

LIFE PASTORALP



LIFE16 CCA/IT/000060

Pastures vulnerability and adaptation strategies to climate change impacts in the Alps

Deliverable E3

**Proceedings of the international
scientific conference**

March, 2023



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1. Executive Summary

GLOBAL CHALLENGES IN MOUNTAIN AGROPASTORAL SYSTEMS - Scientific evidence on impacts, adaptation and policies was the stimulating title of the international scientific conference organized in the frame of the LIFE PASTORALP project at Forte di Bard, (Aosta, Italy the 15-17 March 2023). Scientists, policy makers, delegates of local authorities, natural parks' officers, agriculture and extension technicians, farmers' representatives and students participated to the conference. The first day (March the 15th 2023) was devoted to keynote speakers speeches on the topics of the conference and for presenting the main outcomes of PASTORALP project and its impacts on policies and governance. During the second day (March the 16th 2023) scientific talk were given by scientists on the current and emerging issues related to climate-driven global changes in mountain agropastoral systems. The third day (March the 17th 2023) was under invitation; specifically the representatives of 9 LIFE projects (LIFE PASTORALP, LIFE AGRICULTURE, LIFE GRACE, LIFE IMAGINE, LIFE MIDMACC, LIFE REGENERATE, LIFE SHEPFORBIO, LIFE XEROGRAZING, LIFE CLIMAMED) and 1 NO-LIFE project (SUSALPS) were invited to join a hands-on workshop in order to identify the main challenges, barriers and recommendations on mountain pastoral systems. The workshop was organized in three discussion tables, moderated by two facilitators and one rapporteur, and streamlined by guiding questions. Before the workshop, a draft of a joint common position paper was circulated among the invited persons. The position paper (which has been sent to the EC) was then finalized and agreed by all participants. The three topics of the Scientific Conference are summarized below.

Challenges and opportunities for mapping and modelling agropastoral systems

Mapping grasslands and agropastoral systems has become undoubtedly pivotal for global change studies, natural resource monitoring and management, desertification evaluation and or loss of biodiversity. Moreover, the abandonment of marginal land in combination with shrub encroachment and climate changes are critical factors in the continuing decline of Europe's species-rich semi-natural grassland habitats. Traditional mapping methods are time consuming and very costly, hence, alternative approaches (such as modelling, remote sensing products, machine learning) are becoming increasingly important to map changes in pastoral systems and detect mowing and grazing practices. In this session, studies analysing challenges and opportunities of using innovative approaches to model and map grasslands and pastoral systems were presented.

Climate change impacts, adaptation and mitigation

As climate change continues, and climate extremes such as droughts, heatwaves, and intense precipitation increase, it is important to advance our understanding of their impacts on ecosystem structure and function. Natural and managed ecosystems, such as mountain pastures, have indeed the potential to face future climate change challenges if preserved and sustainably managed. This session focused on observational, experimental and modelling studies related to climate change impacts on mountain grasslands, pastures and other agropastoral systems, as well as studies investigating the role of agropastoral systems for adaptation and mitigation opportunities in mountain areas.

Governance under global changes: the interface between policy and science

The science-policy interface presents several challenges to both scientists and policy makers, however, the growing severity of challenges imposed by climate change, and the policies needed

to face them, implies that more frequent collaborations between scientists and policy makers are crucial. This session included the presentation of studies and experiences at the interface between policy and science in the context of mountain agropastoral systems, including the definition of adaptation or mitigation strategies or plans. The session aimed also at describing the current gaps, challenges, skills and strategies facilitating the uptake of scientific knowledge in policy formulation and implementation.

All presentations are downloadable from PASTORALP websites (<https://www.pastoralp.eu/final-conference/>).

2. Programme of the international scientific conference

Day 1 (15/03/2023)

Keynote talks

Camilla Dibari – University of Florence: *“The LIFE Pastoralp project”*

Carolina Adler – Executive Director Mountain Research Initiative, Lead Author for the Intergovernmental Panel on Climate Change (IPCC): *“Climate change in mountain regions: key findings from the IPCC’s sixth assessment and prospects for climate-resilient mountain social-ecological systems”*

Uta Schirpke – Eurac Research, Institute for Alpine Environment; University of Innsbruck, Department of Ecology: *“Global change impacts on ecosystem services of mountain grassland”*

Maria Luisa Paracchini – European Commission, Joint Research Centre, Sustainable Resources Directorate: *“Integrating scientific results into EU nature protection and restoration policies”*

Alessandro Rota – Assessorato Agricoltura e Risorse Naturali, Politiche regionali di sviluppo rurale: *“Pastoralp results in operational tools for rural development programme 2023/27”*

Day 2 (16/03/2023)

Session 1: Challenges and opportunities for mapping and modelling agropastoral systems

Analysis and conservation of secondary grasslands: the case of Maiella National Park. **Gigante, D.***; Angelucci, S.; Morbidini, L.; Pauselli, M.; Vizzari, M.; Di Cecco, V.; Bonini, F.; Madonna, L.; Valenti, B.; Di Martino, L. | *Dip. Scienze Agrarie, Alimentari e Ambientali, Università di Perugia, Italy

Large-scale mapping of shrublands in altitude pastures using the 20-m Sentinel-2 Normalized Anthocyanin Reflectance Index (NARI). **Bayle, A.***; Choler, P. | *Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, LECA, Grenoble, France

Characterization of Alpine Pastures using Multitemporal Earth Observation Data within the Climate Change Framework. **Orusa, T.***; Farbo, A.; De Petris, S.; Sarvia, F.; Cammareri, D.; Borgogno-Mondino, E. | *Department of Agricultural, Forest and Food Sciences (DISAFA), GEO4Agri DISAFA Lab, Università degli Studi di Torino, Italy

Incorporating ecotone monitoring into alpine land management and biodiversity conservation: a pilot study from the Chamonix valley. **Carlson, B.***; Bayle, A.; Bison, M.; Boulangeat, I.; Delestrade, A. | *CREA Mont-Blanc, France

Monitoring pasture vegetation using satellite remote sensing: which images and workflow? **Oriani, F.***; Aasen, H.; Schneider, M.; | *Agroscope – Swiss Center of Excellence for Agricultural Research, Switzerland

GPS tracking: Opportunities for a better understanding of the interactions between pastoralism and vegetation in high altitude pastures. **Perron, R.***; Garel, M.; Bayle, A.; Choler P. | *Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, LECA, Grenoble, France

Animal-borne sensors to monitor pastoral systems: opportunities and challenges. **Schneider, M.***; Pauler, C. | *Agroscope – Swiss Center of Excellence for Agricultural Research, Switzerland

Session 2: Climate change impacts, adaptation and mitigation

Pastoral management and climate have a comparable effect on the variation of botanical composition of alpine pastures: an evaluation over a 20-year time span. **Pittarello, M.***; Nota, G.; Marengo, G.; Lombardi, G.; Lonati, M. | *University of Torino, Department of veterinary sciences, Italy

Yield and nutritional quality of drought-resistant leys under extreme and contrasting climatic conditions. **Probo, M.***; Dereuder, E.; Frick, R.; Frund, D.; Raymond, B.; Mariotte, P. | *Grazing Systems, Agroscope, Switzerland

Quantifying the environmental effects of pasture restoration through scrubland clearing combined with livestock management. **Pascual, D.***; Pla, E.; Nadal-Romero, E.; Zabalza Martínez, J.; Lasanta T.; Foronda, A.; Reiné, R.; Barrantes, O.; Pueyo, Y.; Lana-Renault, N.; Ruíz-Flaño, P. | *CREAF, Barcelona, Spain

Re-grazing of abandoned mountain pastures to maintain soil functions and biodiversity? The case study "Brunnenkopfbalm". **Dannenmann M.***; Jentsch A.; von Heßberg A.; Ramm E. | *KIT (Karlsruhe Institut for Technology), Campus Alpin; Garmisch-Partenkirchen, Germany

Using robust ruminants to preserve mountain pastures under global change conditions. **Pauler, C.M.***; Lüscher, A.; Kreuzer, M.; Berard, J.; Schneider, M.K. | *Agroscope, Forage Production and Grassland Systems, Switzerland

Session 3: Governance under global changes: the interface between policy and science

A conceptual model of mountain socio-ecological systems to support multi-stakeholder collaborations on the governance of mountain regions and agropastoral systems. Cristofari, H., **Urbach, D.***; Otero, I.; Reynard, E.; Guisan, A.; Randin, C. | *Global Mountain Biodiversity Assessment, Assessment, Institute for Plant Sciences, University of Bern, Switzerland

Pyrenean Climate Change Strategy at the crossroads of science and political agenda at regional level. Vergèr D*.; Terrádez Mas J.; García Balaguer E.; **Pascual, D.** | *Pyrenean Climate Change Observatory (OPCC) of the Working Community of the Pyrenees, Spain

The national school of pastoralism (SNAP): first realisations. **Battaglini L.***; Barbera F.; Bindi L.; Franca A.; Claps S.; Storti D.; Membretti A.; Omizzolo A.; Semplici G.; Nori M.; Arneodo G.; Tallone G.; Di Meglio F.; | *DISAFA, University of Torino, Italy

A multi-taxa approach in mountain ecosystems. **Cerrato C.***; Ghidotti, S.; Rocchia, E.; Aimone, B.; Bionda, R.; Movalli, C.; Pedrotti, L.; Vettorazzo, E.; Viterbi, R. | *Gran Paradiso National Park, Italy

Does the flexibility of resource governance regimes illustrate their sustainable adaptation? An analytical framework based on the concept of flexible socio-ecological systems to identify the adaptability of agropastoralism to global uncertainties. **Sarrazin, C.***; Napoleone, C.; Targetti, S. | *INRAe (Ecodéveloppement)

Day 3 (17/03/2023)

Project networking (under invitation)

9:00-9:10 **Giacomo Trombi** (UNIFI) "Aims, methodology and expected outcomes of the networking meeting"

9:10-9:20 **P. Borsotto** (CREA) and **F. Benvenuti** (MASE, LIFE NCP) “Strengthening complementarity between the LIFE Programme and the CAP”

9:20-9:45 Round presentation of each project invited:

- **LIFE AGRICULTURE**, Luca Filippi (Consorzio di Bonifica dell'Emilia Centrale)
- **LIFE GRACE**, Luca Colombo (FIRAB)
- **LIFE IMAGINE**, Daniela Gigante (UNIPG)
- **LIFE MIDMACC**, Diana Pascual Sánchez (CREAF)
- **LIFE REGENERATE**, Antonio Pulina (UNISS)
- **LIFE SHEPFORBIO**, Tommaso Campedelli (Dream)
- **LIFE XEROGRAZING**, Ginevra Nota (UNITO)
- **LIFE CLIMAMED**, Maria Doula (BPI)
- **POLLINATORS**, Simona Bonelli (Butterfly Conservation Europe)
- **SUSALPS**, M. Dannenmann (KIT)
- **Parco Natuale Mont Avic**, Daniele Stellin

9:45-11:00 hands on discussion on the main topics

11:00-11:15 Coffee break

11.15-12:30 final outcomes, wrap up

12:30-13:00 conclusion of the meeting

3. Abstracts - oral presentations

3.1 Challenges and opportunities for mapping and modelling agropastoral systems

Analysis and conservation of secondary grasslands: the case of Maiella National Park

Daniela Gigante¹, Simone Angelucci², Luciano Morbidini¹, Mariano Pauselli¹, Marco Vizzari¹, Valter Di Cecco², Federica Bonini¹, Luca Madonna², Bernardo Valenti¹, Luciano Di Martino²

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The secondary grasslands represent an emblematic challenge for nature conservation in protected areas. Their semi-natural origin and intrinsic dependence on grazing, as well as their huge variety of types and notable floristic richness, represent the two sides of the same coin and embody the result of a long-lasting, dynamic tension between use and preservation. This is particularly true in the Apennine: a crossroad of historical, anthropological, biogeographical, environmental, and climatic drivers. Mapping and monitoring grassland habitats, when represented by Annex I types, are activities required by Directive 92/43/EEC, in order to understand their dynamics in space and time and define sustainable management practices. Their maintenance in a favorable conservation status should in fact be grounded on an integrated approach, combining a floristic, phytocoenotic, and ecological understanding with the implementation of sustainable use and practices. Field surveys carried out by botanists still represent an essential step for habitat detection and identification, while trends and processes may receive adequate support from remote sensing technologies. The territory of Maiella National Park, one of the biodiversity-richest sites in Europe, hosts huge grassland areas. It has been affected in the last decades by land depopulation and a long-lasting trend of reduction in livestock farming activities and extensive grazing. We present here the results of an integrated study of the areas occupied by grassland vegetation within the hilly, montane, and, partly, subalpine belts of the Park, taking into account their floristic composition, vegetation traits, ecological-environmental characteristics, pastoral value, distribution, and productivity indices. The collected data allowed the identification of 20 plant communities belonging to different phytosociological classes, from *Festuco-Brometea* to *Nardetea strictae*, *Molinio-Arrhenatheretea*, and *Elyno-Seslerietea*, mostly referable to the Annex I Habitat types 6210(*), 6230*, and (to a lesser extent) 6510 and 6170. An NDVI-based web interface, running on Google Earth Engine, has been implemented for near-real-time analysis of the vigor and phenological phases of the grassland vegetation, as a support for more rational and sustainable use of the areas by farmers and shepherds, taking into account that the main grazing strategies vary according to the species raised. Indeed, continuous grazing is the main strategy in cow-calf and dairy cows systems, with consequent non-optimal pasture utilization showing under or over-grazed areas, while daily grazing circuits characterize sheep and goat shepherding. Our approach intends to contribute to the development of an integrated management system, taking into account environmental priorities, as well as the economic, social, and cultural needs of a protected area, bringing attention to the ecological role of extensive livestock farming and its products.

Large-scale mapping of shrublands in altitude pastures using the 20-m Sentinel-2 Normalized Anthocyanin Reflectance Index (NARI)

Arthur Bayle, Philippe Choler

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While the upper limit of the forest has been studied and monitored for many years, the distribution of low woody plants (or shrublands) in the Alps is often poorly considered in the mapping and management of mountain environments (Bayle et al. 2019). However, shrublands are now a structuring and sometimes dominant habitat of the mountain vegetation cover, and their extension at the expense of grasslands leads to a certain number of "ecosystem disservices" with known consequences on pastoral activities (Camacho et al. 2008). The commissioning of new satellites such as Sentinel-2 offers scientists and land managers the possibility of improving spatio-temporal monitoring of mountain environments (Dedieu et al. 2016), thanks to the better spectral, spatial, and temporal resolution of this new generation of images.

Bayle et al. (2019) recently demonstrated the potential of Sentinel-2 to detect the accumulation of anthocyanin pigments during autumn in shrublands dominated by Ericaceae using the red-edge band to compute the Normalized Anthocyanin Reflectance Index (NARI), thus allowing to refine land cover maps by distinguishing between shrublands and grasslands. We have taken this work to a larger scale in order to propose for the first time a mapping of low woody heaths on a regional scale (French Alps). First, (1) we constructed a dataset of photo-interpreted samples for forest, shrublands, grasslands and bare soil based on very-high resolution images (BD ORTHO IGN) and used Random Forest classification to map shrublands at the French Alps scales. Second, (2) as all shrublands-forming species do not redden at fall, we used floristic plots to analyze the relation between shrublands probabilities and species composition and abundance. Third, (3) we analyzed the distribution of shrublands in relation to French pastoral units to better understand the potential threat of shrub encroachment to pastoral activities. Finally, (4) trends in alpine vegetation greenness have been highlighted in recent studies (Carlson et al. 2017; Choler et al. 2021) while shrub growth and encroachment have been observed on another note (Anthelme et al. 2007; Francon et al. 2023). We compared the greening trends obtained from the Landsat time series (1984-2021) between shrub and grasslands to identify a specific responses of life-form to forcings.

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Characterization of Alpine Pastures using Multitemporal Earth Observation Data within the Climate Change Framework

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Climate change is profoundly affecting alpine ecosystems. Pastures are one of the most affected ecosystems since they are generally weakly managed and located at medium-high altitudes where climate change effects are known to be stronger. Pastures monitoring is therefore desirable to test their reaction to the currently varying climate conditions. Long time-series (about 40 years) of Earth Observation (EO) data, with special concerns about the USGS NASA Landsat missions, can be effectively used to explore spectral and thermal behavior of these areas in the climate change framework. In this work, more than 900 acquisitions covering the period 1984-2022, from the Landsat 5-9 missions were obtained through Google Earth Engine (GEE) and the correspondent maps of Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) analyzed.

LST was assumed as indicator of the capability of pastures of limiting/improving thermal fluxes. NDVI was used to read the biomass content of pastures and support interpretation of heat fluxes related to LST. LST and NDVI maps were initially pre-processed by filtering out, at pixel level, "bad" observations and smoothing the remaining ones by Savitzky-Golay filter. The yearly LST/NDVI maxima were then selected and a 39-years long time series of LST maps generated to explore trends with yearly granularity.

Pasture areas were preventively mapped with reference to the available cadastral maps from the Aosta Valley (NW Italy) SCT geoportal. This made possible to focus the analysis on the pastures pixels solely from the LST/NDVI time-series. A 1st order polynomial was used to fit yearly values of LST and NDVI at pixel level. The correspondent gain and offset values were mapped and used to investigate pastures reaction to climate changes looking for eventual relationship between local behavior (in terms of both LST and NDVI) and topographic features (altitude and aspect) as derivable from the Aosta Valley Regional Digital Terrain Model. This analysis based on EO data allow to understand and preliminary quantify how alpine pastures respond to climate change and what are the main drivers of such changes.

Incorporating ecotone monitoring into alpine land management and biodiversity conservation: a pilot study from the Chamonix valley

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Despite the implications of shrub expansion for habitat structure, biodiversity and ecosystem (dis)services in the Alps, the response of the dwarf shrub ecotone to global change during recent decades remains poorly understood and quantified. From a mapping perspective, the recent arrival of Sentinel-2 satellites has at last enabled reliable distinction between alpine grass, shrub and tree cover, however this methodological advancement has yet to be effectively integrated into land cover mapping and biodiversity monitoring efforts in alpine regions. For a pilot-study in the Chamonix valley, France, we utilize an array of phenological, bioclimatic and spectral indices derived from Sentinel-2 time series to incorporate a dwarf-shrub *Ericaceae* class into a comprehensive land cover map, which provides the basis for automated mapping across mountain vegetation ecotones in the years ahead. We also test a methodological framework for identifying hotspots of vegetation change based on annual trends in classification probability, as a proof of concept given the limited number of years of Sentinel-2 imagery currently available. Finally, we discuss the potential of ecotone monitoring as a tool for land management and biodiversity conservation in the context of an adaptive monitoring framework.

Monitoring pasture vegetation using satellite remote sensing: which images and workflow?

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Mountain pastures are part of an ecosystem that hosts a rich plant biodiversity organized in various distinct plant communities. An accurate long-term monitoring of these habitats, going beyond the sole ground survey, is of primary importance for nature conservation and forage production planning.

Within the GrassSense project, we develop a novel analytical framework to identify and monitor plant communities in mountain pastures based on the joint statistical analysis of ground data and satellite imagery. The driving research questions are whether it is possible to distinguish mountain pasture communities using commonly available satellite imagery and which analytical workflow and satellite products are suitable to track spatial and temporal changes.

We investigate two study zones: a mid-mountain pastoral environment in the Northern Swiss Pre-Alps (Toggenburg district, canton of St. Gallen) and mid-to-high elevation mountain pastures surrounding the Swiss National Park in the Grisons canton. Both environments are ground mapped for pasture vegetation associations, including fertile pastures, wetlands, dry plant communities, and dwarf shrubs.

The preliminary results show that using publicly available images from the Landsat program (NASA), with a 30-m spatial resolution and sub-monthly revisit time, can catch a clear difference between wet and dry plant communities and, to some extent, between different fertile and low-productive ones. This is observed by computing the Normalized Difference Vegetation Index (NDVI) as a proxy for photosynthetic activity. Moreover, NDVI shows a different intensity of vegetation activity for different months, reflecting the phenological cycle of vegetation communities. The temporal difference among communities is not clearly visible since Landsat has a too infrequent (15-day) revisit time, suggesting that a higher temporal resolution, e.g. using commercial satellite products, could improve the temporal analysis.

The results also show that shadow cast by mountains is one main disturbing factor of the statistical relation between vegetation activity and the observed spectral properties. As a solution, cast shadow can be computed for every image to select non-disturbed areas or to apply a radiometric correction.

This research proceeds in the direction of the joint spatial analysis of NDVI and other spectral properties in relation to altitude, aspect, and climatological conditions, with the goal of identifying a set of explanatory variables to track the change of vegetation communities in these highly complex ecosystems.

GPS tracking: Opportunities for a better understanding of the interactions between pastoralism and vegetation in high altitude pastures

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The widespread use of GPS technology for tracking domestic animals now offer the opportunity to study the movement of sheep flocks in high altitude pastures throughout the summer months. The fine localisation of the herd is especially promising for a better understanding of the use of the mountain pasture by pastoralism and its impact on the vegetation. High spatial resolution trajectories can be linked to satellite imagery which now reaches a resolution of 10 m by 10 m (Sentinel-2).

We equipped 9 sheep flocks with GPS collars during the summer of 2022. The flocks are located in five study sites spread over the French Alps. All the flocks were dedicated to meat production and located in, or in close vicinity to, protected areas with different status (National Park, National Reserve, National Hunting Reserve, Regional Natural Park), with sizes ranging from 200 to 1500 animals.

The quantitative data acquired, supplemented by interviews with the shepherds and farmers, allow to trace in detail and understand the movements of the herd and to characterise its activities on the mountain pasture. Preliminary results will illustrate **(1)** the use (grazing, movement, resting) of the different habitats of the mountain pasture, and its relation to the productivity and phenology of the pasture habitats; **(2)** the multi-facet impacts of grazing (by the tooth, the foot and the faeces of the animals) on different habitats; **(3)** the challenges of characterizing these impacts using high-resolution remote sensing for upscaling at the massif scale.

Animal-borne sensors to monitor pastoral systems: opportunities and challenges

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Mapping mountain grasslands aims at characterizing pasture types. Thereby, it informs about ecosystem services related to pastoralism by ruminant herbivores. Often, however, there is a lack of knowledge on how these pasture characteristics influence the behavior of grazing animals – and vice versa. Animal-borne sensors have the potential to reveal these plant-herbivore interactions in a quantitative way. We focus on opportunities and challenges of animal-borne sensors as learned in our own mountain grassland research.

Recently, we conducted three grazing experiments on heterogeneous mountain pastures in the Swiss Alps. GPS trackers, pedometers and nose-band pressure sensors were fitted to sheep, goats and cattle. Additionally, we applied classical grassland monitoring methods by analyzing vegetation composition, forage quality and quantity and soil characteristics. Finally, we combined these data and analyzed their relationship.

We found that (1) distribution of grazing animals on mountain pastures strongly depends on topography and vegetation but that the effects of grazing management are much weaker; (2) there are substantial differences between ruminant species as well as breeds in space use and forage selection, e.g. low-productive cattle use the space more evenly and less selectively than high-productive breeds; (3) this has consequences for vegetation composition, e.g. resulting in less overused areas, less bare soil and a lower cover of woody plants in pastures of low-productive breeds.

Opportunities: (1) Animal-borne sensors allow for monitoring activities of grazing animals continuously, objectively and without disturbing their natural behavior. (2) Sensors can monitor processes not directly observable by humans but sensed by the animal. (3) The high temporal and spatial resolutions allow for new algorithms of data interpretation, which reveal novel ecological relationships between livestock behavior and vegetation structure. Thereby, animal-borne sensors allow to gain insight into underlying mountain grassland processes and to understand reciprocal relationships. Thus, holistic pasture research combines animal-borne sensors and classical grassland monitoring.

Challenges – from a practical point of view: (1) Accurate fitting of sensors is time-consuming and challenging, especially if sensors are not particularly made for the species or breed of interest. (2) Animal interactions and outdoor conditions can damage sensors. Since most devices were developed for in-house deployment, they need careful adaptation and testing for their application in mountain environment. (3) Assessing the accuracy of data is crucial. (4) Quantifying and accounting for the uncertainty of data is challenging, but essential.

3.2 Climate change impacts, adaptation and mitigation

Pastoral management and climate have a comparable effect on the variation of botanical composition of alpine pastures: an evaluation over a 20-year time span

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The main aim of the research was to evaluate the relative effects of climate and grazing management on the composition of pastoral vegetation in alpine environments. The specific objectives were: i) to assess the magnitude of variation in botanical composition of pastures over a ~20-year period (2003 - 2021), ii) to test the effect and weight of climatic and management variables on botanical composition. From a large database of vegetation surveys carried out in the early 2000s (historical surveys) throughout the western Piedmontese Alps and by considering the proximity of weather stations, 58 surveys spread across 5 pastures were selected. In 2021 and 2022, the selected surveys were carried out again in the same position of the historical ones and with the same methodology (recent surveys). The climatic variables considered were the total annual precipitation and average annual temperatures for the period 2003-2021. The livestock stocking rate over the period 2003 - 2021 and the terrain slope were used to quantify the management pressure. The climatic variables and the stocking rate were related to the years by means of linear models to quantify their trend of variation (i.e., angular coefficient) over the considered timespan. To assess how much the botanical composition changed over time, a transform-based Principal Component Analysis was carried out and, subsequently, the Euclidean distance for each survey pair (historical-recent) was calculated using principal components 1 and 2. The distance was interpreted as the magnitude of change in botanical composition: the further the historical survey was from the recent one, the greater the change in botanical composition. To test the effect and weight of climatic and management variables on botanical composition change, a Generalised Linear Model was used. The Euclidean distance between historical and recent surveys was specified as the dependent variable and the angular coefficients of the trends of total annual precipitation, mean annual temperatures and stocking rate in interaction with slope were specified as explanatory variables. Management and climatic variables showed a similar importance in affecting changes in botanical composition. The interaction between the stocking rate and slope showed that the most pronounced changes in botanical composition occurred in conditions of over and under grazing. Vegetation changes were larger where the trend of increasing average annual temperatures has been most rapid over the last twenty years and where total annual precipitation has decreased. This research showed that, in a climate-change context, management plays a crucial role in conditioning the botanical composition of grazed alpine pastures. For this reason, it would be advisable to promote the application of farm-specific tools for the regulation sustainable grazing management actions, considering that stocking rate has to balance the grassland carrying capacity (e.g. Grazing Management Plans).

Yield and nutritional quality of drought-resistant leys under extreme and contrasting climatic conditions

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One of the most important trends related to climate change is the increase in the frequency and intensity of extreme periods, such as severe droughts alternating with heavy rainfalls. This phenomenon is putting a strain on forage production, with higher yield variability, especially during summer periods, which are increasingly characterized by drought and heatwaves. As part of the France-Switzerland Interreg SPAD (Systèmes de Production Agricole Durables) project, five different drought-resistant summer leys were tested on three farms in the Swiss Jura mountain region: 1) Sudan grass (*Sorghum sudanense*), 2) hybrid sorghum (*Sorghum bicolor* x *Sorghum sudanense*)-Persian clover (*Trifolium resupinatum*)-Egyptian clover (*Trifolium alexandrinum*), 3) foxtail millet (*Setaria italica*), 4) pearl millet (*Pennisetum glaucum*), 5) black oat (*Avena strigosa*)-Crimson clover (*Trifolium incarnatum*), and compared with a commonly used ley, i.e., 6) oat (*Avena sativa*)-pea (*Pisum sativum*)-common vetch (*Vicia sativa*). The leys were sown in a completely randomized block design, within 40-60 x 5-6 m strips, with three replicates in each farm. The trial was carried out during the summers of 2021 (characterized by record rainfall in July, with 300 mm) and 2022 (characterized by a severe drought in July, with just 35 mm of rainfall and recurrent heatwaves in July and August). The yields and nutritional value of the six leys were analyzed and compared. The yield was significantly different among leys ($P < 0.001$), while there were no significant differences between years. The leys providing the highest yields were 2) and 3), with 2.8 ± 0.2 and 2.9 ± 2.1 Mg DM ha⁻¹, while the leys producing less biomass were 4) and 5). The leys 1) and 6) produced intermediate biomass levels and were not significantly different from the others. Overall, the leys having higher crude protein content and lower fiber content were the most legume-rich, i.e., 2) and 6). In contrast, ley 3) showed the lowest nutritional values. In conclusion, the six summer leys tested produced stable yields, even under extreme and contrasting climatic conditions. In particular, ley 2) provided the highest biomass production and good nutritive values and it can be considered as a valid alternative to the leys commonly used in the region and as a possible adaptation strategy to future climate change scenarios.

Quantifying the environmental effects of pasture restoration through scrubland clearing combined with livestock management

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Mountain areas in southern Europe are considered highly sensitive to the impacts of climate change effects, such as the extent and severity of droughts and the increased frequency of fires. These areas have also suffered rural abandonment and reduced socio-economic activity in recent decades. Within this framework, LIFE MIDMACC project promotes alternatives in the mid-mountains that allow them to adapt to climate change and improve their socio-economic development. We do so through the implementation of landscape management measures in La Rioja, Aragon and Catalonia (Spain): (1) the recovery of pastures through scrubland clearing and introduction of extensive livestock farming; (2) forest management for fire prevention and maintenance with extensive livestock farming; and (3) the introduction of vineyards in mountain areas.

The recovery of pastures was implemented in La Rioja and Aragon during 2019-20, consisting of the elimination of scrubland in a specific area to stimulate pasture regeneration, extensive livestock farming and fire risk reduction. After the clearing, the area was divided into fenced subplots (10*10 m) to test the environmental effects of four livestock loads (3 replicates for each livestock): no livestock, low (animals enter once per year), medium (twice per year) and high (three times per year). In addition, areas with no intervention were fenced to monitor the site evolution with no actuation. In the subplots, a monitoring network was installed to evaluate the effects on soil properties (soil analysis, soil moisture), pasture variables (biodiversity, production, quality), hydrogeomorphological response (runoff, infiltration rates, sediments) and site meteorological conditions.

The results after three years of monitoring (2020-21-22) showed some interesting trends, although with high variability depending on the sites. Soil analyses showed an increase in organic carbon in the superficial soil (10 cm) in the cleared subplots compared with the control, with different intensities depending on the livestock load. Generally, pasture monitoring showed a positive effect of the scrubland clearing on biodiversity and pasture production. An effect of the livestock load was also found in pasture biodiversity, the low or medium being the most beneficial depending on the site. The hydrological and sedimentological responses were higher in the cleared subplots than in the control plots. Runoff generation increased with increasing level of grazing; however, in terms of soil erosion, the response was low and no clear differences were found between grazing intensities. Finally, significant differences were related to soil moisture at annual and seasonal scale in the three sites.

These results provide managers and stakeholders with information on different management practices that can improve the adaptive response to climate change in areas with few socio-economic alternatives, due to their biophysical, historical and anthropogenic conditions.

Re-grazing of abandoned mountain pastures to maintain soil functions and biodiversity? The case study “Brunnenkopfalm”

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Traditionally grazed alpine pastures with their vast biodiversity have shaped the landscapes of the European Alps for centuries. However, many steep and remote mountain pastures have been abandoned since the 1950s. While climate change has been promoting re-forestation of abandoned mountain pastures below the tree line, re-grazing is thought to be the most practicable approach to preserve them. Still, re-grazing effects on soil functions and biodiversity are hardly studied. Here we present a synthesis of the pilot re-grazing experiment using the traditional cattle breed “Murnau-Werdenfelser” at Brunnenkopfalm, Northern Calcareous Alps, Germany (1500-1700 m a.s.l.). The experiment was started in May 2018 after 63 years of grazing abandonment. It is part of the SUSALPS project (www.susalps.de) which is aimed at developing climate-smart grassland management to maintain both economic and ecologic soil functions and ecosystem services.

Throughout the five years of re-grazing, plant species diversity, abundance and biomass of the vegetation have been analyzed annually and compared with respective data from grazing exclosures. Furthermore, animal groups such as butterflies, grasshoppers, leaf cicadas, birds, spiders or earthworms were recorded. At the beginning of the Alm revitalization, the dominance of competitive grass species was evident. Nevertheless, with 228 vascular plant species on the 4 ha alpine pasture, a still remarkably high initial diversity was recorded given six decades of grazing abandonment. Despite grazing-induced biomass removal, nutrient redistribution and the mosaic-like mechanical disturbance of vegetation cover by trampling, floristic species diversity remained remarkably constant. In line with the Intermediate Disturbance Theory, grazing overall reduced the dominance of competitive grass species and their competition for light, thereby promoting the establishment of herbaceous species.

Studies on soil C and N biogeochemistry showed that gross N mineralization and nitrification as well as nitrate and dissolved organic carbon (DOC) concentrations only increased in trampling-induced spots of bare soil. Due to the extensive management, these spots of bare soil however contributed only 1 to 8 % to the re-grazed area so that concentrations of nitrate and DOC in the draining creek remained generally very low. Still, increased trampling impact in years with relatively wet soil resulted in increased DOC and nitrate exports.

Overall, re-grazing of this mountain pasture maintained or promoted biodiversity and had limited effects on soil organic matter availability, microbial community composition, and biogeochemical cycles, highlighting its resilience to short-term impacts of extensive re-grazing with adapted, rustic cow breeds. Our results provide urgently needed knowledge to develop management strategies targeted to preserve mountain pastures from degradation.

Using robust ruminants to preserve mountain pastures under global change conditions

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Climate change improves growth condition of woody plants in subalpine areas and leads to a continuous uplift of the tree line. Consequently, shrubs increasingly overgrow mountain pastures. This trend is enforced by land use changes due to a reduction of farming activities. In the European Alps, the most invasive shrub is green alder (*Alnus viridis*). This nitrogen-fixing pioneer shrub leads to a tremendous decline of biodiversity, pasture land and appealing landscape. Moreover, the surplus fixed nitrogen is emitted as N₂O – a most effective greenhouse gas – or it eutrophicates surrounding soils and downstream waters.

Because green alder is hardly to control mechanically, we tested which robust breeds of different livestock species damage green alder most efficiently. We observed two herds of Dexter cattle, two Engadine sheep herds and one Pfauen goat herd in subalpine pastures in the eastern Swiss Alps. In a rotational grazing system, they grazed 15 shrub-grassland mosaic paddocks. We quantified (1) animal movement by GPS tracking, (2) digestibility of green alder leaves and bark, of green alder understory and of fertile and of nutrient-poor pastures as a measure of feeding value and (3) the ratio of debarked and undamaged shrub branches. Debarking represses green alder stands in the long term, because debarked branches die off within a year.

There was no significant difference in digestibility between green alder understory and vegetation of open pastures. The digestibility of green alder leaves was slightly lower ($P < 0.05$). The crude protein content of alder understory and leaves was higher ($P < 0.05$) than in open pastures, due to the symbiotically fixed nitrogen. In contrast to previous assumptions by practitioners and scientists, green alder stands are a valuable forage resource in marginal mountain areas. All three ruminant species exploited the green alder stands, but differed in space use evenness, with Engadine sheep using the heterogeneous area most evenly (Camargo evenness: cattle=0.39; sheep=0.52; goats=0.47). Cattle preferred flat slopes and open pastures most clearly (relative presence in green alder stands: cattle=0.55; sheep=0.76; goats=0.80). Cattle foraged understory vegetation, but did not debark green alder branches. Thus, they have a rather small impact on green alder prosperity. Unexpectedly, Engadine sheep debarked green alder branches frequently, especially at the edge of the stand. Thereby, they actively counteract green alder expansion. Goats debarked green alder less frequently than Engadine sheep (sheep=7.4% of green alder branches; goats=0.8%), but almost completely debarked the few elderberry trees (*Sorbus aucuparia*) growing in the green alder stands. Thus, goats must be kept under high grazing pressure to drive back green alder shrubs. However, all robust ruminant breeds investigated slowed down shrub expansion at least and thus are an important option to mitigate global change impact in subalpine pastoral ecosystems.

3.3 Governance under global changes: the interface between policy and science

A conceptual model of mountain socio-ecological systems to support multi-stakeholder collaborations on the governance of mountain regions and agropastoral systems

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Mountain environments are facing growing sustainability challenges as a result of cross-scale and interacting drivers. Climate change is one such driver that alone and in interaction is driving the rapid evolution of mountain social-ecological systems. Addressing these complex challenges and identifying feasible and fair adaptation and mitigation strategies requires a process of knowledge co-production not only between scientists and policy-makers, but amongst multiple groups of actors that recognize multiple ways of knowing and doing. However, the existence of diverse perceptions and interests often makes such a process difficult. The co-formulation of governance and management options thus calls for a shared representation of the system in its contextual specificities. Such a common representation is equally necessary in designing the adaptive monitoring programs that are needed to mutually inform science and management. Here, we first present the conceptual model of mountain socio-ecological systems we developed to anchor different stakeholders' perceptions in a common ground of discussion. We further explore its applicability in the context of mountain agropastoral systems and their governance.

Our mountain socio-ecological systems (MtSES) is designed as a boundary object, i.e. a representation that both sums up commonalities and supports the expression of different perspectives. It results from (i) an assessment of the usability of the conceptual framework of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) as well as Klein et al. (2019) work on the characteristics and challenges of mountain systems; (ii) 15 interviews with professionals from the sectors of tourism, agriculture, energy, and forestry, that were qualitatively analyzed; and (iii) a continuous bibliographical search. The interviews were performed within a study region comprising the Swiss cantons of Valais and Vaud and followed a method based on the description and categorization of pictures.

The model is constructed around the distinction, which pervaded the interviews, between nature and humans. We thus give an equal representation to both, with a Natural Mountain System and a Human Mountain System, without however opposing the idea that humans are part of nature. In the latter, which represents a distinguishing contribution to existing models, we specifically look at what humans make, as well as the underlying cultural development, the social processes at play, but also characteristics of the people themselves. This human system is further refined with five personal stance components that help describe how individuals position themselves with respect to the system.

Pyrenean Climate Change Strategy at the crossroads of science and political agenda at regional level

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The Pyrenean massif is the southernmost mountain range cross-border in Europe. The Pyrenees are particularly sensitive to the impacts of climate change, due, among other things, to the decrease in available water resources, the duration and severity of droughts, hot spills and the increase in forest fire frequency. Climate change therefore has a considerable impact on biophysical and socio-economic systems such as flora, fauna, water resources, energy and tourism, or agriculture and pastoralism. For these reasons, there is an urgent need to coordinate and count on ambitious climate policies, able to face the proposed challenges. The seven territories of France, Spain and Andorra that make up the Pyrenean Climate Change Observatory (OPCC) have already defined specific adaptation pathways and strategies for this purpose. However, most of them do not take into account two essential factors: the cross-border approach and the specific character of the Pyrenees bioregion.

The Pyrenean Climate Change Strategy (EPiCC), which was approved in 2021 by all 7 governments, provides a framework that addresses both of these elements while complementing and improve coordination the existing adaptation instruments developed by the seven territories of France, Spain and Andorra. The EPiCC has been built with the collaboration and contribution of hundreds of people from the scientific, political, socio-economic and civil society spheres integrating the vision of them. This strategy has been built through a broad participatory and inclusive process that took place from June 2020 to September 2021, enriched by the contributions of many Pyrenean actors from the seven border territories. The EPiCC is based on a vision aimed to achieve a Pyrenean territory resilient to the effects of climate change and within five fundamental principles: cross-border cooperation, the creation and transfer of knowledge, the promotion of innovative actions, to complement the existing adaptation strategies of the territory, and to improve the visibility of the Pyrenees in Europe and the world. The EPiCC is also composed of five systems from which a series of challenges arise: climate, resilient natural areas, an adapted mountain economy, population and territories and governance. Associated action plans will enable the implementation of EPiCC by 2030 and 2050, and the first one is already underway (approved in March 2022).

The EPiCC proposes a dynamic governance system, capable of promoting horizontal coordination with other sectoral policies (related to the effects of climate change), vertical coordination with the strategies and policies defined at State and European levels, in accordance with international treaties and finally territorial coordination with local and regional strategies. Furthermore, the governance of the EPiCC aims to integrate the great diversity of policies, entities and social, economic and scientific actors of the Pyrenean region, facilitating the creation of relationships adapted to the constant evolution of needs and ready to respond to the changes that an uncertain future requires.

One of the success factors of EPiCC governance is the Technical Committee. This committee is made up of government representatives from the climate change departments of the 7 governments that converge in the Pyrenees. The Technical Committee meets periodically to ensure the coherence and synchrony of the actions promoted through the EPiCC with its own strategies, ensuring complementarity. In addition to catalyzing horizontal coordination between climate policies, this committee is a meeting point that acts as a bridge between climate change technicians from the different administrations, the scientific community and decision-makers.

The EPiCC will continue to work in collaboration with local stakeholders through a new monitoring and transparency body called the Monitoring Board.

The national school of pastoralism (SNAP): first realisations

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SNAP was created as a project of the "Appia" Network, the Italian Network of Pastoralism. The project includes sectoral thematic modules, methods, and content with a national/European orientation, organized in relation to the profile of the school's target audience, the territory of training and the interest of local actors. The first experimentation, called Young Shepherds School and co-funded by the Cariplo Foundation, is currently underway, coordinated by the Association "Riabitare l'Italia," in partnership with CREA (Italian Ministry of Agriculture and Forest), the National Rural Network and some actors active in the Piedmont region (Agenform Consortium and NEMO Cooperative). The SNAP group's Scientific Committee has also solicited the interest of the Anglona-Coros GAL, which, with funding from the Region of Sardinia and scientific coordination from the University of Sassari in collaboration with some of the SNAP group's subjects, is also producing a Sardinian edition in winter-spring 2023. Finally, also within the national comparison that is being activated with the SNAP group, a project is underway as part of the Life ShepForBio project on pastoralism in Casentino (Tuscany, Italian Apennines) as the third experimentation. Other similar initiatives are being planned in central and southern Italy.

The common goal is to define an adequate "narrative" of the figure of pastoralist (shepherd, herder) capable of enhancing his figure and work from a cultural, social, and economic point of view. To achieve this paradigm shift, the SNAP group has invested in a training program that is able to specialize new professional profiles to enhance the value of this sector, with the intention of addressing critical issues and introducing innovations (e.g., those included in the Pastinnova PRIMA Project). This is also to overcome the low generational turnover due to the limited profitability of a sector that is fundamental for ecosystem expressions in favor of the most fragile areas of the Italian territory.

A multi-taxa approach in mountain ecosystems

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Mountain biodiversity is characterised by a high sensitivity to climate and land-use changes. Many species in mountain ecosystems, in particular invertebrates, are indeed specialised, often linked to narrow temperature ranges and specific micro-habitats. At the same time, many species living around and below the timberline are dependent on open semi-natural habitats, whose persistence relies mainly on pastoral activities.

To evaluate the vulnerability of mountain biodiversity and to identify focal conservation areas, monitoring field data are essential, especially if collected along broad spatial and time ranges.

In this framework, we will present results from the project “Monitoring of Animal Biodiversity in Mountain Ecosystems”. Six Italian Parks, located in the Alps and covering its natural variability, from west to east, shared a common protocol for studying animal biodiversity in mountain ecosystems. Along 24 altitudinal transects (132 sampling stations, from 550 to 2700 m a.s.l.), 7 taxa were monitored (Coleoptera Carabidae, Coleoptera Staphylinidae, Araneae, Hymenoptera Formicidae, Orthoptera, Lepidoptera Papilionoidea, Aves), using semi-quantitative techniques. Each sampling site has been characterised by vegetation cover, micro-climate, presence of human activities (grazing, mowing). This protocol has been carried out every five years (2012-2014, 2018-2019) and will be maintained over time.

Such a network of protected areas, sharing the same monitoring protocol, offers the possibility to gain a better understanding of biodiversity patterns along altitudinal gradients and more robust evidence of the effects of climate and habitat changes on α - and β -diversity.

We showed results of common points and differences between geographic areas, altitudinal zones and the presence/absence of human activities. Particularly, observed changes between the two sampling sessions, allowed us to identify vulnerabilities to climate and land-use changes and highlight the potential role of human activities (grazing/mowing) in long-term biodiversity conservation.

4. Abstracts - poster presentations

4.1 Challenges and opportunities for mapping and modelling agropastoral systems

Se4Alps, tools for pasture planning

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The Regional Administration, namely the Department of Agriculture and Natural Resources, aware of the significant results and opportunities deriving from the analysis of pastures within the Gran Paradis district, has signed an agreement with Arpa Vda, aimed at extending certain methodological approaches acquired in PASTORALP to the entire regional territory. The convention, biennium 2020 - 2021 & 2022 - 2023, has led to the realisation of 3 different products regarding meadows and pastures: the mapping of the grassland surface; the mapping of the productivity in terms of dry matter and the mowing/grazing detection which is still on-going. Moreover, the first two products have already been used in the CAP 23/27 programming. From these products, an analysis was carried out in order to define areas compatible with mowing and grazing having the following features: altitude < 2700 m.a.s.l.; slope < 40°; dry matter productivity > 300 kg/ha. The result of this analysis is a graphic layer (Raster) of the eligible areas defined as Pasture Mask. The pasture areas at an altitude above 1200 m.a.s.l. that are representative of the pasture system were processed by generating a comparison with the current AGEA (National Paying Agency for Agriculture) agricultural parcel identification system, highlighting the substantial reliability of the method and its applicability for the new CAP 23/27 programming. In order to establish a compatible livestock rate for the Regional Pastureland Plan according to the new CAP 23/27 programming, a plausible requirement of 20 kg of dry matter/LU/day was assumed, with an utilisation index of 0.6. A criterion was then established for the distribution of compatible average livestock rates by altitude range where a robust correlation with dry matter productivity can be found.

Altitude range	Average livestock rate/year
1200-1500	0,37
1500-1800	0,28
1800-2000	0,21
2000-2200	0,15
2200-2500	0,1
2500-2700	0,07

The model was applied to concrete cases, revealing a high representativeness which is consistent both with the territory and with the traditional management methods adopted by the majority of farms in Valle d'Aosta.

Conclusions:

Good practice – application of PastorAlp guiding principles

CAP 23-27 – programming framework which allows the contextualization of the approach–factual data for discussion among stakeholders and enhancing awareness

Solid approach for developing tools for pasture planning

Understanding interactions between cattle and woody vegetation in two French alpine pasture using GPS data and DNA fecal analysis

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Alpine grasslands are evolving either in quantity and or in quality due to agricultural abandonment, changes in livestock, hotter and drier summers and an ever-increasing number of visitors. These various pressure factors put mountain farmers under further pressure, especially in summer, and contribute to the uncertainty about the future of mountain pastoralism.

The Salève is a 1375 MASL mountain located on the French-Swiss border in the department of Haute-Savoie. Since Neolithic times, pastoralism has shaped its summit plateau. Due to draining subsoils and karstic topography, water management within the meadows has always been a challenge during summer season for the alpagists. In recent years, retention ponds and wells had to be built, as well as finely adapt grass management to the herds. Woody vegetation, which was traditionally systematically shredded or treated within pastures, is now offering a relay resource to undergo the hottest summer weeks, such as those of July and August 2022.

Since the spring of 2021, the University of Applied Sciences of Western Switzerland (HEPIA) along with the Salève Mixte Syndicate (SMS) conduce a multidisciplinary project to study interactions between cattle and woody vegetation. To clarify the relationship thereof, the research design included four main themes, such as : 1- mapping plant communities (as finely as the phytosociological association); 2- making a comprehensive inventory of woody species within two pilot pastures (“Chenex” and “La Thuile”), sorting vegetation by vertical structure and by degree of isolation; 3- equipping twenty cows with GPS collars to trace their movements between May and October (both in 2021 and 2022); 4- analyzing cattle’s macro-remains under the microscope, as well as genetically, by the Spygen laboratory.

Nearly 70,000 GPS points were collected from the two alpine pastures, and more than 1,500 woody plants were surveyed. Tracks built from these data showed that forest edge, grove and isolated shrub are highly used during summer season. This was evidenced by a high proportion of woody species in cattle’s excrements. The genetic analysis allowed us to identify recurrent taxa, such as *Acer*, *Fagus*, *Picea*, *Prunus*, *Ribes*, *Rosa*...

This study shows that, in the context of global warming and frequent droughts, woody plants constitute a primordial resource for shade and diet diversification. Moreover, they favor a diversification of habitats for a number of species, both herbaceous and woody, positively impacting both agricultural practices and biodiversity conservation.

Forest suitability for a sustainable silvo-pastoral use: examples and criteria for selecting climate adaptive measures

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Forest and pastures are two different ecosystems, sometimes located in a mixing landscape which often request a common vision in the management, which in Italy has been regulated since 1923 by the Serpieri law, in the face of that time situation of human and livestock overpopulation in mountain regions. Nowadays the natural and socio-economic contexts have radically changed and climate changes imposes a vision adapted to the times by developing appropriate adaptation strategies and measures, also for the preservation of residual rural landscapes (hay meadows, grasslands and tree rich grasslands, mixed crops). In this context a rational use of agro-silvo-pastoral systems represent an effective way to provide alternative agro-economic model in marginal mountain areas to challenge both globalized agro-industry and land abandonment. Specifically it is often a matter of revisiting traditional practices by implementing technical and conceptual innovation in the identification and treatment of fodder trees, in the implementation of silvo-pastoral thinnings, in the programming of diversified treatments in forest planning. In this context, the use of innovative technologies such as remote sensing using drones makes it possible to identify points, linear and areal elements useful in the analysis and planning of interventions and the implementation of silvo-pastoral thematic maps.

In Italian Western Alps national and regional forest regulations allows grazing in certain forest ecosystems such a larch grazing woods ("lariceti pascolivi"). Secondary forests, sometimes badly perceived at various level and often reduced to undifferentiated biomass reservoirs for energy purposes, are another context in which the potential of silvo-pastoral management, well integrated into the landscape and the local economy appears important. A typological reference model for the italian western alpine areas and a review of regional forest regulations concerning forest grazing and silvo-pastoral practices is proposed here with a detailed analysis of the elements characterising the main silvo-pastoral types present in the territorial context of the Gran Paradiso National Park. The definition of a "forest suitable to a sustainable pastoral use" is also proposed, as highlighted by the LIFE-Pastoralp platform.

Species richness in subalpine dry pastures colonized by *Laserpitium halleri* Crantz: A case study for the Dötra region in Southern Switzerland

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Since its emanation in 2010, the Swiss Ordinance on the Protection of Dry Meadows and Pastures of National Importance has implemented conservation measures for approximately 24'000 hectares of highly endangered thermophiles habitats. These areas often include vast grasslands in mountainous ranges, managed by traditional extensive grazing during summer months. For a balanced exploitation these areas, herders and landholders receive additional incentives, such as agro-environmental direct payments from the Federal Government.

The Dötra region, in the Blenio district of the Republic and Canton of Ticino, features nearly 150 hectares of inventoried biotopes, ranging from 1700 to almost 2000 meters above sea level. On the silicate-dominant substrate, these grasslands mainly include phytosociological associations varying from mesophilic *Geo montani-Nardetum*, meso-xerophilic *Hypochoerido-Nardetum*, and often unexploited *Polygalo vulgaris-Poetum variegatae*. The latter share in their phytocoenosis several taxa, including the Haller's sermountain (*Laserpitium halleri* Crantz) of the umbellifers family (*Apiaceae*). This species tends to be avoided by grazing livestock and proliferates in marginal pastures or in unexploited parcels, recurring with abundances up to $\geq 75\%$ of total vegetation's coverage.

To evaluate the impact of local diffusion of the Haller's sermountain on species richness, we analyzed 55 non-permanent plots distributed depending on *Laserpitium halleri*'s cover and according to the indexes of Braun-Blanquet. Vegetation composition and species cover were estimated in a 3 meters' radius from the center of each plot. These estimates have been calibrated with several quantitative surveys and allowed us to compute the Bray-Curtis dissimilarity and to run a Principal Coordinates Analysis (PCoA). The PCoA discriminate 28.9% of variability. Furthermore, we superposed the explanatory variables to the distribution, resulting in a statistically significant correlation for the type of land use ($r^2 = 0.290$, p-value = 0.001***) and the classification in the protected inventory ($r^2 = 0.063$, p-value = 0.042*). Moreover, we analyzed species richness with a nonparametric Mann-Whitney *U* test, revealing that *Laserpitium halleri*'s cover has little to no impact on floral diversity, in opposition to land use, which is progressively poorer from abandoned areas, to mowed parcels, to pastures. Paradoxically, inventoried areas in protected zones seemed to be less diverse than their unprotected counterparts (p-value = 0.016*) with medians respectively decreasing from 41 to 34 species per plot (28.3 m²).

Conclusions of this study uncover potentially unexpected impacts of financial subsidies for pastoral exploitation of dry meadows, and on the importance of large-scale considerations for ensuring the optimal variety of grassland exploitations and, in turn, floral expressions.

Spatio-temporal snow cover trends from 2000 to 2022

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Snow plays multiple roles in mountain areas, and its spatio-temporal changes have as many implications, both on biotic and abiotic processes and on human activities, on both global and local scales. From an ecosystem perspective, snow dynamics is crucial in alpine ecosystem for its role in thermoregulating soil and vegetation during the cold season, controlling the length of the growing season and hydrological cycles. On a large scale, numerous studies have been conducted to study spatio-temporal trends of snow, while, on a fine scale, few studies are available due to the lack of data sets that provide an adequate spatial and temporal resolution. In this study, which is currently in progress, we will analyze trends in snow phenological parameters, namely First Snow Day (FSD), Last Snow Day (LSD), Snow Cover Duration (SCD), and Vegetation Season Length (VSL), over the past 20 years at fine scale (30 m) using a dataset obtained from the fusion of different optical sensors [1], carried by Terra Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat and Sentinel-2 constellations, over a mountain area in the Italian Western Alps, the Gran Paradiso National Park. First, we will validate the retrieved time series of snow cover maps, by comparison with available *in situ* data collected by weather stations. Then, we will use a pixel-wise Mann-Kendall test to map the eventual trends and Sen's slope estimator to unveil the trend type. The resulting maps will be useful for understanding the fine-scale climatic trends and to inform other studies, such as on plant and animal populations dynamics. This work is framed within the Belmont Forum ABRESO project.

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Composting animal mortalities by using natural zeolite – A sustainable approach for Agro-Silvo-Pastoral systems

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Animal mortalities management is a difficult procedure and of doubtful appropriateness, mainly because the methods used are not environment friendly, are likely to disperse diseases to humans and animals, and do not promote the circularity of livestock units. The problem of unsustainable management is exacerbated by the lack of national and European legal frameworks, mainly due to pathogens content. Recycling through composting is a brand-new approach for Europe and may contribute to the protection of natural resources from pollution to the increase of soil organic carbon, nutrient recycling, while at the same time it promotes circularity of the Agro-Silvo-Pastoral systems. This study presents a composting methodology as a solution for managing animal mortalities and green-cultivation wastes, as an approach that it could provide a lot of benefits to the management of Agro-Silvo-Pastoral systems. Two composts were prepared using as feedstock sheeps and green wastes. Clinoptilolite (natural zeolite) was added to one of the two composts as additive due to its capability to improve the properties of the final product. Comparison of the compost properties with the EU standards for the safe use and application of composts/organic materials as soil amendments, indicates that the zeolite-compost can be used without any limitation on soil for plant growth, land rehabilitation or carbon sequestration. The research concludes by providing benefits for Agro-Silvo-Pastoral systems, in terms of mortalities management, soil properties improvement and soil organic matter increase.

4.2 Climate change impacts, adaptation and mitigation

The flora taxonomic, functional, and phylogenetic diversity in seminatural grassland habitats: A case study of grazed and abandoned alpine pastures in the Southern-Western European Alps

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Diversity and complexity are intrinsically part of nature, thus features that shape a wide range of different habitats and ecosystems. Additionally, the global race of human activities to exploit the natural capital has led to alterations of such natural systems, often causing the loss of biodiversity. Such activities have induced, and keep inducing, novel complexities, of which cause-effect relationships are in need to be fully understood, especially as facing global climatic changes. In seminatural grassland habitats (Habitat Directive 92/43/EEC), pastoral activities allowed the development of a natural-human ecosystem which have driven the coevolution of different taxa, leading to the establishment of new and diverse vegetation assemblages. The rational use of alpine pastures is capable of maintaining these habitats in balance with the grazing pressure by enriching biodiversity. The latter trend might be reversed in situations of overload and/or underload of livestock, and, especially, with the abandonment of pastoral lands. Many areas in the European Alps are experiencing cessation of grazing activities, thus the phenomena trigger the establishment of secondary vegetation succession. As a consequence, it is expected a shift in the vegetational composition of those habitats under different levels of diversity.

The EU-CLOE project takes places in three Natural Parks in the South-Western European Alps where data on vegetation composition of seminatural grassland habitats (grazed and abandoned) was gathered. The latter is used for gaining a deeper understanding of the complexity and diversity of these habitats through a multidisciplinary approach that integrates taxonomic, functional traits and phylogenetic analysis. These metrics may shed light on assembly processes, reflected by the structure of the niche occupied by communities, and their degree of functional specialization. Also, there is need to use evolutionary methods to better evaluate ecosystem quality status. The preliminary results demonstrate, as it was expected, a shift on the taxonomic, functional and phylogenetic diversity on vegetation assemblages of the studied areas, of which changes are significantly driven by the history of land-use, degree of grazing pressure and environmental filters. Furthermore, there is need to explore the connectivity that a pluralism of different grassland habitats provides to nature. Thus, the project will further integrate data on pollinator species, such as Lepidoptera, that will be related with vegetation data both from grazed and abandoned scenario. The data on pollinator species is then analysed as for the vegetation one, highlighting the diversity of taxonomic, functional and evolutionary origins.

Agropastoral suggestion to maintain the endemic butterfly *Polyommatus humedasa*

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Polyommatus humedasa is an endemic species narrowly distributed in a few sites in the Aosta Valley (NW Italy). Similarly to the other alpine butterflies and to the majority of pollinators, the survival of the species is closely linked to the maintenance of seminatural grassland through agropastoral activities. For the first time, data on this species was collected in summer 2022 in the site of Pont d'Ael, the site best known by scientists and collectors. We used butterfly GPS-positioning and the mark-release-recapture (MRR) method to estimate its population size, sex-ratio, lifespan and density. The size (881 individuals) and density (73 N/ha) of this population are higher than those of other endemic *Polyommatus* species (e.g. *P. exuberans* and *P. gennargentii*). Data suggests the species is monophagous on *Onobrychis arenaria* and preferred to lay eggs where the host plant is more abundant. In 2022, characterized by extreme temperature and low rainfall, the species preferred to lay eggs in ecotonal areas with some shrubs (average 8%) and high herbaceous cover (average 68%). Among all plants within plots, the species preferred to lay eggs on higher stems of plants with a high number of stems, suggesting a preference for plants in a better physiological condition. Currently, woody species encroachment, climate change and sample collection are the major threats to the species in the studied area thus the lack of management of the area makes its population seriously threatened. We suggest developing and applying a management plan that includes: 1) small herds in rotation within the area to reduce woody species encroachment and maintain patches of shrubs, to favor the host plants even in the context of climate change; 2) stricter control against collectors.

Topography, climate, species composition, and phenology affect forage yield and quality in alpine summer pastures (NW-Italy, Gran Paradiso National Park)

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The long permanent grasslands extensively managed on the Alps harbor a high plant species diversity and support the provision of valuable forage sources (Ravetto Enri et al. 2016). The main issue in Alpine grassland management is the optimal exploitation of the available forage resource in relation to seasonal advancement and vegetation composition. However, little is still known about forage yield of species-rich alpine pastures and related chemical composition. In this work, we aim at characterizing forage quantity and quality exploring the deterministic relationships with topographic, climatic and vegetation variables throughout the growing season.

The study was carried out in an Alpine valley of the Gran Paradiso National Park (NW-Italy). We selected six grassland types within two altitudinal and three fertility levels. Each grassland type was surveyed five times during summer in 2019 and in 2020, for a total of 162 vegetation surveys. The relative percentage covers of different functional species pools (i.e., wide-leaf grasses, narrow-leaved grasses, sedges and rushes, legumes, other species) were computed. A forage sample was also harvested at each survey using a portable lawn-mower, then air-dried, weighed and analyzed for proximate composition and digestibility. Topographic variables (i.e., elevation, slope) were recorded in the field. Temperatures and precipitations were measured throughout the trial and combined in a synthetic eco-climatic variable (ΔPrET) calculated as the difference between the total precipitation and the potential evapotranspiration from the day of snowmelt. Plant phenology was recorded according to the Lambertin (1990) scale. Data were analyzed with Generalized Linear Mixed Models to assess the relative importance of topographic and climatic variables, plant phenology and functional species pool covers in explaining forage yield and quality (in terms of NDF, ADF, ADL, soluble sugars, crude protein, digestibility).

Herbage quality (except for soluble sugars) was negatively affected by ΔPrET , with a larger relative importance compared to the other explanatory variables (digestibility: ΔPrET $\beta = 0.18^{***}$; phenology $\beta = -0.11^{***}$; sedges and rushes $\beta = -0.04^{**}$). Plant phenology showed a remarkable role in explaining also crude protein and fiber contents. More specifically, a decrease in crude protein and an increase in fiber fractions was observed at advanced phenophases, thus resulting in a reduced digestibility. The cover of wide-leaf grasses primarily promoted biomass production, which was in turn lowered by increasing elevation and slope.

Along the season, ΔPrET and phenology were the main degrading factors of forage quality in the study area. Nevertheless, we argue that the abundance of wide-leaf grasses and legumes can counterbalance these negative processes. Pastoral management should therefore aim to maintain and enhance these functional species pools, especially to face the ever more frequent summer droughts and heat waves.

Soil properties and GHGs emissions from a mixed system of olive trees cultivation and sheep farming

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A common practice among Mediterranean smallholders is the coexistence of trees cultivation with livestock farming. There are many reasons for this practice, as for example, (a) grazing keeps weeds under control and helps owners to cope with costly, time-consuming and often environmental damaging weeding practices; (2) reduction of feeding costs, at least as long as there are weeds in the field; and others. The owner of the orchard and the breeder may be the same person or different persons under a private agreement, which may or may not provide for a rent payment by the later one. This practice has also societal importance because sometimes causes disagreements and conflicts between the breeders of an area, who compete each other for the available orchards to feed their animals.

In the framework of the LIFE ClimaMED ¹project “Innovative technologies for climate change mitigation by the Mediterranean agricultural sector”, which foresees the development of a system for real time measurement of GHG emissions from various agricultural systems (e.g. intensive agriculture, organic agriculture) five different crops (annual and perennial) and different cultivation systems were studied.

In the present study, one of the LIFE ClimaMED fields, i.e. olive trees cultivation in coexistence with sheep farming, is described. The field was monitored for two years, and field and animal data was collected and assessed in terms of the benefits for soil properties and GHGs emissions, namely CO₂, N₂O and CH₄.

The most important outcomes of this study are the remarkably high organic matter and the high nutritional capacity of the soil, as well as the lower GHG emissions in comparison to all other agricultural systems studied.

¹ <https://life-climamed.eu/home>

Impact of climate on some features of ex-arable successional grassland vegetation from forest-steppe area

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Important land surfaces from hill and mountain areas from the northern hemisphere formerly used for cropping were abandoned. Often, the abandoned land evolved by natural succession to grassland, shrubland or even to forest. The main goal of this paper is to bring new knowledge necessary for the understanding of the evolution of ex-arable grassland vegetation from forest steppe area in relationship with climate. The researches were performed in locality Grădinari (Caraș-Severin County, Western Romania) on an ex-arable plot abandoned since 1995. The vegetation data were collected during 19 years (period 2003 – 2021). The analyzed vegetation features were: floristic composition (grasses, legumes and forbs), biodiversity (species richness, Shannon and Simpson indexes) and pastoral value (on 0 – 100 scale). The climatic data considered were air temperature and rainfall amount. The climate data were analyzed considering monthly averages, averages from the entire year (months I-XII) and the averages during the vegetation season (months III-IX). The vegetation and climate data were correlated statistically having in view to highlight climatic benches implied in the evolution of the grassland floristic composition, biodiversity and pastoral value.

Successional grasslands are a potential resource of biomass, biodiversity and habitat for wildlife. Such naturally recovered ex-arable grassland ecosystems are able to restore their natural cycles and provide ecological and socio-economical services as a natural one.

The resilience of the analyzed ex-arable land was good even in the present climate conditions with years characterized by higher temperatures and severe droughts or hard rainy time intervals. The rainfall regime less disturbed in comparison with the temperature probably had a good impact on the transition of the abandoned arable land to successional forest steppe grassland at our experiment time-scale. Other element that has been implied in the good recovery of the grassland vegetation was the soil seed bank. But, the random grazing with sheep and mulching works applied late in autumn could have an important contribution on the great restoration rate and even on the increase of the biodiversity and the high presence of late successional grassland species. The domestic and wild herbivores, respectively the grassland maintenance tools and machineries probably were vectors for grassland species propagules that probably have speed up the natural restoration process of the grassland species. Thus, climate change pressure on the natural restoration of the biodiversity and pastoral value of ex-arable forest steppe grassland could be mitigated by random grazing and mulching works.

The impact of climate change on the natural restoration of ex-arable successional grassland shall be investigated more for a better understanding of the implications at different levels as: vegetation structure, biodiversity, floristic composition, forage value, productivity, carbon sequestration, economic and social value etc.

Bartonella spp. distribution assessment in foxes coupling geospatially-based techniques

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Abrupt changes in climate conditions may influence species distribution and pathogens' spreading. Therefore, researches on the complex combination between wildlife-diseases dispersion and environmental patterns have to be strengthened, and the assessment of wildlife and zoonotic diseases will represent a key point. In particular, geospatially-based analysis can help Veterinarians and Public Health Officials, to better understand changes in eco-epidemiological factors related to climate changes. Nowadays, reports on the presence of *Bartonella* spp. in Italy, especially in wild canids, are few in literature. In this study, the prevalence of *Bartonella* spp. was investigated with reference to fox populations (*Vulpes vulpes* L.) culled or found dead in the provinces of Cuneo and Biella (Piedmont) and Aosta Valley (NW Italy). The analysis was carried out at municipality level by coupling molecular diagnostic techniques and satellite remote sensing with the aim of testing possible relationships between pathogen presence and environmental conditions. The DNA was extracted from the spleen of 114 sampled animals and 7.9% (9/114) of samples yielded *Bartonella* spp DNA by means qPCR (*ssrA* gene). Positive samples were further analyzed by end-point PCR for *ssrA*, *gltA* and *rpoB* genes of *Bartonella* spp.: PCR products of eight samples were sequenced and based on the results, *Bartonella schoenbuchensis* R1 was found to be the most abundant *Bartonella* species (62.5%, 5/8). *Candidatus* "*Bartonella gerbillinarum*" was found in 25% (2/8) of samples. Concerning remote sensing contribution, data from NASA USGS Landsat 4-9 missions (TOA collection), ranging from 2011 to 2022, were processed in Google Earth Engine. Assuming (as reported in literature) that pathogens, especially in rangelands, can be influenced by humidity, the Tasseled Cap Wetness index (TCW) was computed (Baig & DeVries, 2020) for each date temporal profile consisting of composite images for each meteorological season.

Seasonal TCW was positively associated to *Bartonella* spp. infection in foxes as infection was always associated to TCW >0.7. This threshold seems to be an important parameter for the *Bartonella* spp. risk mapping. To test the relationship between TCW and *Bartonella* spp. presence, the Moran's index I was calculated per each composite imagery to test the existence of a spatial correlation, and LISA (Local Indicators of Spatial Autocorrelation) maps at the municipal scale were created. Moran I proved to be always ≥ 0.90 , and therefore statistically significant. Moreover, Canonical Corresponding Analysis between pathogen prevalence and municipal-based TCW show a strong link between positivity and TCW, demonstrating the possible use of TCW as a parameter to facilitate disease management and control.

In conclusion, a simultaneous spatial correlation between *Bartonella* spp. DNA presence in foxes of the municipalities considered and the TCW was detected.

Evaluation of dehydration indicators in dairy goats bred at pasture

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At pasture, high temperatures, solar radiation, and absence of shade are factors that contribute to increase heat stress, forcing the animals to make great thermoregulation efforts. For these reasons, it is essential to ensure easy access to water points for livestock, either natural (e.g., ponds, river) and artificial (e.g., cisterns, fountains, collection tanks). However, no valid indicator is available to assess the effect of prolonged thirst on the welfare of dairy goats at pasture. Aim of this study was to evaluate the dehydration condition of dairy goats using tests already validated in other species during the summer alpine grazing season. Two assessors collected data in 10 farms located in Piedmont (NW Italy), divided into six alpine pastures (A1 to A6), and rearing Camosciata delle Alpi, Valdostana and their crossbreeds. The Skin Tent Test on the neck and sternum and the Capillary Refill Time on the gingival mucosa were applied on a sample of 60 lactating goats and each animal was tested by two assessors during both morning and evening milking. The Skin Tent Test evaluates the skin turgor, by determining the time taken by the skin to return to its original state after being pulled up, while the Capillary Refill Time evaluates the time taken by the gum to return to its natural colour after being pressed. A Wilcoxon signed rank test was applied and results showed a significant difference for the Skin Tent Test collected on the sternum ($P=0.037$), between the morning and evening milking (MORNING = 1.67 ± 0.75 s; EVENING = 1.40 ± 0.62 s), only. However, this difference was not expected, as the skin returned to its natural state earlier in the evening than in the morning in five out of six alpine pastures. Possible explanations are the absence of water in the night shelter for some mountain pastures (A1; A2; A4), the absence of the evening milking for A6 and the overcrowding of the night shelter in A5, despite water availability. A GLM was then applied to check the effect due to the interaction between alpine pasture \times test, and the main statistical difference was found for the Skin Tent Test collected on the neck ($P=0.035$). Our preliminary data suggest that the Skin Tent Test could be used to evaluate the dehydration of dairy goats reared at pasture, but further studies are needed to validate this test as no information is available on the relationship with physiological parameters that may confirm the state of dehydration.

Global pastures - ethnographic explorations of Alpine grassland connections

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In our paper we present a recently started research project, funded by the Swiss National Science Foundation (SNSF), Lead: Prof. Viviane Cretton (HES SO, Valais Wallis, CH), collaborator Dr. Almut Schneider, Project Partner: Prof. Elisabeth Tauber (Free University of Bolzano-Bozen, Italy), collaborator Dr. Stefan Festini Cucco. "*Global pastures - ethnographic explorations of Alpine grassland connections*" responds to strong ecological concerns about environmental changes in the Alpine area and in particular to species loss. These have been the focus of ecologists for several decades but only now start to raise concern in the public sphere. A crucial aspect of this urgent subject matter is hardly perceived by scientists and the public: the concealed connections of fragile ecological areas with the global market. The proposed project wants to explore and understand these connections.

We focus our investigation on Swiss and northeast Italian semi-natural grasslands - a food resource for herded sheep - and on those aspects of the international feeding industry and animal market that bear on species survival on these grasslands. We use grass as a non-human subject to glean more about the human world and propose a comparative ethnographic study of herding practices, grasslands and the international feeding and animal market in Switzerland and north-eastern Italy. To catalyse ethnographic knowledge, the project asks the following questions: What is to be learned from pasture grasslands when they are taken to be part of a 'chain of relations', interlinking people, animals and the international feed and food market? How are grasslands, still one of the world's largest biomes, re-acting to changing human practices? What are the interdependencies of these local actors with the global ones, and how do these grassland connections allow one to look beyond Alpine pastures and to relate global issues back to them?

To answer these questions, multi-sited ethnographic fieldwork with a multi-species approach will be conducted in several places in Switzerland (Grisons and in the Jura mountains) and in northeast Italy (South-Tyrol and Friuli) and with different types of actors: herders, animals, grass as well as representatives of the animal market and the feeding industry. Ethnographic fieldwork is conducted on certain high Alpine summer pastures, by accompanying several itinerant herders moving between higher and lower-lying pasturelands and with several feed production facilities and livestock auction houses.

This research is all the more profitable as it allows us to take into account concrete interdependencies between local pasture practices and the global agrobusiness and thus to identify potentials on a larger scale, notably concerning European environmental policies.

Alpine pastures in the Alps: cultural relics or resources for the future?

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Many research projects at the Alpine level are investigating the impact of climate change on mountain agro-pastoral systems, in terms of modification of fodder resources and biodiversity of high-altitude grasslands, as well as of production and organizational systems in relation to the increased frequency of intense climatic events, and finally also in relation to the degree of perception of these phenomena by farmers and mountain populations in general.

At a societal level, attention is also beginning to be focused on the impacts of new climatic conditions on mountain territory and alpine activity.

Studies and projects are trying to identify new ways of adapting pastoral practices to changed contexts (which are not only climatic) and new solutions for building more modern and efficient pastoral systems.

In order to restore economic and social value to pastoral practices in a "smart mountains" vision that is attentive to the changes taking place CIPRA Italia believes it is necessary to:

- Continue with research and studies into ongoing climate change in the mountain territory, with particular attention to the risks of loss of biodiversity of habitats, disappearance and/or migration of species; into livestock biodiversity, i.e. on breeds suited to cope with the new climatic conditions and into animal welfare in order to define welfare indicators suitable for species reared under conditions of climatic stress;
- Provide for the adaptation of mountain pastures and mountain huts with pastoral equipment (e.g. water reservoirs, watering points);
- Demand that the authorities include specific adaptation-oriented management methods based on mandatory grazing plans in the rental and concession specifications for alpine pastures;
- Develop and adopt forms of payment for ecosystem services in favor of sustainable grazing practices;
- Make farmers more aware of the processes at work and their contribution towards safeguarding biodiversity, native breeds and alpine grasslands by promoting information and training programs;
- Build an interregional network for monitoring changes in pasture areas by involving alpine farmers and recognizing their importance as local observers and surveyors;
- Promote Pastoralism Schools to foster particular attention to the issues of the impact of climate change on Alpine biodiversity and the management of animals reared under extensive conditions and exposed to climate change;
- Launch information campaigns for tourists and hikers aimed at raising awareness on these issues and on the role of mountain pastures and pastoralists in mountain management.
- Adopt support measures (from CAP and RDP) to recognize the role played by mountain pasture practices;
- Disseminate good study, monitoring and management practices on the various issues.

Training Young Shepherds in the Alps of Italy: an opportunity for new peopling and youth *restanza*

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Are particular knowledge and skills needed to stay or to move permanently and successfully to mountain and inner areas, developing one's life and work project? Pastoralism may foster new peopling and *restanza* (willingness to stay) in these territories? What kind of training can enhance and support these dynamics?

In order to offer some answer to the above questions, a case study from the Italian Alps is here presented: the "School for Young Shepherds", a pilot training experience run by the association Riabitare l'Italia and CREA, together with a wide network of stakeholders in North-western Italy.

The analysis here presented moves from the literature on of the phenomena of "*restanza*" (Teti, 2022) - a neologism referred to young people actively remaining in their territories of origin — and "new peopling" - the movement of the so called *nuovi montanari* or *new highlanders* (Dematteis, 2011; Membretti et al., 2017) - that are currently characterising the mountainous areas of several European countries. These socio-demographic and cultural processes contribute to shaping what has been defined as the "*metromontagna*" (the metro-montane space), i.e. a physical and symbolic-cultural space identified by fluid, reciprocal and circular relations between metropolitan areas and inner valleys that is emerging in recent years, after decades of urban-centric narratives and policies (Barbera & De Rossi, 2021).

To enhance this change of perspective, supporting the socio-demographic renaissance of the Alps and the European mountains in general in a renewed relationship with the urban dimension, it is pivotal to support those who decide to remain and invest in the highlands - or those moving to the mountains from the plain - offering them the specific knowledge necessary to face the challenge of inhabiting, working, and relating to fragile contexts in terms of ecosystem and socio-economic milieu.

The "School for Young Shepherds" represents a concrete and innovative practice in this direction, focusing its activities and training on giving the participants - both *new highlanders* and *restanti* - solid scientific knowledge not only about shepherding as a profession but also regarding the renewed role that mountain pasture fills in protecting local mountain micro-habitat and fostering the renaissance of local communities, facing in an innovative way the challenges posed by climate change-related factors.

The core of the offered course consisted of two weeks of intensive and residential training realized in 2022 in Stura Valley, in the province of Cuneo (Piedmont), offering thematic modules focused on topics as local production, animal breeding and land care, with the support of local enterprises and according to a place-sensitive approach of local development. The methodology applied fostered a practical approach, centered on first-hand experience in the field, learning-by-doing, and peer-to-peer exchange.

4.3 Governance under global changes: the interface between policy and science

Presentation of UNA Foundation – Man, Nature and Environment

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Fondazione UNA ETS

Fondazione *UNA – Uomo, Natura, Ambiente* (UNA Foundation - Man, Nature, Environment), is a non-governmental and non-profit organization which since 2015 represents the meeting point between hunting, environmental, farming and scientific-academic worlds. The Foundation was founded with the purpose to create a new environmental production chain as well as tangible projects aiming to the safeguard and the management of nature in view of biodiversity preservation, thanks to the commitment of its founding members: Federcaccia, Arcicaccia, Enalcaccia, Comitato Nazionale Caccia e Natura (National Hunting and Nature Committee) and University of Urbino.

Aware of the importance of synergistic actions to develop ideas and projects, Fondazione UNA has built over time a strong system of partnership with strategic and active actors on environmental issues, such as Coldiretti, Federparchi, IUCN, Slow Food, Fondazione Symbola, University of Milano and University of Pollenzo until the recent entry into the Mountain Partnership – FAO, subjects with which concrete projects of environmental protection are developed, adopting the best practices of sustainable economy and supply chain and ensuring the maintenance of natural balances.

Especially, in collaboration with Federparchi Europarc – Federazione Italiana Parchi e Riserve Naturali (Italian Federation of Park and Natural Reserves)-, Fondazione UNA launched the initiative *Biodiversità in Volo*, project aimed at raising public awareness about the need to safeguard some species and territories in Italy, as well as to promote a responsible and sustainable hunting activity. Through three initiatives that took place along the Italian territory, Fondazione UNA took its interlocutors on a journey to discover the protected species within some wonderful Italian parks, with the aim of educating the community of hunters itself on the importance of adopting a model of sustainable hunting in contrast to any form of poaching. During the last year, the main parks were the Gran Paradiso National Park, the Abruzzo, Lazio and Molise National Park and the Maremma Park.

The activities included the sighting, where possible, of the specimens at risk, with the notions and the help of park rangers and experts, who provided valuable information about the animals and the natural environment in each park. Events in the Gran Paradiso National Park and the Abruzzo, Lazio and Molise National Park were also the first example of activity of awareness on the importance of protecting and preserving the most ancient mountain scenery of Italy and of promoting the sustainable development of these territories. As a matter of fact, these places consist mainly of a set of mountain ranges and, in general, enjoy a very complex morphology.

Moreover, over the past few years Fondazione UNA has developed a project named “*Selvatici & Buoni*”, with the purpose of providing a high quality and safe product, to be inserted in a traced and sustainable supply chain. We started from the Lombard Alps (in the province of Bergamo), together with leading academic partners such as UNISG - University of Gastronomic Sciences of Pollenzo, University of Milan - Faculty of Veterinary Medicine and the veterinary world represented by SIMEVET, the mountain community and all alpine areas of the Province of Bergamo. We created training courses aimed at both the hunting world and the food service one in order to provide useful tools to treat properly this type of product. The creation of these traced and sustainable supply chains allows in a concrete way to relaunch the economy and to create

jobs in areas that are gradually neglected, such as mountain areas, and to intervene on food security aspects, protection of the fauna and respect of the environment.

The activity of Fondazione UNA to protect ecosystems and biodiversity will continue to focus on the entire Italian territory, also and especially through the new collaboration with FAO Mountain Partnership and projects such as the one with Federparchi.

Integration of natural and socio-economic sciences to assess the effects of land use change on the alpine landscape: the ABRESO project

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The Belmont Forum project ABRESO (Abandonment and rebound: Societal views on landscape and land-use change and their impacts on water and soils) [1] aims at determining the effects of land use changes on the Italian Alps at the landscape scale, by comparing different management strategies, from the traditional alpine pasture to the complete abandonment of grazing and forest recolonization. The project aims at integrating both the natural sciences and the social sciences perspectives, co-constructing an inter-disciplinary approach. In fact, most modern societal challenges have to be investigated using expertise from many different scientific fields, particularly when addressing solutions for decision making on sustainable resource management [2]. However, truly interdisciplinary approaches are hard to establish [3-4]. The ABRESO project started in 2021 and involves an international partnership including five countries (United States, France, Italy, Japan and Taiwan). Italy participates with three case study sites distributed in the Alps: Noaschetta site, in the Gran Paradiso National Park, Val Grande site, in the homonymous national park (both these sites are in Piedmont region), and Tesino site, in the Autonomous Province of Trento.

Time series of Land Cover (LC) maps extracted from both Landsat and Sentinel-2 datasets, with focus on specific target classes (e.g., grasslands), and trends in Snow Cover Duration (SCD) during last 20 years will be provided for each study area of the project. The Earth Observation (EO) data will upscale and will be validated against *in situ* measurements. The observed environmental processes will be compared with the perceptions of the relevant local stakeholders, who determine the local land management practices and policies. In particular, the perceived ecosystem services and disservices deriving from land use change processes will be identified. The combination of information derived from the natural and the social sciences are supposed to help policy makers identify the best spatial management strategies and policies within the different Alpine scenarios.

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Grazing plans aimed at the dissemination of good management practices for the biodiversity in Lombardy

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The Life IP Gestire 2020 is a project aimed at the protection of biodiversity in Lombardy. Among the numerous activities it also includes the protection of some habitats of community interest mainly located in mountain and pasture areas (4060, 6150, 6170, 6210, 6230, 6430, 6520, 7110, 7140). The project has envisaged a specific action (A17-C9) that includes the realization of 10 Grazing Plans for 10 pastures located in different areas of the Lombardy Region. ERSAF manages 5 of these while the other 5 are managed by other entities, both public and private. The main objective of these grazing plans is the definition of methods and actions for a better management of the areas. This should be able to protect the natural biodiversity, to ensure the continuity of important ecosystem services and to promote the sustainable management of resources in accordance with the Habitat Directive. The grazing plans are documents that contain the necessary information for a management which is compatible with the conservation of the Habitats on the one hand, and the vitality of the economic activity of the pasture on the other hand.

Each grazing plan consists of the following documents:

- Methodology: how the grazing plan has been produced and which are the monitoring indicators;
- Grazing plan;
- Cartographic tables: pastoral types; habitat; grazing compartments; improvements.

The methods for the analysis of the pastures have been developed using information from the scientific bibliography. The boundaries of each pasture have been based on information contained in various cartographic sources. The rough localization of the vegetation reliefs was then planned on GIS which also included the detection of the presence of flocks and herds, the portions of pasture used, the grazing methods, the effects of previous management, the current management of livestock, the provision of structures and infrastructures, management problems, the necessary interventions. Everything has been discussed with the current breeders through interviews. The grazing plans has been than shared with the owners and breeders and each owner of the area have officially accepted all grazing plans. The objective of the activity is not to improve the situation of these habitats in the context of the entire regional territory. In fact, the surfaces of these pastures are only a small percentage of the total. Rather, we would like to enhance the state of conservation of specific sites and to publish and disseminate best practices that can be used by managers other than ERSAF, such as municipalities and mountain communities. Each grazing plan also includes a facilitation (consultancy) activity for the use of community and regional funds for the implementation of the suggested interventions. The group is working to implement future monitoring activities of the effectiveness of the interventions for the protection of these habitats.

The grass-fed supply chain in Piedmont: farm production and farmers point of view

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In Europe an interest in the short food supply chains (SFSCs) is growing. Their development is configured as a key pillar of the “Farm to Fork” strategy for the transition to a more sustainable food system and for the recovery of rural economies. On the consumer side an appreciation for the possibility of safeguarding the environment, following a healthy diet, and for greater quality in terms of transparency and traceability is expressed. The term “short” does not necessarily refer to physical distance, but to the proximity between the actors, of the actors with the territory, and of the consumers with the food products. So, the criticism of conventional global supply chain boosts new demand that is driving structural changes in rural organizations to be more sustainable and innovative, such as in the dairy and beef sector which is facing great challenges. Livestock systems are among the main contributors to greenhouse gas emissions, land degradation, deforestation for grazing and feed cultivation. In this context, the research financed through the European Agricultural Fund for Rural Development (EAFRD) is developing. In particular, this contribution originates within the FILIERBA Project, which has the general objective of promoting the development of beef and dairy supply chains based on the use of grass with high biodiversity as feed (polyphitic feed) in Piedmont, a region in northwestern Italy surrounded by the Alpine arc. The initial aim is to analyse various features of agropastoral systems and to evaluate the sustainability perceptions of the farmers involved. In this context, a questionnaire was created with the LimeSurvey tool, to collect data both for milk and beef production from a representative sample of farms in Piedmont. Starting from 338 responses received, 114 were complete and suitable for statistical analysis. The farmers and livestock characteristics, agronomic and pastoral practices, the length of the distribution channels used, the certification of quality and the degree of importance attributed to the environmental sustainability have been requested for the 2020 year. How widespread is the use of polyphitic feed? Who uses this feed also expresses a greater concern for issues related to environmental sustainability? And as for who uses shorter supply chain? The data obtained allow us to reply these questions and furthermore to understand whether the concern regarding sustainability is reflected or not in the practices implemented. This analysis helps to identify the main characteristics, current status, and future potential of these type of traditional agrifood practices and to trace the possible development path for these innovative products. Moreover, the results could be useful for policymakers in developing adaptation and mitigation strategies that preserve these sustainable agropastoral land management practices.

Mobile food processing plants: a strategic economic tool for preserving and enhancing agropastoral systems

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Mountain agropastoral systems and communities are facing many challenges that are driving people to abandon these lands, even though the mountain areas themselves represent a unique development opportunity, in which economic well-being and environmental conservation coexist in synergy. It is in this context that SINT TECNOLOGIE's modular plants for agri-food processing come into play: these turnkey laboratories are the strategic tool available to breeders and farmers for the development of a mountain economy, centred on the Zero-Kilometre valorisation of the animal and vegetable resources, naturally present in the territory. Built in full compliance with EU hygiene and health regulations, SINT TECNOLOGIE's modular plants are set up for slaughtering (white, red and ungulate meat), dairy processing, the production of preserves and essential oils, as well as for the production of flours, artisan bread and pasta, and much more.

Thirty years' experience in Food Processing allows SINT TECNOLOGIE to design and manufacture highly functional modules, that can be customised to the specific needs of each producer. The scrupulous arrangement of the inside spaces ensures a complete and compliant laboratory even in a small area; the possibility of externally cladding the module makes it compatible with any landscape constraints.

Finally, the versatility of modular laboratories finds also expression in their use, which can be stationary or itinerant. Thanks to the integration of a trailer, the module can be moved from one location to another, offering a door-to-door service to micro-producers in the area.

Ongoing discussions with our customers have shown that having a modular laboratory has enabled them to:

- i. Reduce transport costs and related issues (e.g., animal welfare)
- ii. Reduce operating costs, thanks to the space optimisation (e.g., water consumption)
- iii. Ensure that product quality is preserved at every stage of the supply chain.
- iv. Increase their revenue by selling their processed product directly.
- v. Shorten the timeframe between the decision to process and the very beginning of the business, not being constrained by the timing of construction work.
- vi. Develop and upgrade the farm gradually, in line with their production capacities.

Experience and case studies show that the flexibility and adaptability of the modular system enable to overcome – in a short time- the logistical, infrastructural and environmental difficulties typical of the rural and mountain areas. The economic benefits that the modular plants bring to the producers are also evident but often related to the individual initiative. Such benefits can be extended to a specific target area, thanks to a collective and systemic approach. In this perspective, the joint action and cooperation between producers, local institutions and research bodies are crucial to fully profit of the potential of the modular plant as strategic tool for the preservation and development of agropastoral systems.

Unconscious slaughtering practice in pigs: promising results of the first trial in extensive systems

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Sustainable intensification drives new European livestock development production strategies. Rural and mountain areas become one of the main drivers to the success of the new agroecosystem management model. However, these areas must be provided by all basic services so that production can be carried out maintaining the necessary requirements, including those of animal welfare throughout the whole production chain. Animal transport is one of the main stressful phases of animal time life, and it is directly correlated with the time of transport. Hence, the presence of slaughterhouses represents a bottleneck for the social sustainability of the production system: unfortunately, Italian and the European reality are characterized by a strong numerical contraction. Therefore, the development of an on-farm slaughtering system may be a solution to this problem.

32 pigs organically reared in Tenuta di Paganico farm (120±10 kg of LW) were equally and randomly allotted to two groups: group T was transported alive to the abattoir and then slaughtered; group F was stunned and bled directly on-farm, then carcasses were transported to the slaughterhouse by a refrigerated trailer in less than 2 hours. Animal welfare was assessed by blood sampling at exsanguination: creatinine kinase, lactate dehydrogenase, total protein, albumin, glucose, and serum cortisol were determined. Moreover, the microbial contamination of meat and carcasses was investigated in two different climatic conditions (cold and warm seasons).

No significant differences were found for any parameter evaluated, except for serum cortisol: F method seemed to be less stressful than T, respectively with 61.64 and 130.89 ng/mL ($P = 0.01$) of serum cortisol levels. Aerobic Mesophilic Colony and Enterobacteriaceae Counts and, *Staphylococcus aureus*, *Salmonella*, and *Listeria* presence were detected to assess the microbial contamination. Our results demonstrate that the slaughter method does not negatively affect meat safety: in fact, any parameters showed no differences for both slaughtering type and seasons. Finally, meat technological and physic characteristics were analyzed: pH (at 48 hours after slaughter), color, and water holding capacity: no significant differences were found.

In conclusion, on-farm slaughter seems to be a key step in maintaining an extensive farming system sustainable and consistent, guaranteeing an adequate level of animal welfare and meat quality throughout the animal product supply chain. This could foster the valorization - and rediscovery - of the "productive marginality of marginal areas", both rural and mountain, potentially capable of extending the same slaughter method also to bovine. Policy arrives where science can support it: that represents a clear demonstration of new technical possibilities that should point toward new boundaries of a common policy, even in the light of the Regulation (EU) 2021/1422 (certification in case of slaughter at the holding of provenance).

Pursuing resilience in animal production systems in earthquake affected areas. The SAIMarche experience

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Distressed by a series of earthquakes, rural communities in the mountainous areas of Central Italy have been exposed to a socio-economic fragilization, including that of infrastructures. The affected farming communities in these areas either refurbished the lesioned productive units or reconceived the structural and functional layout of stalls, laboratories and shelters to reboot their economic activities. At a territorial scale, this dilemma is mirrored by decisions on infrastructures, such as slaughterhouses: further to rebuild or restore pre-existing structures, an alternative solution is represented by mobile slaughterhouses (MS) that may provide the service in multiple locations of the territory, moving closer to farms and animals, thus reducing transport costs and stress, respectively. The MS hypothesis is being explored by the SAIMarche EIP-AGRI Operational Group (OG) in the Marche region, paralleled by extensive breeding of a new pig genotype (Suino della Marca) suitable for free-roaming husbandry systems such as silvopasture. A MS prototype targeting mid-size animals (sheeps, goats and pigs) has been constructed and made available for the initial testing, taking into account both operational (access to the unit, stun and evisceration of animals, cleaning, cold-chain storage) and management (logistics, calendar for the itinerary service, costs, training of personnel, communication) aspects.

While some more technical issues are being fine-tuned to ensure the practicality of the MS, an intense dialogue has been promoted vis-à-vis three key types of interlocutors to investigate the potential and viability of the service.

- i. Veterinary services: the OG met both public officers and private practitioners to ensure regulatory compliance of both structures and intended procedures, to grant the operability of sanitary inspections and to pre-assess animal welfare conditions. Public veterinary services visited the structure and attended the first MS testing, providing suggestions to improve technicalities and to grant consistency of protocols.
- ii. Local municipalities: the OG presented the itinerant service opportunity to key mayors in the area. Availability in providing facilities and covering costs (e.g. for water and power connection supply; effluent discharges) for MS unit hospitality has been achieved in three different municipalities.
- iii. Breeders, slaughterers and butchers: the itinerant slaughterhouse service is intended to serve a much larger community than the OG partners and economic operators represent its key stakeholders. A broad consensus emerged about the service benefits and the MS potential in addressing pressing needs. Yet, it is not seen by the various operators as an economic business that can be implemented by one breeder/butcher or a collective thereof, without a substantial public support.

Room for improvement of the itinerant slaughterhouse service has been identified and will receive committed attention in the next future, not least in terms of its effective governance. Its economic competitiveness and its manageability by the operators themselves need to be further investigated, including identifying a trained squad delivering the service in the territory. Yet, it is encouraging to ascertain the availability of local Institutions to enable such approach through dedicated facilities made available in a few villages as well as to contribute to set tailor-made procedures beyond business-as-usual conditions. This readiness of institutional actors to explore agile and innovative conditions in the market-regulatory interface, provides a blueprint for the scalability of resilient solutions for animal slaughter, notably for inner areas affected by a lack of infrastructures such as bad road systems and scarce accessibility to slaughter facilities.