy. This led to an increase in livestock numbers, peaking in 2019 with over 70 million animals. The high livestock numbers and climate change are considered the main causes for land degradation in Mongolia. Mongolia is facing a 2°C rise in temperature and changing precipitation patterns. Extreme winter events are becoming more frequent, leading to livestock mass mortality. Climate change, high livestock numbers and social changes threaten rangeland health and the livelihoods of nomadic herders who depend on healthy pastures. Further research is needed on natural resources and rangelands at various spatial scales and under the impact of climate change. In addition, more links between ecological and social studies are needed to better understand the complex systems of pastoral livelihoods.



**Using Genetic Monitoring for Evidence-Based Management of Large Carnivores in the Alps**

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Large carnivores are among Europe's most charismatic — and most controversial — wildlife. Once heavily persecuted and driven to extinction or near-extinction across much of the continent, they have staged a remarkable comeback over recent decades, reclaiming large parts of their historic range. While this recovery is rightly celebrated as a conservation triumph, it brings real and pressing challenges, as communities re-learn how to share landscapes with ancient competitors in the heavily modified environments of modern Europe. Meeting these challenges requires thoughtful, evidence-based management. Advances in molecular genetics now give us powerful tools to support that. Genetic monitoring allows us to accurately track the abundance and distribution of large carnivore populations and understand how they grow and spread. It also allows us to study their diet and feeding behaviour, helping us better assess their actual impact on wild prey and livestock. Finally, it allows us to closely monitor their conservation status from genetic as well as from demographic perspective. This knowledge is indispensable — both for designing effective conflict-mitigation measures and for providing a rigorous scientific basis for any management interventions, whether removing problem individuals or regulating population numbers. None of this is simple, and the costs of coexistence are not borne equally. Our societies are often increasingly polarized regarding large carnivores' conservation and management, but it is the farmers, herders, and rural communities living alongside these animals who carry the heaviest burden. Large carnivores are key components of European ecosystems and a shared natural heritage worth protecting — but their conservation must go hand in hand with genuine support for the people most affected. This is the only way to build trust, and trust is the only foundation on which any true coexistence can be based.

**Sámi reindeer pastoralist system facing anthropogenic land use pressure: Considering limitations in access to pasture, what characterizes herding communities that still have room to adapt to climate change?**

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Reindeer (Rangifer tarandus) have been domesticated by the Sami indigenous people for about 400 years through an extensive pastoralist system in which production depends on climatic conditions and land availability. In response to climate change and resulting habitat loss, reindeer herding strategies evolved over time to reinforce or maintain productivity. Wind turbine expansion has grown substantially, by over 2-fold in 8 years, and mine exploitation continues, with 13 active mines in Sweden. This anthropogenic land use destroys suitable reindeer habitat, forcing reindeer and herders to seek alternative grazing areas, often at the expense of high-quality pasture. With this study, we aimed to define the characteristics of the reindeer herding communities (RHC) that mitigate the effects of wind turbines and mines on herd productivity. We focused on the 51 RHC in Sweden practicing different herding systems (migratory, sedentary, or with specific boundaries and permissions). We divided our analysis between the summer and the winter areas. We compiled calf slaughter data and herd sizes stored by the Sámi parliament between 1996 and 2024. We gathered data on the positions of wind turbines and mines recorded in the RenGIS database. Then, we fitted four separate linear mixed-effects models, two assessing the influence of wind turbine density or mine presence, respectively, on calf slaughter weight in the summer area, according to the herding system. The other two were testing their effects on herd size in winter. We found that mountain RHCs that use migration routes are more sensitive to anthropogenic disturbances than other, more sedentary herding systems. Given the importance of flexible pasture selection for responding to climate change, assessing herd productivity in relation to anthropogenic activities is essential for determining the scope for adaptation in reindeer herding systems.



**Farmers' perspectives on large carnivores damage prevention tools and management alternatives in mountain livestock systems**

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Mountain livestock systems where large carnivores are present require farmers to make management decisions to reduce the risk of attacks to livestock while maintaining the economic viability and work quality on their farms. In these contexts, the acceptance and uptake of damage prevention tools, farm management adjustments and damage compensation schemes are key elements that shape long-term coexistence of livestock and wild predators. Understanding how farmers evaluate these alternatives in different livestock farming systems is therefore essential to assess the viability of coexistence strategies. This study analyses data from a face-to-face farmer survey (n=107) conducted in four different case study areas located in two mountain ranges in Spain: the Central Mountain System and the Cantabrian Range. The survey captures farmers' perspectives on livestock–wildlife interactions and their views on a wide range of management and damage prevention tools, compensation schemes and their attitudes towards different large carnivore population management options. It also addresses the extent to which livestock attacks and carnivore presence influence decisions related to grazing practices, herd management and the intention to persist in the farming activity. The results indicate that farmers' perceptions of damage prevention tools are shaped by their perceived effectiveness, feasibility, and particularly their perceived compatibility with existing farming practices. Attacks on livestock were also found to influence longer-term farm management choices and risk perceptions. Overall, our study suggests that the potential effectiveness of damage prevention and compensation alternatives depends not only on their technical design, but also on how they are socio-cultural perceived and trusted and on the extent to which farm management must be modified to uptake them.

**Infection pathways of animal diseases transmitted on alpine pastures, using tuberculosis as an example**

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Austria has been officially bovine tuberculosis (TB) free since 1999. Since 2008, however, sporadic cases of TB in cattle have occurred in the western Austrian federal states of Tyrol and Vorarlberg. Simultaneously, cases of TB in red deer (cervus elaphus) were recorded in western Austria and Bavaria, caused by Mycobacterium (M.) caprae. In so-called TB hotspots, temporary prevalences of more than 30% were observed in red deer. Studies have shown that red deer in Alpine regions act as maintenance hosts of M. caprae and can transmit the pathogen to cattle through direct or indirect contact during the summer grazing season on Alpine pastures. TB poses a threat to animal health, food safety and, as a zoonosis, to humans. Infections of cattle in Alpine regions also constitute a challenge to the agricultural cultural heritage of summer grazing. To better control the disease, this study investigates infection pathways, how TB spreads between red deer, and particularly focuses on the transmission to and between cattle. Data from the last 10 years provides an overview of the evolution of TB in different regions. Whole Genome Sequencing (WGS) helps to analyse the genomic connection between selected samples from red deer and cattle using Ridom SeqSphere+. Geographical and epidemiological information is collected including movement history of cattle and contact tracing during summer grazing season and is compared to the genomic findings. This information helps to reconstruct time, place and spread of infection. Preliminary results show that cattle become infected either from red deer on the Alpine pasture or from other cattle on the farm or the pasture. The results will provide more knowledge about TB transmission and could help to fight the disease more effectively.



**Assessing the use of virtual fencing for managing European Bison in the Swiss Jura – a pilot study**

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The Wisent Thal project, located in the Jura region of Switzerland, explores the reintroduction of European bison (Bison bonasus) to promote species conservation and natural restoration. The rewilding project faces challenges in balancing the management of bison movement with human land use. A potential approach is to integrate virtual fencing (VF), previously effective for livestock management, to guide a bison herd within designated areas. However, VF has not yet been used for wild species. Thus, this study aimed to test VF in European bison by examining their learning behavior and behavioral responses during VF adaptation. Four leading females from a herd of eleven bison were equipped with VF collars (Nofence AS, Batnfjordsør, Norway) that emitted audio tones (AT) and electric pulses (EP) when crossing a virtual boundary. The study consisted of a training phase at attractive rapeseed plots and a main trial in which the herd was moved between two adjacent paddocks enclosed by electric fences and separated by a virtual fence. The bison showed learning progress during training but did not apply it to the main trial. The VF system failed to contain the herd. Signal counts and escapes per animal per day increased from training (4.3 ± 6.7 AT, 1.9 ± 4.3 EP, 0.2 ± 0.7 escapes) to the main trial (10.7 ± 11.4 AT, 5.1 ± 5.8 EP, 1.4 ± 1.4 escapes). Key findings include: 1) Bison require longer VF training than cattle; 2) Collared animals were greatly influenced by uncollared herd members, compromising individual learning; and 3) Factors such as inaccurate positioning, battery lifetime issues, animal morphology, and group dynamics may have contributed to the VF system's limited effectiveness. While VF showed little success in this pilot study, the results highlight the importance of considering species-specific constraints. Effective VF application in European bison may require protocol adaptations, such as extended training, collaring the full herd, and refining technical aspects to address the species' morphology and spatial behavior.

**Farmers' perspectives on the legitimacy of the governance of the livestock and large carnivores' conflict in mountain areas**

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Effective governance of the human-carnivore conflict in the context of mountain livestock systems depends not only on technical solutions, but on socio-political aspects such as farmers' trust in stakeholders and perceptions of fairness and legitimacy of governance processes. Farmers' acceptance and uptake of tools and strategies to reduce large predator damages are closely linked to their views of the governance process of wildlife-livestock interactions. This study analyses data from a face-to-face farmer survey (n=107) conducted in four different areas located in two mountain ranges in Spain: the Central Mountain System and the Cantabrian Range. We examined farmers' trust in different stakeholders involved in the management of wildlife-livestock interactions, such as farmer institutions, technicians, environmentalists, as well as their perceptions of justice and equity within the current governance arrangements. The study further explores farmers' views on policies, including whether decision-making processes are perceived as knowledge-based and inclusive of farmers' interests, and how farmers perceive social recognition of their activity. The results point at consistent patterns across sites in relation to trust and legitimacy perceptions, with clear differences between stakeholders closer to farming and those more distant from local realities. Finaly, our findings seem to indicate that the reduction of farmer-carnivore conflicts in mountain livestock systems requires governance approaches that strengthen trust, enhance fairness perceptions, and meaningfully incorporate farmers' knowledge and perspectives, alongside ecological and technical objectives.



**Measuring resilience at the farm level: Do objective and subjective indicators tell the same story?**

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Mountain livestock farming systems face increasing socioeconomic and environmental pressures that threaten their long-term viability, reflecting broader challenges across livestock systems and placing farm resilience at the centre of academic and policy debates. However, resilience remains methodologically underdeveloped, particularly regarding its operationalisation through farm-level indicators. The extent to which objective and subjective approaches capture distinct, complementary, or overlapping dimensions of resilience remains poorly understood, and comparative analyses integrating both perspectives are scarce. This study addresses this gap by comparing objective and subjective indicators of resilience in livestock farms within and beyond mountain farming contexts. We conducted a face-to-face farmer survey (n=221) across five livestock farming systems: dairy sheep and beef cattle in mountain areas, dairy goat and pig production in non-mountain areas, and meat sheep as an intermediate system used seasonally in mountain areas. We analysed correlations between 93 objective and 26 subjective indicators of farm resilience attributes, collected through the survey, to assess their degree of correspondence and whether farm characteristics are related to famers' perceptions of resilience. We found 36 significant correlations linking 36 objective indicators with 18 subjective indicators, indicating partial alignment between farm characteristics and farmers' perceived resilience. Objective indicators related to the resilience attributes honours legacy, social support, knowledge and innovation networks, and farm local interdependence showed a strong correlation with subjective indicators. Other objective indicators did not align empirically with farmers' understanding of farmers, suggesting that, in these cases, objective and subjective indicators capture different dimensions of the concept. These findings highlight the need for integrated assessment frameworks that explicitly combine objective and subjective indicators, rather than favouring one approach over the other.

**Perception of unfavourable topography as a barrier to grazing in Europe**

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Understanding constraints on grazing is important for improving the sustainability of grassland-based systems. A survey among young livestock farmers and students (≤40 years) across eight countries assessed the perceived barriers to grazing. Unfavourable topography was an important perceived barrier (Table 1), defined as terrain too steep for successful grazing management. Table 1. Respondents who chose unfavourable topography in their top five most important barriers to grazing, main ruminant species, and mean slope of grasslands in eight countries. CountryRegionTopography as barrier (%)Main species (C=cattle, S=sheep)Mean slope of grasslands (%)*ItalySouth Tyrol50C19.9Sardinia25S6.7Portugal31S4.5Ireland27C3.1France22C5.7Romania14S5.6Germany9C3.2The Netherlands4C0.4Sweden3C1.8*Mean values of the LUCAS survey points (https://esdac.jrc.ec.europa.eu/projects/lucas) according to the EU-DEM digital elevation model (https://ec.europa.eu/eurostat/web/gisco/geodata/digital-elevation-model/eu-dem) Table 1 closely reflects landscape structures. Mountainous and rugged regions such as South Tyrol, but also Mediterranean upland areas in Sardinia and Portugal, showed high percentages of respondents perceiving topography-related barriers. Steep slopes and fragmented parcels constrain herd mobility, increase labour requirements, and complicate infrastructure development. Steeper slopes are also partly associated with a higher prevalence of sheep grazing relative to cattle grazing, reflecting species-specific adaptations to terrain steepness. In contrast, in the Netherlands and in large parts of Sweden that are dominated by lowland or gently rolling terrain, topography is rarely perceived as a barrier. Intermediate values likely reflect heterogeneous landscapes within countries. Understanding how terrain interacts with farming structures and regional conditions can help to develop optimal grazing strategies and policy measures to support grassland-based livestock production systems across Europe.



**Dairy goat systems productions in alpine mountains area: sustainability and profitable approach**

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Dairy goat farming in the alpine regions like South Tyrol plays a niche but increasingly important role in mountain agriculture, offering potential solutions to the challenges faced by traditional dairy cattle farms. This study investigates the economic viability and environmental impact of ten dairy goat farms in the region through a combination of full-cost accounting and life cycle assessment (LCA). Economic data were collected via farm visits and interviews, while environmental impacts were assessed using openLCA, applying both per-kilogram and per-hectare functional units.Results reveal substantial heterogeneity among farms, with income levels highly dependent on subsidies and herd size. Fixed costs significantly exceed variable costs, and without public support, many farms operate at a loss. Despite this, farmers show strong commitment to continuing milkproduction and improving yields. The environmental analysis shows that GWP100 and other impact indicators vary widely depending on the chosen functional unit, with per-hectare assessments favouring extensive systems. A significant relationship was found between farm income andGWP100, suggesting a trade-off between economic and ecological performance. Thus, we conclude, that targeted efficiency improvements—such as structured breeding programs and better forage quality—could enhance sustainability without increasing herd size. These findings providevaluable insights for policymakers and stakeholders aiming to support resilient and environmentally sound dairy goat farming in alpine regions.

**Is valorisation within the textile sector economically viable for local alpine wool? Evidence from a regional break-even analysis**

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Due to its lower fibre quality relative to specialised wool breeds, wool from sheep reared in the Alps is regarded as a low-value by-product, more often managed as a problem than exploited as a resource. Although shearing is mandatory to ensure animal welfare and represents an unavoidable cost, the economic sustainability of wool valorisation depends on the additional costs incurred after shearing. This study evaluates whether valorisation within the textile sector can offset these incremental costs in mountain sheep farming systems. The Pura Lana Piemontese ("pure Piedmontese wool") project implemented a regional-scale system for the collection of greasy wool in Piedmont (NW Italy), combined with qualitative selection and certified analyses to assess textile suitability. During 2023–2025, 151 farms (about 38,000 sheep) delivered around 148 t of greasy wool to 3 authorised collection centres. Wool was then manually sorted into quality classes based on fibre traits, and selected lots were analysed in accordance with IWTO standards. Results show mean fibre diameters of 34–35 µm and scoured yields of 58–62%, confirming the coarse, heterogeneous nature of wool from non-specialised breeds. Potential market prices ranged from 0.20 to 0.80 € $kg^{-1}$, depending on quality. A techno-economic assessment estimates post-shearing costs at approximately 0.60 € $kg^{-1}$, including storage, transport, manual selection and certification. Under current conditions, the break-even point is explicitly quality- and organisation-dependent, with only higher-quality lots approaching or exceeding the operational threshold. Economic viability therefore depends on scale effects, improvements in on-farm wool quality, logistical efficiency, and regulatory frameworks. While textile valorisation alone does not yet guarantee profitability, a regional supply chain may represent a key component of integrated strategies to improve the sustainability of mountain livestock systems.



**Dairy steer fattening to replace suckler beef systems in mountain regions**

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Traditional mountain dairy farms are shifting to suckling beef production: less labor intensive allowing working outside the farm for small structures typical to the mountain region and well adapted to the extensive alpine pastures. However, the use of suckler cows is problematic when considering both the rising recreational use of alpine pastures where suckler cows graze and the inefficiency of suckling beef from an environmental perspective. About 60'000 Swiss organic dairy cows produce yearly about 30'000 male calves, for a large part with 100 % dairy genetics because of the ban on sperm sexing. Organic beef fatteners have no interest in theses calves because of their poor fattening potential, worsened by the frequent use of small-framed dairy cattle by organic farms because of their efficiency to use grassland to produce milk. As a result, organic calves largely end up in conventional fattening units. The shortage of organic Swiss meat would be an opportunity to use these male dairy calves as steers to produce organic meat. The lesser growth potential of dairy steers would be compatible with extensive seasonal alpine pastures, and steers are better compatible with the recreational use of alpine pastures than suckler cows. Replacement of suckler cows by fattening steers may also spare up to 22% CO2 emissions per kg of meat. Important issues remain to be solved. Organic legislation requires feeding these calves full organic milk, which current price results in male calves being too expensive at weaning compared to their fattening potential. Further, cubicles are a well spread housing system for suckler cows in Switzerland but this housing system is less well suited to fattening steers. Last but not least, poor meat yield of the dairy steer carcasses is regarded as detrimental to meat quality by the meat industry. Several studies showed this is a misconception, yield of noble cuts and meat quality can be comparable to beef cattle. Opportunities to use male calves from organic dairy farms in mountain regions to supply the demand for organic meat are present. However, the issues to address necessitate the involvement of the whole chain, from the dairy farmers to the meat retailers. Currently, the lack of interest of the former and the misconception of the latter remain main hurdles.

**Working Conditions on Alpine Farms – From Shepherds to Cheesmakers**

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In December 2023, the Swiss Alpine Season, with its various ecological, cultural and economic functions, was recognised as an immaterial UNESCO cultural heritage. The value of practices associated with the Alpine season in Switzerland is widely acknowledged. To preserve this cultural heritage and cope with increasing pressures such as climate change, seasonal workers require in-depth knowledge and a wide range of skills – from animal husbandry and pasture management to interacting with tourists and administrative tasks. However, such workers are in short supply and rarely stay on alpine summer farms for long periods of time. We therefore launched a research project to investigate the reasons why seasonal workers do not return to alpine farms, or do so only in the short term. Our study, which comprised an online survey (n = 366) and in-depth semi-structured interviews with alpine farm workers (n = 13), shows that the reasons are manyfold: Conflicts with employers and colleagues or hard and long working hours combined with low wages are relevant factors. However, one of the main reasons why seasonal workers do not return to alpine farms is that they often experience difficulties with the long-term integration of their alpine farm employment into their general life situation. Thus, due to inadequate working and living conditions on the farms as well as a lack of possibilities to combine the "alpine farm life" with the "other life", there is a shortage of skilled labor on Swiss alpine farms. Interestingly, the return rate on an alpine farm and the overall evaluation of the last alpine farming experience varies largely between different functions of the workers (e.g. between a shepherd and cheesemaker). Also, our data shows variation in terms of satisfaction / dissatisfaction of the workers with various aspects of alpine farming depending on their respective function. A closer look at these variations may be useful for policy makers and single farms to find the proper measures of adaptation. Discussions are currently taking place with various stakeholders on how to tackle these difficulties in alpine farming.



**Impact of alpine pasture grazing on butter fatty acid profile, and physicochemical properties**

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Cows' breeding and feeding systems have a major impact on the nutritional profile of milk and dairy products. This research aimed to explore relationships among fatty acid (FA) composition and physicochemical properties of butter produced under three production systems during the summer season. A total of 31 butter samples were collected and analysed: 9 samples from 3 lowland production plants processing cream from dairy herds intensively managed and fed corn silage-based total mixed rations (TMR); 11 samples from 4 mountain plants processing cream from dairy herds fed hay-based TMR; and 11 samples from 5 small artisanal plants processing cream from alpine-grazing dairy herds. Exploratory factor analysis of the FA profile identified two orthogonal factors explaining 56.2% of the total variance (D1 = 44.4%; D2 = 11.8%). D1 described the main compositional gradient, contrasting medium-chain saturated FA (negative loadings) with long-chain FA, which loaded positively, including C18:0, major C18:1 isomers, and conjugated linoleic acid. D2 was characterised by positive loadings for C15:0 and negative loadings for palmitoleic and linoleic acids, indicating a secondary gradient within summer butter samples. The samples of alpine-grazing based butter showed a shift towards the positive D1 coordinate, with minimal overlap with samples from both lowland and mountains. This highlights a distinctive signature of the alpine pasture-based production system on FA profile of butter. Conversely, butter samples from both mountain and lowland areas clustered predominantly on the negative D1 coordinate, reflecting a greater relative contribution of medium-chain saturated FA. The factor analysis outcomes were consistent with the linear model results. Alpine-grazing based butter differed significantly from TMR fed samples in colour and rheological properties, showing greater yellowness, shorter latency times in the melting test, and higher spreadability. These results indicate that summer butter FA composition is primarily driven by the feeding/production system (alpine grazing vs. TMR feeding), whereas geographical location (mountain vs. lowland) is a minor source of variation.

**The Quality Beef from Carpathian Pastures**

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Genetic and environmental factors, including cattle nutrition, determine the quality and safety of beef and milk. Grazing-based feeding systems, particularly those utilizing the botanically rich pastures of the Carpathian region, may positively influence beef quality. Extensively managed wooded pastures, regarded as archetypes of traditional European agricultural landscapes with high natural and cultural value, are characteristic of the Carpathians. In the Polish Carpathians alone, approximately 1,700 native and permanently established plant species occur, including numerous endemics restricted to the Carpathian arc. This high botanical diversity supports ruminant grazing and distinguishes Carpathian pastures and meadows from monoculture grasslands. The aim of this study was to evaluate the quality of beef from native cattle breeds grazed on Carpathian pastures and fed indoors during winter. Bulls of Polish Red Cattle and Simmental (Poland) breeds were slaughtered at 18–20 months of age. Samples of the m. supraspinatus and m. semitendinosus muscles were subjected to physical and chemical analyses. Cooking losses measured in a thermo-circulating oven were comparable to values reported in the literature, and meat colour parameters (L*, a*, b*) were typical for beef from young bulls. The analyzed beef was characterized by high protein content and relatively low fat content. Meat from pasture-reared cattle showed a higher proportion of unsaturated fatty acids, particularly PUFA n-6, PUFA n-3, and conjugated linoleic acid (CLA), compared to meat from cattle housed indoors. Beef from young cattle grazed on Carpathian pastures exhibited a more favorable nutritional profile, which may enhance consumer interest and support the development of sustainable cattle production in the Carpathian region. Moreover, pasture-based and sylvopastoral systems contribute to improved animal welfare, an aspect increasingly valued by consumers.



**Predicting Beef Fatty Acid Composition from Diet and Plasma Profiles Using Multivariate Models**

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The nutritional quality of beef is closely related to its fatty acid composition, which is strongly influenced by animal diet. This study evaluated whether diet proximate analysis or plasma fatty acid profiles could be used to predict intramuscular fatty acid composition, providing a reliable and non-invasive alternative to post-mortem assessment. Eighteen young crossbred cattle (Limousine × Sardo-Bruna) were finished either on natural pasture or on hay- and concentrate-based diets in stalls. Plasma samples and intramuscular fat from the Longissimus thoracis and Musculus gluteus maximus muscles were analyzed. Canonical correlation analysis revealed strong relationships between dietary antioxidant capacity and meat lipid profiles, particularly for α-linolenic acid and conjugated linoleic acid, which are associated with positive effects on human health. The redundancy index indicated that diet explained 38% of the variance in fatty acids of the Longissimus thoracis and 20% in the Musculus gluteus maximus. Partial least squares regression models showed high accuracy and predictive ability ($R^2$ up to 0.94; $Q^2$ > 0.85), with low prediction errors, in estimating intramuscular fatty acid composition from plasma profiles. In conclusion, diets characterized by high antioxidant capacity and rich in n-3 fatty acid precursors promote healthier beef lipid profiles, and plasma fatty acid profiling represents an effective, non-invasive tool for monitoring meat quality and improving farm management strategies.

**Development of a Grass-Fed Beef production system in Sardinia**

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In Sardinia structural constraints such as high feeding costs and limited finishing capacity have reduced the economic feasibility of local beef production. At the same time, Sardinia is characterized by extensive mountain areas, rich in permanent grasslands that are poorly suited to intensive farming but highly suitable for pasture-based systems. Grass-fed beef production represents a strategic opportunity to valorize and protect these areas while improving meat nutritional quality. This project originates from a request expressed by Sardinian beef farmers' association (Asabona), who called for a structured research initiative aimed at the valorization, recognition, and market differentiation of grass-fed beef. The project seeks to establish and achieve formal recognition of a Sardinian grass-fed beef production system by improving productive efficiency and meat quality in grass-fed conditions, transferring and disseminating the "Carne al pascolo iGRAL" production protocol among beef cattle farms, and supporting the development of a structured supply chain as a prerequisite for the creation of a Slow Food Community and a future Slow Food Presidio for grass-fed beef. At the Agris Sardegna experimental farm, a trial has been launched to compare pasture-based rearing of female heifers and castrated males, representing a novel approach for this production system. Feed intake and productive performance are currently being monitored, while subsequent analyses will focus on carcass yield as well as the chemical and sensory quality of the meat. One of the Asabona farms has been selected as a pilot farm to transfer the trial's management practices and innovations. Technical support will accompany farms during the application of the iGRAL protocol, while collaboration with Slow Food Sardinia will support consumer communication and product valorization. Expected outcomes include improved technical guidelines for grass-fed beef production, supporting a more structured application of pasture-based systems and contributing to the technical organization of the emerging Sardinian grass-fed beef supply chain.



**Quantifying nitrogen input and output flows of mountain farms in Grisons to support site-adapted fertilisation**

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Nitrogen (N) surpluses from overfertilisation lead to environmental N losses with negative effects on ecosystems and human health. In mountain grasslands, strong variation in topography and yield potential can cause mismatches between uniform fertiliser recommendations and local N demand, increasing the risk of N surpluses and highlighting the need for site-adapted fertilisation. We analysed fertilisation practices of 14 grassland-based mountain farms to assess the potential of an ex-post analysis of N input and output flows as a basis for site-adapted N fertilisation. N inputs were quantified using farmers' fertilisation records, atmospheric N deposition estimates[1], and two methods each for estimating symbiotic N fixation[2,3] and soil N mineralisation[3,4]. N outputs were approximated based on yield assumptions derived from management intensity and elevation. Across 62-100% of plots (depending on the mineralisation method), N inputs exceeded N removal, and 9-57% of plots showed more than double the N inputs relative to outputs, indicating an elevated risk of N losses. These results point out the potential for site-adapted fertilisation while also highlighting uncertainties linked to yield estimation, symbiotic N fixation and soil N mineralisation. Overall, the study shows how an N input-output analysis can be implemented with limited and heterogeneous data to identify N surpluses and deficits. Future work should focus on inter alia improving yield estimation, e.g., via remote sensing, to reduce uncertainty and advance scalable decision-support tools for precision N management in mountain grasslands. 1 Rihm, B., et al. Nitrogen Deposition and Exceedances of Critical Loads for Nitrogen in Switzerland. (2023). 2 Nucera, E., et al. Method for estimating nitrogen input by symbiotic fixation on Swiss farms. Agroscope Sci. 164, (2023). 3 Sinaj, S., et al. Principles of fertilisation of agricultural crops in Switzerland. Agrar. 8, (2017). 4 Coleman, K., et al. RothC-26.3 – A Model for the turnover of carbon in soil. in Evaluation of Soil Organic Matter Models. 237–246 (Springer, Berlin, 1996).

**Technological needs and challenges faced by Scottish stakeholders in mountain areas**

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Across Europe, extensive livestock systems provide a variety of products and services, contribute to local economies and preserve landscape. They face multiple challenges but innovative technologies could help improve the future viability of these farming systems. The DIGI-Rangeland project (GA 101183132) is a network of 11 countries for sharing knowledge on digital technologies and innovations useful to farmers in extensive areas across Europe. In autumn 2025, a series of workshops were organised to collect and understand farmers' agricultural and environmental needs and challenges. The workshop held in Scotland focused on identifying and prioritising the main challenges faced by meat sheep and cattle farmers and advisors in the management of extensive livestock systems around the Loch Lomond and Trossachs National Park. Fifteen participants identified and prioritised challenges for three thematic areas. On improving farm management of extensive livestock systems and practices, the main challenges were related to capital costs and infrastructure, the amount of required data to collect, labour and time management issues. On facilitating the land use of grazing areas and land sharing among different users, the main challenges were articulated around a lack of awareness from other land-users, antisocial behaviour, sharing with wildlife, issues of connectivity. Finally, on developing and promoting quality products/services provided by extensive livestock systems, challenges identified included quantifying each of the other benefits [e.g. biodiversity, wildfire prevention, tourism], audiences at best unaware of the range of services provided or at worst with formed misperceptions, and, that extensive systems are capital intensive, leading to a challenge in getting financial support for investment. The next steps will be to identify which, and how, digital technologies can help resolve issues identified. Some solutions have already been identified (e.g. virtual fences, farm management software, QR codes and tourism apps, etc.) but this exercise will continue collectively throughout the project.



**Acute behavioral responses of ewes to virtual fence cues**

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Virtual fencing (VF) systems use auditory warnings followed by mild electrical stimuli to confine animals within a specified grazing area. However, the technology might impose acute stress responses, and this remains insufficiently documented in small ruminants. This study examined the immediate reactions of 20 naïve ewes equipped with Nofence and Monil collars to VF cues in a controlled grazing environment. Acute stress responses were evaluated using real-time bolus sensors, with movement count data, and a behavioral ethogram of their reactions, obtained via video surveillance. Over 2 weeks, 1,032 cues (904 auditory and 128 electrical) were emitted, grouped into 638 cue bouts, defined as consecutive cues occurring within 6 minutes of each other. The bolus movement data for each animal were labelled with its cue bout timestamp and analyzed across five time windows: 12 minutes before and after (Pre12 and Post12), 6 minutes before and after (Pre6 and Post6), and during the cue bout (Event). Statistical analyses were performed using linear mixed models with repeated measures to evaluate differences across time windows in movement counts and to quantify weekly changes in the distributions of behavioral responses. The analysis revealed that movement count values increased sharply during the Event window and returned to baseline, with Pre12 and Post12 being statistically similar to each other (25.8, 31.4, 89.7, 38.5, 28.4 #/Cue Bout; $p<0.01$ for Pre12, Pre6, Event, Post6, and Post12, respectively), demonstrating that physiological reactions were short-lived. Video analysis showed that the most extreme reaction category was never observed, and fear responses decreased over weekly periods (10.2% vs. 4.4%; $p<0.01$). Reactions labeled as ignored with no response (10.5% vs. 4.1%; $p=0.01$) or mild, including perking ears (9.0% vs. 2.5%; $p<0.01$), decreased over the weekly periods. Conversely, appropriate responses, including turning around calmly, increased from 54.4% to 73.3% ($p<0.01$) from week 1 to week 2, indicating animal adaptability to the system. These findings support the conclusion that acute stress related to VF cues induced by Nofence and Monil collars is short-lived and that animals show improved predictability and controllability of the VF system.

**Pasture use intensity and vegetation: insights from multi-year GPS tracking and remote sensing in historical alpine pasture of Eastern Alps**

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Understanding grazing patterns' effects on vegetation productivity is crucial for sustainable management of alpine pastures, which sustain biodiversity and ecosystem services. This study analyzes monitoring data collected between 2019 and 2025 (excluding 2021–2022) from a historic alpine pasture in the Eastern Italian Alps (1900 m a.s.l., SD = 90 m), covering 180 ha and grazed by a herd of 150 cattle. We integrated GPS tracking of dairy cows with remote sensing to assess the relation between pasture use and vegetation condition. Across the years, the herd was daily conducted to different selected areas by shepherd between milking periods and allowed to roam freely during the night. GPS tracking involved multiple collars with a fixed schedule of one position every two minutes from July 11 to September 5 for each year. Vegetation productivity was estimated via end-September NDVI from Sentinel-2 (10 m resolution), with typologies mapped using Braun-Blanquet surveys. The pasture was divided into three use-frequency areas by integrating GPS data and shepherd plans. The end-September NDVI values were compared across the three grazing-frequency areas over multiple years, considering the different vegetation typologies to evaluate late-season regrowth after grazing. The analysis showed consistently higher and more homogeneous NDVI values in the areas most frequently used by the herd, namely those located near the barn and night-resting sites. In contrast, the more marginal areas were used less intensively and were also less productive, as indicated by their lower and more heterogeneous late-season NDVI values. Significant inter-annual variation was also observed, with the lowest NDVI values recorded in 2020 and the highest in 2024 and 2025. Overall, these findings highlight the potential of vegetation indices for assessing the effects of grazing intensity on pasture conditions and underscore the value of integrating remote sensing and GPS tracking to monitor this agroecosystem and support improved management planning.



**LIVEBIOTRACK: Smart, Green Technologies for Livestock Tracking and Grazing Management**

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LIVEBIOTRACK aims to enhance the efficiency, sustainability, and resilience of pasture-based livestock systems through the development and validation of innovative Precision Livestock Farming solutions based on green electronics. Pasture-based systems play a key role in food production, biodiversity conservation, and landscape management, particularly in marginal and mountainous areas, but they are often constrained by limited animal control, high labor demand, inefficient pasture utilization, and increasing losses due to predation. The project addresses these challenges by integrating biodegradable and low-impact animal-based sensors, advanced data analytics, and decision-support tools into a unified management framework. LIVEBIOTRACK will develop novel devices which will enable real-time monitoring of animal location, behavior, welfare status, and early detection of predation events. In parallel, the project will implement a web-based decision support system that integrates animal-derived data with remote sensing and pasture growth models to provide spatially explicit information on pasture biomass availability and forage quality. This integrated approach will support informed grazing management decisions, optimize stocking rates, reduce overgrazing and land abandonment, and improve overall system productivity. LIVEBIOTRACK combines research with extensive field validation across cattle, sheep, and goat farms in central Apennines and Alps. Through close collaboration with farmers and stakeholders, the project promotes co-design, usability, and adoption of the developed technologies. Aknowledgement This project was carried out within the FISA program supported by the Italian Ministry of University and Research.

**GPS-based indicators to support grazing management in dairy sheep**

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Grazing management relies on information about herbage availability, animal nutritional requirements, and how animals use pasture in space and time. GPS tracking offers opportunities to support management decisions. We investigated the spatial and temporal patterns of pasture use in Nera di Arbus sheep, an autochthonous Sardinian breed, at the Agris experimental farm (Macomer, Italy) within a 2.12 ha grazing area, during spring (March) and summer (June) by GPS tracking. Pasture space use was quantified by (1) individual daily utilization distributions (UD95). For each day, we calculated the area in which the animal was likely to be found with 95% probability, using a dynamic Brownian bridge model. (2) the Camargo's index of evenness (CI), quantifying the uniformity of space use. Seasonal differences in both indicators were assessed using generalized additive mixed models, accounting for individual and day-level random effects. Mean UD95 was comparable between periods (1.205±0.069 ha in March and 1.091±0.127 ha in June, with no significant difference, $p = 0.496$). Sheep used approximately 56.8% of the total grazing area in March and 51.5% in June, indicating that, even in a small paddock, actual space use can be substantially lower than the available area. CI exhibited marked season-dependent diel patterns. In March, animals spread out more uniformly during the central hours of the day (approximately 09:00–17:00), whereas during the same time window in June the CI was much lower, indicating reduced movement and spatial aggregation, consistent with heat-avoidance strategies. In both seasons, CI reached similar and low values, during night time hours (approximately 21:00–04:00), reflecting a spatial concentration of animals within limited portions of the pasture, potentially associated with resting. The combined use of GPS-derived spatial metrics (UD95) and temporal aggregation indices (CI) provides complementary insights into pasture use. Beyond describing animal behaviour, these indicators have management implications, such as identifying critical hours for providing shade, or strategies to mitigate heat stress.



**The TeAMa platform as an innovative technology for pasture management in mountain areas**

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The TeAMa platform was developed and tested in dairy sheep farm, under real mountains condition, to integrate and analyze multidisciplinary data, supporting farmers in rational pasture management and livestock decision-making. Specifically, the platform generates pasture management indicators and evaluate livestock feeding efficiency. Farm data include livestock body weight and Body Condition Score (BCS), feed type and quantity, and milk production. Pasture availability is estimated trough the Normalized Difference Vegetation Index (NDVI) derived from satellite imagery and correlated with field grass cuttings. The platform integrates animal movement data collected via GPS devices and pasture availability information and provides structured thematic reports to support management decisions. Zootechnical reports summarize flock productivity and nutrition, including indicators such as average BCS and mean live weight, individual feed intake and feed efficiency expressed as Feed Conversion Ratio (FCR), enabling continuous monitoring and optimization of feeding strategies. Environmental reports assess grazing system quality using biodiversity indices and pastoral value based on vegetation composition highlighting the potentially high natural value of the area. Agronomic reports integrate GPS data to analyze grazing distribution, pasture use, and available biomass, supporting an efficient pasture planning. In conclusion, the platform can serve as a decision-support tool for rational livestock management. Although implementation requires farmers' commitment in data collection and entry, it enhances awareness and responsibility in management decisions. Designed for sheep farming in mountain pasture systems, the platform can be adapted and transferred to other production contexts, encouraging farmers to integrate traditional practices with technologies and digitalization. The TeAMa platform demonstrated the effectiveness of an integrated research and technology-based approach in improving sheep farming management in marginal areas.

**Efficacy of satellite based monitoring of dry matter yield per hectare (DMY/ha) in grassland: A case study in the Upper Rhine Region**

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Climate change is increasingly altering precipitation patterns and the frequency of drought periods in Central Europe, with direct consequences for grassland based livestock farming. Pasturelands are highly sensitive to water deficits, which can reduce biomass production and forage availability. The present study has been carried to correlate satellite Sentinel-2 NDVI time series data with DMY/ha in case study. The study objective was to evaluate the efficacy of satellite based monitoring in supporting agricultural decision making processes across the entire Upper Rhine Region. A reproducible workflow was developed to generate cloud masked NDVI time series for the 2025 growing season. Seasonal patterns and spatial differences between pasture areas were assessed, with particular focus on summer periods prone to drought stress. Satellite indicators were compared with weekly grass growth data from test farm in the Upper Rhine Region. The assessment showed that cutting and silage affect the comparability of grass growth and NDVI values. Therefore a consistent and structured protocol for recording management events (timing, intensity, type) is recommended to explicitly account for these effects in the statistical framework. Cloud cover and small field sizes limit precision in fragmented landscapes. However, corrected NDVI values with respect to these influences showed, that climatic impact on the grassland could be recognised. In the case study positive correlations between the grass growth DMY/ha and the NDVI values was found (Spearman p=0,74). Remote sensing approaches (NDVI) offer practical opportunities to monitor vegetation stress, evaluate spatial variability, and support climate resilient grassland management. Future integration of long term satellite records with farm level data could strengthen early warning systems and help optimize grazing and forage planning under increasingly variable climatic conditions.



**Multi-sensor correction of Sentinel-2 LAI for pasture biomass estimation in Northern Apennine grasslands**

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Accurate quantification of pasture above-ground biomass (AGB) is essential for precision grazing management in marginal areas. In operational remote sensing, AGB is often inferred from structural descriptors such as Leaf Area Index (LAI), estimated from Sentinel-2 (S-2) imagery. However, LAI products are strongly influenced by plant phenology and acquisition constraints, particularly cloud cover and complex topography. To improve the reliability of S-2 LAI for grassland AGB estimation, we evaluated weather- and multi-sensor-based correction approaches at two contrasting sites in the Northern Apennines (Italy): a grazed pasture (~200m, Site 1) and mown meadows (~700m, Site 2). We tested three methods: i) temperature-based correction (TBC) using a Gaussian response curve; ii) a Liebig Factor (LF) combining temperature and precipitation; and iii) a Vegetation Physiological Index (VPI), a newly developed multi-sensor index integrating Sentinel-1 SAR backscatter with temperature, precipitation, and solar radiation. Weather inputs included ERA5 temperature, CHIRPS precipitation, and CFSV2 solar radiation. All methods were calibrated on field-measured LAI and evaluated for their ability to estimate dry AGB (n=75 samples, 2019-2022). Correction approaches substantially improved AGB estimation accuracy. At Site 1, correlation between corrected LAI and field AGB increased from r = 0.34 to r = 0.51, with RMSE decreasing from 39.3 to 36.0 g m-². At Site 2, improvements were more pronounced (r: 0.30 → 0.80; RMSE: 15.6 → 12.9 g m-²), with TBC and LF performing equally well and outperforming VPI. Optimal temperature differed between sites (18°C vs 14°C), reflecting altitude-driven thermal adaptation. Hence, the integration of weather-based corrections substantially enhances the reliability of S-2–derived LAI for AGB estimation, supporting optimal stocking rate and grazing timing decisions in pastoral systems.

**Field-based grazing evidence proxies livestock stocking rate in alpine pastures**

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Alpine summer pastures are key forage resources for livestock in mountain farming systems. Grazing shapes vegetation through biomass removal, soil disturbance, and nutrient cycling from excreta. However, these impacts vary in space as livestock concentrate their activity in favorable areas, especially given the environmental heterogeneity of alpine landscapes. Quantifying site-use intensity is therefore essential for adaptive pasture management that balances forage exploitation while preserving the sward. However, direct monitoring (e.g., GPS collars) is often costly. We evaluated whether simple and field-observable grazing evidence can serve as reliable proxies of livestock site-use intensity in an extensive alpine pasture in Gran Paradiso National Park (NW Italy; 1800–2400 m a.s.l.). An 83-ha pasture was grazed for 75 days by 100 Pustertaler-Barà cattle (87 LU). We equipped 10 animals with GPS collars to spatially quantify site-use intensity. At the end of the grazing season, we visually scored three indicators, namely defoliation, trampling and dung deposition, at 715 regularly spaced control points using a five-class scale (1 = absent, 5 = extreme). For each point, we related the indicator scores to the number of GPS fixes within 5 m buffers to verify which indicator best explained livestock spatial distribution. All three indicators captured the variation in site-use intensity. Defoliation performed best, discriminating site-use intensity across most of the ordinal scale. Dung deposition also showed a high fitting, whereas trampling was less informative and did not effectively separate moderate from high or extreme use. Overall, easily recorded grazing evidence, and in particular dung deposition and defoliation, can be effectively used to map livestock site-use intensity in extensive alpine pastures, supporting adaptive management to limit local degradation (due to both over- and under grazing).



**GPS-based insights into movement behaviour and space use of the Rock Partridge in Apennine Mountain grasslands**

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Mountain grasslands of the Apennines are undergoing rapid structural alterations due to climate change and the decline of extensive grazing, leading to shrub encroachment and a reconfiguration of landscape structure. The Rock Partridge (Alectoris graeca), a Near Threatened galliform associated with high-altitude grasslands, is traditionally considered sedentary; however, quantitative GPS-based evidence on its movement behaviour and space use remains limited, constraining evidence-based conservation and pastoral management strategies. Within the AGRITECH project (NextGeneration EU), we analysed seasonal movement patterns of A. graeca in the Monti Sibillini National Park (central Italy). In spring 2025, four male individuals (two adults and two juveniles) were equipped with solar-powered GPS transmitters (<3% body mass) and monitored from reproduction to mid-winter. After filtering for positional accuracy (HDOP ≤ 6), 9,501 GPS locations were retained. Net Squared Displacement identified resident and exploratory phases, and space use during resident phases was quantified using 95% Minimum Convex Polygon and k-Local Convex Hull estimators. Juveniles showed strong site fidelity and small MCP95 home ranges (163.0±49.2 ha), remaining within 1.5 km of capture sites. Adult males exhibited greater spatial plasticity, including settlement shifts and long-distance displacements up to 14.5 km, with MCP95 increasing from 130.6 ± 11.7 ha during reproduction to 291.1 ± 27.6 ha post-reproduction. Resident phases consistently occurred in mosaic landscapes where open grasslands co-occurred with shrub and woodland patches. Environmental suitability for A. graeca cannot be inferred at local scales alone. The observed capacity for extensive movements highlights the importance of landscape-scale habitat continuity and heterogeneous grasslands maintained by extensive pastoral systems. Additional data from more individuals, including females, are needed to draw robust conclusions and fine-scale habitat selection analysis within home ranges are also essential to understand functional habitat use and.

**Landscape legacies and disturbance responses in Alpine semi-natural dry grasslands**

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Semi-natural dry grasslands represent biodiversity hotspots of high conservation concern in Europe, yet their persistence is increasingly threatened by land-use change, landscape homogenization and altered disturbance regimes. In the Alps, these pressures interact with strong historical landscape legacies and recent extreme events, shaping present biodiversity patterns in complex ways. In this study, we investigate the long and short-term drivers of plant biodiversity and conservation status in semi-natural dry grasslands within the Susa Valley (NW Italian Alps), an area historically maintained by extensive agro-pastoral practices, abandoned since 1950s, and affected by a severe wildfire event in autumn 2017. We applied landscape scale analysis to better understand fine scale vegetation dynamics. We assessed the effect of topography and both historical (1954) and recent (2015) landscape structure on current vegetation biodiversity and habitat conservation status, as well as their effect on short-term vegetation changes over disturbance events (i.e., fire severity and grazing intensity). Our results revealed dense forest expansion leading to substantial grassland loss and fragmentation. Model outputs suggested that current dry grassland biodiversity and conservation status are strongly associated with historical landscape configuration, with sites embedded in formerly long-standing and spatially extensive open areas hosting more diverse and better preserved communities. Post-fire responses differed markedly according to pre-disturbance conditions: degraded grasslands exhibited significant increases in habitat-typical species, whereas well-preserved grasslands showed limited compositional changes, indicating a higher resistance to disturbance. Our findings highlight the importance of landscape and vegetation legacies in shaping semi-natural dry grassland dynamics. Management strategies should therefore integrate historical landscape knowledge with current vegetation conditions to effectively maintain these high conservation value habitats and their suitability to grazing.



**Which mountain pastures matter? Fine-scale selection within pastoral systems by a mountain bird of conservation concern**

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Mountain pastures and traditional pastoral systems are key habitats for many mountain species, sustaining biodiversity through open and heterogeneous habitats. Among these, the Rock Partridge (Alectoris graeca) is classified as Vulnerable and targeted by a National Action Plan prioritizing habitat maintenance. While recent research focused on displacement patterns and home-range dynamics, fine-scale habitat selection within pastoral landscapes remains largely unexplored. Within the AGRITECH project (NextGeneration EU), we investigated fine-scale habitat selection during reproductive and post-reproductive periods using high-resolution GPS data from four male individuals (two adults and two juveniles) in central Apennine pastures, analysed with Step Selection Functions. Observed steps were compared with 20 available steps generated from empirical distributions of step lengths and turning angles. Environmental covariates were extracted at a movement-defined spatial scale (75th percentile step), including topography, habitat configuration and land-cover classes. Model selection supported a context-dependent process, with biological group and settlement phase improving model fit. Adults showed selection for proximity to habitat edges (OR= 0.83, $p < 0.01$). Elevation effects were group and phase-dependent, with juveniles selecting higher elevations across phases as the adults in the post-reproductive one. Adults also selected north-facing microhabitats across phases (OR= 1.12–1.19, $p< 0.05$). Relative to open habitats and pastures, deciduous forests were avoided (OR= 0.41, $p< 0.001$), whereas coniferous forests did not differ from open habitats (OR= 0.95, $p > 0.05$). Our results suggest that not all mountain pastures are functionally equivalent, highlighting the importance of heterogeneous, mosaic landscapes under ongoing land-use change. Data from a larger sample of individuals, including females, are required to strengthen inference.

**Optimising protein production on dairy and beef cattle farms in mountainous areas**

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In the context of global population growth and limited planetary resources, cattle farming plays a key role in human nutrition. The challenge is to produce food while limiting competition between animal feed and human food resources. Ruminants are often criticised as inefficient protein producers despite their capacity to valorise grasslands, particularly in mountainous areas where arable land is scarce. The Interreg Proscor project addresses this issue in a transboundary mountain-context between France and Switzerland, where cattle farming relies mainly on permanent grasslands and, in Switzerland, on seasonal transhumance to alpine pastures. The project aims to: (1) develop indicators to position farms in terms of protein production efficiency and land use; (2) involve farmers in the construction and reflection of these indicators; and (3) disseminate a simple tool to estimate farm-level efficiency and identify improvement pathways. Two groups of dairy cattle farms (9 French, 8 Swiss) and two groups of beef cattle farms (5 French, 7 Swiss) were analysed. Based on literature review and farmer discussions, five indicators were selected, including edible protein feed conversion efficiency (epFCE; Rouillé et al., 2023) and land use ratio (LUR; van Zanten et al., 2016). To assess protein production, additional indicators were developed: protein autonomy (PA), global protein yield (GPY) and net protein yield of the production system (nPYPS). These indicators effectively differentiate farms and highlight strengths and improvement potential. Results show that mountain cattle systems based mainly on grass and limited amounts of co-products (e.g. rapeseed meal) hardly compete with human food resources. These findings demonstrate that, with well managed forage production areas, high efficiency and productivity can be both achieved. Farmers successfully adopted this multi-criteria approach and identified concrete levers for improvement through adjustments in feeding strategies and forage land management.



**Assessing pastoral value in alpine grazing systems using remote sensing**

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Semi-natural alpine pastures are complex and multifunctional environments providing key ecosystem services. At the same time, these grasslands play a crucial productive role, supplying forage for livestock and enabling production in marginal agricultural conditions. However, optimal pasture use depends on appropriate management, while declining stocking rates across the Alps often result in uneven grazing pressure. In this context, we propose a novel remote sensing-based approach to predict pastoral value (PV), a synthetic index integrating plant species composition and abundance with nutritive value and palatability. Using Partial Least Squares (PLS) regression and 111 observed plots, Sentinel-2 and Google Embeddings imagery were used to model the spatial distribution of PV at 10 m resolution in cattle-grazed alpine pastures (ca. 1650 m a.s.l.) of two alpages in the Eastern Italian Alps (Mount Zoncolan, Udine, IT). The models yielded $R^2$ values between 0.53 and 0.75, with RMSE ranging from 9.11 to 12.08. The spatial variability of PV among pasture types, and its relationship with slope as a proxy for management intensity, were analysed and compared with PV trends derived from predictions for 2017-2018. Predicted PV matched expectations across different pasture typologies. A significant decreasing temporal trend in PV was detected, consistent with declining stocking rates. The decrease was negatively correlated with slope (r= -0.40/-0.59), also after accounting for spatial autocorrelation, indicating stronger degradation on steeper slopes. Overall, the study highlights the usefulness of remote sensing for monitoring alpine pastoral systems and supporting management to avoid under- or over-grazing.

**Predicting pasture nutritive parameters using low-cost NIRS on fresh and dried samples**

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Knowing the nutritive quality of pasture is essential for optimizing performance and welfare of grazing animals. The PASCOLOVE project aims to develop tools that allow farmers to rapidly assess pasture quality, thereby supporting daily pasture management and supplementation decisions. The project focuses on the use of low-cost NIRS technology with the goal of providing near-real-time information on pasture quality. During the first year of the project, pasture samples were collected from different plots at five farms, with four sampling sessions between May and October 2025. To increase sample variability, additional 17 samples from Swiss alpine pastures were included, resulting in a total of 124 samples. Pastures were sampled in the morning (1 m2), stored in coolers, and processed in the afternoon or the following morning. Fresh grass samples were reduced to smaller particles (3–6 cm) using a garden shredder to improve homogenization and spectral quality. Spectra of wet samples were acquired in duplicate using two diode-array instruments (Corona Extreme, Zeiss, Jena, Germany; AuroraNir, Grainit, Padova, Italy). Samples were then dried at 60 °C, ground through a 1-mm screen, and scanned again with both instruments. Reference analyses included dry matter (DM), crude protein (CP), ash-corrected neutral detergent fiber (aNDFom), lignin (ADL), water-soluble carbohydrates (WSC), and digestible NDF (dNDFom30). These data were associated with both wet and dry spectra to develop partial least squares (PLS) calibration models. Cross-validation errors for wet and dry samples were respectively 1.8 and 1.9 %DM for CP; 2.5 and 4.5 %DM for aNDFom; 0.5 and 0.7 %DM for lignin; 0.8 and 1.9 %DM for WSC; and 2.6 and 3.8 for UFL. Coefficients of determination ($R^2$) for cross-validation of wet samples were relatively low, ranging from 0.10 for WSC to 0.70 for CP, whereas drying and grinding substantially improved model performance, with $R^2$ values ranging from 0.67 for UFL to 0.92 for CP. Prediction of pasture quality in wet samples remains challenging, as water acts as a strong interferent and reduces NIR prediction accuracy, resulting in errors that were nearly double those observed after drying and grinding.



**Trade-offs among grass-based veal production systems along an altitudinal gradient**

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Developing grass-based veal production from male dairy calves may offer a low-input and welfare-oriented alternative, particularly in organic systems. While previous studies reported significant univariate differences between farming systems, it remains unclear whether systems differ when all traits are considered jointly, and how trade-offs emerge among production, animal health, environmental, and economic traits. We fattened 72 calves from 90 to 180 days of age in four Swiss grass-based systems: one hay-based indoor system and three pasture-based systems located in lowland, mid-elevation and alpine areas. Plant diversity was monitored repeatedly in pastures throughout the grazing season, and in-vitro methane production was assessed from rumen fluid collected on farms shortly before slaughter. Productivity, meat quality, animal health and carcass price were measured after slaughter. System differences were evaluated using a permutational multivariate analysis of variance (PERMANOVA) followed by linear discriminant analysis (LDA). The PERMANOVA revealed a significant multivariate differentiation among systems ($p < 0.001$, $R^2 = 0.35$). The LDA showed a clear separation between systems (90% correct classification), mainly driven by average daily gain, meat quality traits and blood haemoglobin concentration. Alpine and mid-elevation systems were associated with higher plant diversity and improved animal health, whereas the indoor system showed higher growth performance, lower in-vitro methane production, and more protein-rich and tender meat. Despite these differences, carcass prices were similar between alpine and indoor systems, partially due to seasonal effects. These results highlight distinct trade-offs among grass-based veal production systems in terms of food provision, biodiversity conservation, and climate change mitigation, which should be considered in policy design and large-scale modelling.

**Evolution, prospectives and challenges of cattle farms in mountainous areas**

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Mountain areas in Europe, and particularly in the French Massif Central, have undergone profound structural transformations over recent decades. This presentation retraces the main techno-economic changes that have shaped herbivore livestock farming in mountain regions, with a particular focus on the French Massif Central. Agricultural activity in these territories has progressively specialized around herbivore systems, as biophysical constraints such as altitude, slope and climate limit the development of arable crops. Over time, farms have experienced major structural change, characterized by a decline in the number of holdings and a simultaneous increase in farm and herd size. Despite these adjustments and significant gains in labour productivity, technical efficiency and the capacity to generate value added per unit of labour have often declined, reflecting lower land productivity, increasing capital intensity and a long-term deterioration of agricultural terms of trade. The presentation also examines the growing dependence of these systems on the Common Agricultural Policy (CAP). Public support plays a central role in the economic functioning of mountain livestock farms, not only through direct income support—which in beef and sheep systems often exceeds operating results—but also through risk-management instruments. Cattle and sheep producers are among the main beneficiaries of solidarity payments from the French agricultural disaster compensation scheme (FNGRA), which compensates grassland yield losses caused by climatic hazards. Looking ahead, these systems face increasing uncertainty as climate change is expected to alter grassland productivity and increase climatic variability, while possible reforms in public support could weaken their economic stability. The presentation finally discusses results from recent research assessing adaptation pathways, including diversification of farm activities, on-farm finishing of animals to capture more value along the supply chain, and extensification strategies aimed at reducing input dependence and exposure to market volatility.



**Economic Viability of Swiss Summer Farms**

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Mountain farming and the associated summer pastures are important components of Swiss agriculture. Their importance extends beyond food production and cultural heritage: preserving the typical landscape of the Swiss Alps is just as much a part of the multifunctionality of alpine farming as preserving biodiversity and other ecosystem services. But, the wages of Alpine farmers are considered low, which is a result of the tense economic situation of the farms. However, little research has been done on the economic situation of Alpine farming. The last analysis was carried out in 2011-2013 as part of the 'AlpFutur' project. Since then, there have been substantial changes in the structure of direct payments. This ongoing study examines the economic efficiency of summer grazing farms in the years 2023-2025. We are conducting a cost-performance calculation on a full-cost basis, which was developed as part of the 'AlpFutur' project and further refined here. This allows us to calculate key figures such as the average earnings per working hour and the income per livestock unit. This enables us to compare the economic efficiency of different farms with each other as part of a benchmarking exercise. We conducted a stratified sample by farm type based on the typology of summer grazing farms by (Meyer et al., 2024). The sample comprises 28 summer grazing farms. Accounting data was requested from the farms between summer 2023 and 2025 and farm visits were conducted. The results for the farms were compiled in the form of a summary sheet with comparative figures, reviewed with the farms, and thus validated. The median compensation per working hour on the summer grazing farms surveyed is CHF 29/hour. The range of hourly earnings is between CHF 4 and CHF 76. Raaflaub et al. (2014) showed an inflation-adjusted range of CHF 6.95 to CHF 59.90 per hour. This indicates that although earnings have changed over time, there is still a considerable income gap between the lowest and highest hourly earnings. In the further evaluation steps, we will also examine the income per normal work unit, the share of direct payments in services, and other evaluations related to farm structures.

**Estimating the Costs of Improving Animal Welfare: A Case Study of Italian Simmental Mountain Dairy Farms**

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This case study estimates the economic implications of improving animal welfare (AW) in Italian mountain dairy farming, specifically focusing on Simmental cattle in both conventional (CON) and organic (ORG) farms. Given the increasing demand for higher welfare standards from consumers and policymakers, it is important to assess the economic feasibility of implementing these practices. The primary aim of this study is to develop a proof of concept for estimating the costs involved in meeting specific AW standards. Data were collected from 30 dairy farms (15 CON and 15 ORG), and AW scores were evaluated using both resource-based and animal-based indicators (total score of 90 points). Additionally, AW costs were assessed by calculating the cumulative additional costs, offset by potential benefits. Results show ORG farms achieve higher AW scores (73.99) compared to CON farms (70.28) but incur significantly higher production costs (€1.263/kg ECM for ORG vs. €0.977/kg ECM for CON), primarily due to the dilution effect caused by lower milk production on ORG farms. A nonlinear relationship between AW scores and AW costs was also observed, indicating that higher AW scores in initial farm conditions could, in some cases, lead to cost savings, particularly in larger and more efficient farms. The study emphasizes the need for clearly defined AW standards and a corresponding scoring system that reflects both the welfare impacts on animals and the economic feasibility for farmers. Further, we argue that the aggregation of AW scores should not merely categorize welfare on a simple best-to-worst continuum. Rather, it should account for the specific targets and conditions that policymakers and consumers are willing to support financially.



**A comparative analysis of resilience of mountain and nonmountain livestock systems with different level of intensification**

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Livestock farming systems across Europe are increasingly exposed to interconnected environmental, economic, social and institutional challenges, including climate-related disturbances, market volatility, labour shortages, and policy uncertainty. These challenges interact with their structural and territorial characteristics, generating diverse resilience configurations, yet comparative evidence across contrasting systems, particularly including mountain systems and different degrees of intensification, is limited. This study provides a comparative assessment of perceived resilience across five livestock farming systems in Spain (extensive meat sheep, dairy sheep and beef cattle in mountain areas, and intensive dairy goats and pig production outside these areas) representing an incremental gradient of intensification. Farm resilience was assessed through structured face-to-face interviews. The analysis focuses on farm resilience attributes, resilience capacities, perceived challenges, and farmers' personal resilience. Results show significant differences in resilience attributes and perceived challenges across systems. Mountain ruminant systems display higher scores for resource coupling, diversity and spatial distribution of resources, while intensive pig systems report higher values for economic and infrastructural attributes. Perceived challenges also vary across production contexts. Mountain ruminant systems report higher difficulty related to policy changes, wildlife interactions and recent market shocks, whereas labour shortage and sanitary issues are more pressing in intensive systems. About resilience capacities, mountain systems show higher perceived robustness, while adaptability and transformability vary marginally. Personal resilience indicators were high in all systems. Overall, these findings contribute to a more nuanced understanding of resilience across livestock farming systems along an intensity gradient, with mountain systems relying primarily on resource-related attributes under more demanding environmental and institutional conditions.

**Structural Drivers Reshaping Transhumance Systems in Mediterranean Turkey**

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Transhumance systems in the Mediterranean are undergoing a structural transformation driven by interacting socio-economic, institutional, and environmental forces. This paper analyses the structural drivers reshaping goat transhumance in Mediterranean Turkey and shows how they reconfigure mobility, livestock management, and the functional role of transhumance. The study draws on longitudinal ethnographic and ecological fieldwork along a traditional corridor between coastal and upland regions (2019–2023). Data include walk-and-talk interviews with transhumant households, participant observation during migrations, and rangeland ecological assessments. Results identify demographic change, market marginalisation, rigid governance, climate variability, and shifting land-use priorities as interlinked drivers. These forces fragment routes, eliminate stopovers, and compress grazing periods, producing uneven grazing pressure and weakening established spatial distribution. Reduced collective organisation constrains coordinated movement and adaptive flexibility, while labour concentrates within households and informal institutions for conflict mediation and access negotiation erode. Mobility decisions shift from anticipatory seasonal strategies toward reactive short-term adjustments, undermining ecosystem services including fuel load reduction, habitat connectivity, and climate buffering in marginal landscapes. The findings indicate that transhumance in Mediterranean Turkey is not disappearing but being reshaped into more fragmented and less resilient configurations. This has direct implications for the role of extensive livestock systems in sustainable food production, climate adaptation, and landscape management. Addressing these challenges requires policy frameworks that recognize mobility, seasonal land use, and collective organisation as functional components of livestock systems rather than residual practices



**Resilience of transhumant pastoral systems in the Catalan Pyrenees**

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Building on a background in social anthropology and environmental humanities, Katharina has been directing her work towards food system sustainability. She recently finished her master's thesis focussing on the resilience of transhumance in the Spanish Pyrenees. Currently a junior researcher at the University of Lausanne, she continues this line of work while also delving into territorial aspects of agroecology in the region of Valais, Switzerland. In mountain social-ecological systems like the Catalan Pyrenees, practices of seasonal mobile herding provide essential ecosystem services such as landscape maintenance, insect and seed transportation or fire prevention. On the other hand, those very systems have been increasingly confronted with a series of constraints and shocks, enhancing their decline over the last two centuries. Our research addresses the critical gap of knowledge on these mobile pastoral systems and their ability to adapt to changing conditions, by adopting the SHARP+ tool developed by FAO and retailoring it to our research context. A clustering analysis was done to create a typology of farms potentially engaged in transhumance. 40 interviews were conducted and served as a baseline for the resilience assessment. Identified vulnerabilities include weak participative governance structures and the lack of workforce and organisation of farm succession, especially in the context of small ruminant farms, which seems to be one of the causes of the shift from sheep to cattle farming. We conclude that sheep herding needs to be supported and increased again for its ecological services and potential to support mountain regions' resilience against climate change. Societal and political support needs to target the systemic drivers of decline identified: differentiated marketing opportunities with high added value, education and promotion of herding jobs and farm succession, investment in infrastructure for herders.

**Transhumance: cortisol in milk as non-invasive tool to assess adaptation response**

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Transhumance is a traditional practice in mountain farming and plays a key role in maintaining ecosystem services. However, the associated changes in environment, daily rhythm, and diet may represent a potential stressor for dairy cattle. Cortisol is widely used as a biomarker of stress, and its quantification in milk provides a sensitive and non-invasive tool to assess short-term physiological stress responses. Eight farms from the Lanzo valleys (north-western Alps) were included in the study, five of which practiced transhumance. Individual milk samples were collected at three time points: before transhumance, within 5 days after reaching upland pastures, and one month later, for a total of 488 samples. From these, milk cortisol, composition, and somatic cell count were analyzed. Moreover, data on milk yield, lactation rank and stage, body condition score (BCS), breed, and meteorological temperature and precipitation were also recorded. A conceptual model was developed to illustrate the relationships between transhumance, weather conditions, individual animal characteristics, and milk cortisol content. Based on this, generalized estimating equation (GEE) models were applied to identify factors associated with milk cortisol concentration. Milk cortisol extracted from the population ranged 0.57–3.57 ng/mL. Transhumance was associated with a reduced milk cortisol level (-0.16 ng/mL compared to non-transhumant farms), suggesting a rapid adaptive response in pasture-based systems. Low temperatures were associated with higher cortisol concentrations, with an estimated increase of approximately 0.05 ng/mL per 1°C decrease. Milk cortisol increased by about 0.065 ng/mL for each one-point increase in BCS. Abondance and Brown breeds showed higher cortisol levels and Tarentaise breed lower levels compared to the other breeds. Overall, these findings indicate that transhumance is not necessarily a stressful practice and that stress responses in dairy cattle are influenced by the combined effects of management, environmental conditions, and individual animal factors.



**The role of sheep grazing for the conservation of alpine grassland habitats: a case study from Eastern Italian Alps**

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Livestock grazing in Alpine highland pastures can contribute to several ecosystem services, like habitat and biodiversity conservation. Different socio-economic and environmental factors often lead to the abandonment of the most marginal areas, with a consequent pasture degradation. This research aims to explore the potential role of sheep grazing to support habitat restoring in an abandoned pasture. The study area was the pasture of Monte Coppolo, located in the Eastern Italian Alps, at 2000 m asl. This pasture was used for the summer transhumance of flocks of the local "Lamon" sheep breed (FAO risk status "critical"), but this practice was then abandoned in the last decade. In summer 2022, a rotational grazing plan was defined based on floristic surveys. In summer 2023 a first group of 30 sheep grazed 5ha in the core area of the pasture, and in summer 2024 a flock of 85 sheep grazed the entire area (13.5 Ha). To monitor the effects of sheep grazing on pasture biodiversity, we used an integrated approach based on GPS tracking, vegetation analysis, remote sensing, soil molecular analysis. Pasture use intensity was monitored with GPS collars, used on 3 sheep each year. These data were then combined with environmental variables (end of grazing season residual NDVI, slope, altitude) collected during the study, to assess the grazing effects on the habitat and the relation between pasture-use and vegetation. Soil samples were collected in grazed and non-grazed area (by using exclusion cages) to analyze microbial communities via sequencing (biodiversity and functional profiles) and real-time PCR, targeting the specific microbial genes involved in the nutrient cycles. The results showed a positive effect of sheep grazing on grassland biodiversity and productivity, especially when a rotational grazing plan was adopted. Topsoil microbial taxonomic and functional profiles significantly varied over the two years of the study, in relation to pasture vegetation type. The outputs of this research can support the implementation and monitoring of multifunctional grazing plans aimed to promote ecosystem services of pastoral systems.

**Do biodiversity payments bend the curve? Six decades of evidence on Swiss mountain grasslands**

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Mountain grasslands are among the most species-rich ecosystems worldwide, providing high biodiversity and essential ecosystem services. However, they are increasingly threatened by both land-use intensification and abandonment. Since the early 1990s, Switzerland and other European countries have implemented agri-environmental schemes to conserve grassland biodiversity, ecosystem functions, and cultural values, yet robust long-term evaluations of their effectiveness remain scarce. We assessed long-term changes in plant communities in grasslands across the Swiss Alps. More than 350 vegetation plots (600–2000 m a.s.l.) were resurveyed using historical datasets spanning up to six decades. Most plots were first surveyed in the early 2000s, while a subset originated around the 1980s and was resurveyed in the 2000s. Sites were selected using a stratified design across municipalities to capture broad environmental and management gradients. Changes in plant communities—including species richness, species evenness, ecological indicator values, and floral resource availability—were analyses using generalized linear mixed-effects models. Across most diversity metrics, we observed marked declines prior to the introduction of agri-environmental schemes, followed by partial recoveries under certain schemes. The most sustained recoveries occurred in result-based payment schemes combined with tailored management. Declines were strongest and most consistent in abandoned grasslands. Noteworthy, abundance-weighted diversity showed stronger declines and limited recovery across all schemes than unweighted metrics, indicating that increases in species richness were not accompanied by improvements in community structure. Overall, targeted biodiversity payments, when combined with tailored management, seem to be effective in halting or reversing declines in plant species richness in mountain grasslands. However, their limited effects on abundance-weighted diversity highlight shortcomings in sustaining plant communities and the ecosystem services they support.



**Carcass value of Black Alpine Pigs**

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Black Alpine Pig (Schwarzes Alpenschwein, SAS) is a native breed saved from extinction a decade ago. These pigs are content on steep or alpine pastures with little creep feed supplementation. The SAS label specifies that meat may be produced only in the mountain region and grazing on seasonal alpine pastures is recommended. Beyond the preservation of genetical resources, the SAS breed is of interest in alpine pasture restauration. According to the breeding organisation, SAS differ from commercial pig breeds by a slower growth, shorter back length, longer but strong legs and robust claws. These physical attributes may also be linked to a different carcass value with different proportions of lean and fat tissue and a different proportion of primal cuts than commercial pigs. Carcass weight, lean tissue proportion (MFA 2-points method) and primal cuts weight (belly, back, shoulder, ham) from 12 SAS carcasses originating from three producers were determined. Results were confronted to a database of 306 Swiss Large White crossbred pigs slaughtered at 158 ± 10 days old and 83 ± 3 kg carcass weight. Age of the SAS ranged between 10-12 (n=5) and 24 months old (n=7). Lean tissue proportion was 59 ± 1 %, which is an optimal value for payment of pork carcasses in Switzerland. The younger SAS carcasses weighed 69 ± 11 kg while the older ones weighed 84 ± 11 kg. Proportion of belly, shoulder, loin and leg was 22 ± 3 %, 16 ± 5 %, 37 ± 3% and 25 ± 6 % respectively. This meets the average primal cuts proportions of the Swiss Large White offspring. Our data do not support the hypothesis that SAS have different primal cut proportions than commercial pigs, yet this was obtained with SAS pigs at least twice as old as commercial pigs. It should be noted that younger SAS had a desirable lean tissue proportion only because both fat and meat thickness were low, which is not desirable. This problem was not observed on the older, heavier SAS. Producers of SAS meat claim it to be darker than commercial pork, but report problems of rancidity and soft fat. Age of the SAS pigs certainly plays a role on the color, and fat quality problems might be due to the leanness of some SAS pigs combined to a gras-based diet. Yet these are to be confirmed with further research on these hardy native pig breed.

**Impact of genetic traits, alpine transhumance and grassland traits on carcase characteristics of extensively fattened beef**

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Extensive beef fattening in alpine regions provides several advantages: It conserves biodiversity and traditional landscapes of alpine regions, while using natural ressources which are otherwise not exploitable to humans. It thereby decreases feed-food competition, produced high-value protein-rich food and increases food security. The use of the grassland resource becomes highly efficient when milk and meat production are coupled, and the calves used for fattening are born from dairy cows. In Switzerland several organic pasture-based beef labels exist, that aim at extensively fattening calves from the dairy sector. However, due to the variable genetic traits of calves as well as variable fattening conditions, the performance of pasture-fed cattle is heterogeneous, hindering the growth of the system. For the success of the value chain, it is important that animals achieve required degree of carcase conformation and fatness scores. The identification of crossbreeds that are better adapted to extensive feeding conditions could result in more homogeneous carcasses. To date, however, large datasets including both information on fattening performance, animal traits and feeding data, to identify such adapted genetics and crossbreeds, have been lacking. We used a novel dataset of 60.000 pasture-fattened beef carcasses and crossed this dataset with available information from national animal registries on farm and finishing conditions (zone, alpine summer grazing, altitude). In the following contribution we present first results on the influence of animal traits in interaction with fattening conditions on fattening performance, in particular carcase conformation, fatness score and daily growth. Results show that the breeding values of fathers of crossbred calves reliably predict carcase conformation, even in extensive fattening conditions. Breeding values for fatness scores show a loose relationship with attained fatness scores of fattened crossbreeds, while breeding values for growth showed no relationship to realized growth rates. Transhumance, higher farm altitude and being located in mountain zone tended to reduce carcase conformation and fatness scores.



**Rapid Infrared Spectroscopy for Assessing Beef Quality and Farming Intensification in Europe**

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European livestock sector shows remarkable diversity in beef production systems with different intensification levels, including mountain systems based on grasslands. Different production practices lead to different beef quality grades, creating market differentiation opportunities but also fraud potential. Within the EU-funded INTAQT project, we evaluated performances of different visible/NIR spectral devices, portable and benchtop, coupled to chemometrics for beef authentication and quality in relation to the farming system. Results showed good discrimination among samples according to intensification degree using spectral data from both devices through a Covariate Selection-Linear Discriminant Analysis approach, with the portable tool showing comparable to higher performances than the benchtop (Accuracy>0.72). Highest classification rate was obtained for the classes associated to the outmost intensification degrees (i.e. extensive with exclusive pasture grazing vs indoor with high concentrates proportion in the diet). Prediction of meat quality traits through Partial Least Square regression showed different results depending on the spectral device, with the highest overall performances for the benchtop one. Best regressions were obtained for contents of total and heme iron, moisture, protein, intramuscular fat, many saturated and unsaturated fatty acids contents ($R^2 \geq 0.70$). Unsatisfactory results were obtained for other quality traits such as marbling score, hardness, TBARs, carnosine, anserine and vitamin B content ($R^2 < 0.40$). Our results showed that the portable device tested in our study can achieve performances comparable to the benchtop one for certain authentication tasks, such as classification based on the intensification of the farming system, supporting the potential for implementing accessible field technologies to enhance authentication practices in the beef sector. At the same time, other applications, such as calibration for prediction of quality traits, still require further development.

**From labels to landscapes: mountain products with specification of origin or quality can help maintain grasslands and their ecosystem services**

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European grasslands are threatened by afforestation in steep, cold areas and by conversion to croplands in flatter, warmer areas. Cheese and beef products labelled with a PDO (Protected Designation of Origin), which require the use of local forage resources, may help mitigate this trend. We evaluated this potential in the Massif Central, a French mountainous region. Eight grass-based products were studied, including seven PDO cheeses and one "Label Rouge" beef product ("Label Rouge" is a French quality label). Data were obtained from local professional organisations, extension services and research projects, and concerned farms producing labelled and non-labelled products, for comparison. We quantified the proportion of grasslands supplying forage, and croplands supplying concentrates or silage, to feed animals at the origin of the studied products. We considered both on-farm and total areas (on-farm + off-farm). We also assessed the supply of regulating ecosystem services (ES) using a land-cover-based ES calculator, based on scores from 0 to 5, in which croplands have lower scores than grasslands. On average, labelled and non-labelled products rely on 16.5% and 13.5% off-farm area, respectively, mostly croplands. Permanent grasslands account for 78.9% vs. 48.6% of on-farm areas and 68.0% vs. 45.1% of total areas, for labelled and non-labelled products, respectively. Regulating ES scores are higher for labelled products, by 17.7% on on-farm areas (2.39 vs. 2.03) and by 13.5% on total areas (2.19 vs. 1.93). These results confirm that labelled products can help contribute to maintaining grasslands and enhancing the supply of regulating ES in farming systems. More broadly, our study illustrates how origin- or quality-based food labels can guide land management in ways that promote grasslands and their ecosystem services, in mountain landscapes.



**Individual risk factors for Staphylococcus aureus mastitis in transhumant dairy herds in western Alps**

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As the most widespread and costly disease of dairy cattle, bovine mastitis has been extensively studied in intensive indoor systems. However, farm management practices and consequently individual characteristics of transhumant herds are far different from those of animals reared in intensive system. The aim of this study was to evaluate which individual-level risk factors for S. aureus intramammary infection (IMI) established in indoor system remain relevant in transhumant dairy herds. From April to August 2024, eight typical dairy farms in the internal western Italian Alps were sampled three times: (T0) lowland before transhumance, (T1) within five days after transhumance, and (T2) one month later after adaptation to upland grazing. Overall, quarter milk samples were analysed to identify IMI. Information on individual risk factors, e.g., lactation stage and rank, body condition score (BCS), and breed, was collected. Since quarters are anatomically separate, they were considered the epidemiological unit. A generalized estimating equations model was fitted to account for repeated measures on the same quarter and survey structure while estimating risk for each factor. The IMI prevalence was lower in transhumant herds at T0 but grew higher than non-transhumant at T1 and T2. Consistent with previous literature, IMI risk increased by 9% per month of lactation, while lactation rank and BCS were not associated with risk. Marked heterogeneity among breeds led to classification into specialized and local. However, analysis did not indicate differing risk according to categories, suggesting that observed differences likely reflect herd management practices rather than breed-specific risk. Bedding, cow, or udder cleanliness showed no association with infection risk, supporting the contagious rather than environmental epidemiology of S. aureus. These findings partly confirm established knowledge on mastitis epidemiology while identifying transhumance as a risky moment, providing information to support tailored preventive strategies for animal health and herd profitability in mountain dairy farming.

**Effect of two consecutive heat waves on dairy cow's activity and milk quality**

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Climate change has increased the frequency and intensity of heat waves (HWs). Mountain livestock farming systems are particularly vulnerable to HWs because they rely mainly on grassland grazing for feed in summer. This study aimed to evaluate the impact of HWs on cows' activity and milk quality. Six cows were housed in 2 temperature-controlled rooms with ad libitum diet and water. They underwent 1 wk of neutral temperature (19°C), followed by 1 wk of HW (36°C by day, 19°C by night), and one-week recovery at 19°C. This sequence was repeated to simulate 2 successive HWs (HW1 & HW2). Automatic feeding and drinking systems individually recorded the amounts eaten and drunk, while pedometers were used to determine the amount of time spent standing or lying down. Respiratory rate was measured manually for 1 min before each milking, and rumen temperature was recorded continuously using ruminal boluses. In addition, milk yield, fat content, and protein content were recorded daily at each milking. A mixed model analyzed the variation of these considering day, repetition (R), repetition*day (R:day) as fixed effects, cow as a random effect, and day within repetition per cow as a repeated measure. During HW, cows' respiratory rate (Pday(evening)<0.001) and ruminal temperature (Pday<0.001) raised, showing that cows experienced heat stress. This raise in ruminal temperature was higher during HW1 than HW2 (PR:day<0.001). Time spent standing and lying down did not change over time (Pday>0.05). DMI decreased up to -6 kg during HWs and recovered initial levels after 1-wk recovery (Pday<0.001) while the volume of drunken water stayed stable over time (Pday=0.380). Milk yield and protein content decreased during both HWs but returned to initial levels at the end of recovery period, with a lower decrease amplitude in HW2 than HW1 for protein content. Fat content did not evolve during both HWs but decreased after HW1, while staying stable after HW2. The Fat-to-Protein ratio increased during both HWs and decreased after the HWs. In conclusion, HWs affected the cows' activity and milk quality, with some variations between repetition 1 and 2. Further analysis of milk fine composition is ongoing to describe further milk quality changes.



**Understanding the needs, obstacles, and expectations of farmers and advisors regarding digital innovation and technology for rangeland livestock systems across Europe (DIGI-Rangeland)**

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Rangeland livestock systems support rural economies and landscape preservation, yet their future viability is challenged by mounting constraints and uneven digital uptake. The DIGI-Rangeland project investigates how digital technologies and innovations (DTI) can support sustainable livestock farming in rangeland areas. One of its objectives is to characterise needs, barriers and expectations regarding digital tools from farmers and advisors. Between Nov. 2025 and Feb. 2026, a survey was conducted across countries to capture current practices, access conditions, perceived value, adoption constraints and support needs. Based on more than 1000 answers, we will present the results, focusing on farmers' and advisors' perceptions, and provide a comparative overview of the main findings. Preliminary results show that a great majority of farmers and advisors believe that DTI can help in rangeland livestock management, e.g. tracking, herding, nutrition and health management, predation prevention and pasture management. Around one third of the respondents use DTI regularly, such as EID, GPS tracking, herd flock management software, surveillance cameras. Most respondents are satisfied with the DTI they used, but uptake is mainly hindered by high costs and poor signal or connectivity.

**SatGrass: An Operational Satellite-Based System for Daily Grassland Yield and Forage Quality Estimation in Austria**

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Grassland management in Austria are largely based on practical considerations such as field shape, accessibility, and slope inclination and prevailing weather conditions, while objective, quantitative monitoring of yield and forage quality is currently not available. This limits the efficiency and sustainability of grassland management, as both biomass production and nutrient content are key parameters for optimizing utilization of grassland. The objective of this study was to develop and implement an operational satellite-based decision support system providing daily, field-specific estimates of grassland yield and crude protein content. The SatGrass system integrates freely available Sentinel-2 imagery, meteorological time series, and IACS field geometries. Key methodological components include an algorithm to determine the start of growing season using Sentinel-2 time series and temperature thresholds, a cut detection algorithm based on combined Sentinel-2 and Sentinel-1 observations, and machine-learning models for biomass and crude protein estimation using the Extreme Gradient Boosting (XGBoost) framework. Model calibration and validation were supported by an extensive ground-truth dataset collected across multiple years from nearly 200 grassland sites across Austria. This dataset enabled the representation of spatio-temporal variability in yield and nutrient dynamics across different years, locations, and management regimes. Sentinel-derived vegetation parameters, particularly Leaf Area Index (LAI), proved to be among the strongest predictors for yield, substantially improving model explanatory power, with coefficients of determination of $R^2 = 0.80$ for yield and $R^2 = 0.60$ for crude protein when evaluated at unknown test sites. SatGrass represents the first operational system in Austria delivering daily indicators of grassland productivity and crude protein content at field scale. The system provides a practical basis for data-driven precision grassland management, supporting optimized decisions on cutting dates, utilization frequency, and sustainable management intensity.



**Ecosystem service of erosion prevention: a remote sensing assessment in grassland-based mountain dairy farms in north-eastern Italy.**

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In the context of climate change, extreme rainfall events have increased in intensity and frequency in recent years. The ecosystem service of erosion prevention (ESEP) is therefore increasingly important, especially in mountainous areas with steep slopes. This issue is particularly relevant in Italy, which has the highest soil loss in Europe (24.13 % of the total with an average of 8.46 t $ha^{-1}$ $year^{-1}$). Previous studies have explored the potential effect of vegetation covers in different agroecosystems (arable land, permanent grasslands, orchards or shrubland) on this issue. There is therefore an interest in assessing the factors that can influence ESEP. We studied this issue based on a dataset of 38 dairy farms located in the Italian north-eastern Alps. Using the Revisited Universal Soil Loss Equation (RUSLE) we calculated the monthly soil loss for three plots per farm. With a remote sensing and GIS-based approach, we calculated the monthly variation of the C-factor, which is the RUSLE factor representing the influence of land cover and management on soil loss. Our aim was to identify which factors, particularly those derived from management, most affected the C-factor and consequently soil loss. Preliminary results show that the average soil loss in the sampled plots is 9.47 t $ha^{-1}$ $year^{-1}$, slightly higher than the Italian national average, but nearly half of the plots (46.02 %) are below this value, despite being in areas with steep slopes and high rainfall. The C-factor does not appear significantly influenced by management intensity, but shows significant correlations with altitude and slope, mean temperature, and species richness. This evidence leads us to conclude that, in the study area, the intensity of management associated with the sampled grassland-based dairy farms does not exceed the threshold required to increase the C-factor and, consequently, significantly affect ESEP. This RUSLE-based approach will allow us to investigate future scenarios such as the conversion of grassland to orchards or the abandonment of these areas, and their potential impacts on soil erosion.

**Precision Livestock Farming applications in Alpine dairy systems: a case study in Northern Italy**

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Alpine dairy farming in Northern Italy often involves moving herds from lowlands to mountain pastures during the summer, shifting from indoor systems to extensive grazing on alpine slopes. The summer season in commercial farms often lacks monitoring of animals and diets, limiting the ability to identify factors influencing animal performance. In 2025, 22 Brown cows (parity 2.35±1.57) were monitored over four months across lowland (P1: June; P4: September) and alpine pasture periods (P2: July; P3: August), using pedometers and collars to assess posture, behaviour and GPS position, with biweekly records of milk yield (MY) and quality, body condition and locomotion. Pastures were analysed using a plate meter for biomass quantity, NIRspectroscopy for quality and visual observation for botanical composition. MY significantly declined ($p<0.01$) from P1 to P3, with the dietary shifting from TMR (P1) to pasture grazing, and the increase of NDF content (32.6%±0.78 in P1 to 48.4%±0.98 in P3). Milk fat and protein decreased during summer (from 4.67±0.73 and 3.82±0.40 in P1 to 4.25±0.57 and 3.56%±0.36 in P3, respectively) with a significant increase when back to the lowland (P4; $p<0.01$). Forage Value increased from 21.6±3.68 in P2 to 29.6±4.43 in P3, while plant species richness declined (24.8±0.59 to 22.4±3.42 for P2 and P3, respectively). Daily energy expenditure, computed from the distance covered by cows, varied among periods ($p<0.01$), peaking in P2 and decreasing in P3. This decline was correlated with fewer steps ($r=0.78$), assessed from pedometers, but did not explain the seasonal reduction in MY ($p=0.34$). Precision Livestock Farming (PLF) technologies provide insights into energy expenditure and behaviour across seasons. Variations in MY and composition were primarily associated with changes in diet, rather than in physical activity, while seasonal pasture dynamics influenced nutrient intake and animal performance. PLF tools may support data-driven decisions, improving feeding strategies and enhancing the sustainability and efficiency of alpine dairy systems. Agritech National Research Center – European Union Next-GenerationEU (PNRR-Mis4 Com2, Inv1.4-D.D.1032 17/06/2022, CN00000022)



**Use of GPS collars to assess the effect timing of post-partum upland grazing has on ewe home range area**

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Upland grazing by sheep in the Republic of Ireland has declined due to a perceived loss in pre-weaning lamb performance and additional labour requirements for flock management. This has resulted in reduced grazing pressure on upland areas during peak grass growth periods allowing less palatable species to dominate. To investigate the effect of time post-partum when ewes and their lambs are reintroduced to the upland area on home range (grazing area), 37 Scottish Blackface ewes rearing single lambs were reintroduced into upland grazing at four (T4: n=12), eight (T8: n=13) and, 10 (T10: n=12 ) weeks post-partum on a commercial farm in spring 2025. The farm utilises a 47ha fenced upland grazing area which the ewes had previously grazed during prior lactations or as lambs. Treatment groups were established based on mean days post-partum and balanced for ewe age, live weight and BCS along with lamb birth weight and live weight adjusted to four weeks post-partum. All ewes were equipped with DigitAnimal GPS collars to track grazing behaviour once reintroduced to the upland grazing area. Location fixes were captured at 30-minute intervals and transmitted over Global System for Mobile communication. A total of 92,813 location fixes were generated from May to August 2025. After initial processing by removing points outside of the upland boundaries, 64,060 location fixes were usable, pending a calibration study. Usable location fixes for T4, T8 and, T10 were 74%, 70% and 59% respectively. These fixes were used to generate 95% kernel density maps for each month on ArcGIS Pro (version 3.3.2). Average area occupied for treatment groups T4, T8 and T10 were 16.4 ha (35% of available area), 12.6 ha (27%) and 14.7 ha (31%) respectively over the trial period. During the four weeks pre-weaning, T4 used 20.6 ha (44% of available area), T8 used 16.6 ha (35%) and T10 used 17 ha (36%). These preliminary results suggest that earlier reintroduction to upland grazing post-partum, encourages greater utilisation of upland areas during peak grass growth periods.

**Virtual Fencing for the Management of Dairy Cows in Alpine Pastures: Opportunities, Challenges, and Integrated Technological Solutions**

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Alpine grazing systems play a key role in sustaining mountain farming by providing diversified income sources while delivering essential ecosystem services. Their effective management is crucial to preserve ecological value and ensure territorial stewardship. Virtual Fencing system (VF) may support these objectives by remotely managing grazing areas through GPS-enabled collars emitting a two-step aversive stimulus. This study aimed to (i) evaluate the effectiveness of VF implementation in an alpine context and (ii) assess whether combining VF collar data with remote sensing (RS) imagery can support tailored grazing management, particularly in relation to forage utilization. The research was conducted in the Eastern Italian Alps (Italy), where 35 Bruna dairy cows equipped with VF collars (Nofence®, Norway) grazed sequentially on two summer pastures (Malga Pozof and Malga Tamai) and on ski slopes repurposed for grazing. Grazing areas were expanded daily. Animal adaptation to VF was assessed through the number of electrical pulses emitted, while forage utilization was evaluated by integrating RS-derived vegetation indices and animal movement data. Results showed good animal adaptation to VF, with a low average number of electrical pulses and no significant differences among grazing areas. The integration of VF and RS data provided valuable insights into grazing patterns and forage consumption. Above Ground Biomass (AGB) loss was estimated using pre- and post-grazing RS imagery through the Normalized Difference Red Edge Index (NDRE). These estimates were compared with Kernel Density Estimation (KDE) maps derived from GPS positions associated with grazing activity, inferred from collar-based accelerometer data. KDE maps overlapped with areas of highest AGB loss, indicating effective pasture use. This study highlights the potential of coupling VF technology with RS data to support sustainable and adaptive grazing management in mountain environments, where in situ monitoring is often logistically challenging and costly.



**Foraging behaviour of pigs, Highland cattle and donkeys in woody-encroached silvopastoral systems: a synthesis of three case studies**

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Across European mountains, shrub and tree encroachment is reshaping grasslands, reducing forage quality and availability, and altering key ecosystem services. We synthesize here three case studies quantifying livestock feeding preferences for woody vegetation: pig browsing in a hill woodland (Piedmont, Italy); Highland cattle within shrub-encroached Alpine pastures (Italy and Switzerland); and donkeys in a shrub- and tree-encroached pasture in Gran Paradiso National Park (Italy). Feeding preferences were evaluated via feeding-station direct observations, coupled with selection analyses. Pigs were selective, focusing on a few understory plants (e.g., hazel, bramble) while avoiding many others. After coppicing, they heavily damaged resprouts of chestnut, hazel and wild cherry, exerted only moderate pressure on black locust, and had little or no effect on other species, supporting targeted control but potentially constraining the regeneration of species that should not be controlled. Highland cattle behaved as consistent mixed feeders: woody plants (e.g., green alder, ash., raspberry) comprised 15-46% of the diet, and consumption generally increased with abundance, indicating broad browsing capacity in shrub-dominated mosaics. Donkeys behaved mainly as grazers (89% herbaceous; 4% woody), but selectively consumed a few species above their environmental availability (raspberry, goat willow, whitebeam), while for some plants (e.g., green alder, lady fern) consumption was proportional to abundance. Together, these studies highlighted distinct functions: pigs can apply strong, selective pressure, with species-dependent trade-offs; Highland cattle provide sustained tree and shrub browsing where woody cover is high; and donkeys maintain grazing on the herbaceous layer while selectively browsing a limited set of woody plants and ferns. Overall, such diversity in feeding preferences suggest benefits when integrating these livestock species into grazing management strategies, potentially mitigating woody encroachment, supporting biodiversity and forage quality.

**Foraging behaviour of goats and heifers on mountain pastures encroached by Alnus viridis**

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Woody encroachment threatens grassland biodiversity and ecosystem services worldwide. In Swiss mountain pastures, this process is mainly driven by Alnus viridis (green alder), a tall nitrogen-fixing shrub that reduces plant and animal diversity as well as agricultural production. Targeted grazing combined with mechanical clear-cutting has been proposed as a strategy to control woody encroachment. The present study evaluated the potential of this approach in three encroached mountain pastures. In each pasture, four paddocks were established: (1) goat grazing alone, (2) A. viridis clear-cutting followed by goat grazing, (3) heifer grazing alone, and (4) A. viridis clear-cutting followed by heifer grazing. Overall, 38 goats and 49 heifers were introduced between 2024 and 2025, and direct observations were used to assess their foraging behaviour. In goat paddocks, A. viridis accounted for 12% of the diet when A. viridis was cut and 44% when not cut. Typical A. viridis understory species were also well consumed by goats, particularly in paddocks where A. viridis was cut. In this treatment, fern consumption accounted for about 10% of their diet, while other tall herb species together represented an additional 13%. Across treatments, herbaceous species represented 38% of the goat diet, while it constituted 90% of the heifer diet. A. viridis represented only about 1.5% of the heifer diet, regardless of whether shrubs were cut or not. Heifers also consumed small amounts (~5% of the diet) of other woody species. According to Jacob's index of preference, goats showed a preference for A. viridis, whereas heifers avoided it. Goats also preferred other woody species, while heifers mainly preferred herbaceous species. These findings suggest that goats can effectively consume A. viridis and serve as valuable long-term tools for managing woody encroachment in mountain pastures.



**How dwarf shrub encroachment influences subalpine plant and grasshopper diversity**

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Dwarf shrub encroachment has become a major challenge in subalpine grasslands, driven by declining grazing pressure. Knowledge on the impact of shrub cover on biodiversity is scarce. Earlier research often focused on tall shrubs below the treeline and on plant biodiversity. Thus, we quantified plant and grasshopper diversity on twelve subalpine pastures in the Swiss Alps. Each of the four most relevant dwarf shrub types (Calluna, Vaccinium, Rhododendron, Juniperus) was represented by three independent sites. At each site, we investigated a gradient from open pasture to dense dwarf shrub stands and recorded vascular plant communities in twenty 2 × 2 m plots per site along this gradient. Grasshoppers were surveyed twice per zone using standardized transect walks, with all adult individuals counted and identified. We found that plant species richness peaked at low to intermediate shrub cover, declining sharply toward dense shrub stands. Losses were most pronounced in Juniperus sites, where dense canopy structure and coniferous litter reduced herb-layer diversity. Plant community composition shifted consistently along the gradient from grassland specialists to shrub-associated species. Grasshopper richness showed a similar, but less distinct hump-shaped response, with highest diversity in pasture-shrub mosaics, where structural heterogeneity provided favourable thermal conditions, shelter, and foraging opportunities. In contrast, grasshopper abundance declined steadily with increasing shrub cover, particularly in Rhododendron and Calluna stands. Several grasshopper species showed clear associations with specific shrub types or cover levels, indicating that shrub identity modulates habitat suitability. Overall, our results demonstrate that low to intermediate shrub cover can enhance both plant and grasshopper diversity, whereas dense, closed shrub canopies consistently depress biodiversity. These findings highlight the importance of targeted shrub management and grazing strategies to maintain biodiverse mountain pastures. .

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