

GMBA-DIVERSITAS conference • Chandolin, 27.–30.7.10

Functional significance of mountain biodiversity



Conference abstracts

Abstracts of plenary presentations (by session)

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Achievements of a decade of global mountain biodiversity assessment (GMBA)

GMBA is DIVERSITAS' international scientific network with a high elevation focus, dedicated to the assessment of biological richness in the world's upland and to its significance for ecosystem functioning and for mountainous societies. Over the last 10 years, GMBA built an international community of biodiversity scientists exists, collaborates in international scientific projects, and engages in science and policy fora, such as the Convention on Biological Diversity or the Millennium Ecosystem Assessment (MEA). The GMBA network so far actively involved 500 scientists (as SC members, workshop participants and organizers, authors and contributors to book chapters, articles and MEA mountain chapter) and has more than 1000 subscribers to newsletters. Aiming at a global picture of biodiversity and its function and threats in mountain ecosystems, GMBA went through three major phases of activities, which will be summarized by highlighting results from around the globe from our GMBA synthesis books.

Session 1: Functional significance of mountain biodiversity

Keynote talk

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Mountain Biodiversity, its causes and function in a changing environment

When GMBA started 10 years ago with a similar conference in the Swiss Alps, we had envisaged to build a corporate identity of biodiversity oriented mountain researchers worldwide, with an emphasis to evidence trends in mountain biodiversity, its drivers and its role in ecosystem function. This meeting permits us to synthesize achievements and explore new tasks. In order to arrive at focused activities, we had confined the GMBA networking activity to alpine biota and the uppermost part of the montane belt, close to the natural tree limit. In this introduction I will recall the commonness and contrasts in environmental drivers at high elevation, the significance of diverse plant types in steep terrain for soil stability, the relationships between plant species diversity and productivity and the role of global change factors such as elevated CO₂, nitrogen deposition and climatic warming. I will show new data that evidence the significance of topographic diversity for biodiversity resilience under IPCC warming scenarios in alpine landscapes. I will further introduce the novel web based tools for mountain biodiversity research (the GMBA Mountain Biodiversity Portal, MBP (www.mountainbiodiversity.org), jointly developed with GBIF). Examples will illustrate the type of questions that can be answered by clever utilization of electronic archives. With this, a new era of functional ecology and evolution research will lead us into the next decade of global mountain research.

Keynote talk

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Linking plant diversity, soil microbial communities and nutrient cycles

There is growing recognition of the important roles that linkages between plants and soil microbial communities play in regulating ecosystem processes and the services that they underpin. In this talk, I will explore this issue from three different perspectives. First, I will present findings from a series of in situ ¹⁵N labeling studies that have explored the capacity of plants to compete with soil microbes for organic N forms in soil in mountain grasslands, and how plant and microbial competition for, and the turnover of, DON varies along productivity and elevation gradients. Second, I will present findings from recent studies which have examined how variations in the diversity and composition of plant communities impact on carbon dynamics and ultimately carbon sequestration in grassland ecosystems. Finally, the importance for carbon dynamics of aboveground-belowground linkages will be considered in the context of other components of mountain ecosystems, namely large mammalian herbivores.

Keynote talk

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Using plant functional traits to understand the landscape distribution of multiple ecosystem services from subalpine grasslands

We propose a new approach for the analysis, mapping and understanding of multiple ecosystem service (ES) delivery in landscapes. This method first develops spatially-explicit ES models based on plant traits and abiotic characteristics. Then the combination of maps for multiple ES makes it possible to analyze 'hot' and 'cold' spots of ES delivery, and their determinants in terms of landuse and biotic characteristics. We demonstrate this approach for a grassland-dominated landscape from the central French Alps, where animal husbandry and tourism are the two main economic activities. We show the value of the trait-based approach as compared to a pure landuse approach, and highlight how this approach can improve our understanding of ecological constraints to, and opportunities for, the delivery of multiple services.

Keynote talk

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On the functional significance of mountain biodiversity

In recent years, biodiversity research has more and more been recognized as a discipline with two main questions. In addition to the traditional question of 'what are the causes of variation and changes in biodiversity?' we now also ask 'what is the functional significance of biodiversity change for individuals, populations, and ecosystems?' While there is ample mountain-specific information on the first of these questions, including macroecological information on altitudinal clines and their climatic and edaphic backgrounds, and information on land use effects on biodiversity, mountain-specific information on the second question is only starting to compile. The lecture presents mechanisms and experimental evidence for biodiversity – ecosystem functioning relationships, e.g. relating to production, nutrient retention, carbon storage, resistance to invasion, pests and diseases, or pollination, and discusses the validity and relevance of such examples for the functional significance of mountain biodiversity.

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Plant functional diversity effects on water balance in mountain grasslands across the Alps

Mountains are an important source of water for a considerable part of the human population. Shifts in the components of the ecosystem water balance, such as the ratio of evapotranspiration to deep seepage, may influence water yield from these mountain catchments. We hypothesized that in alpine grasslands, plant diversity and functional composition is a key determinant of water balance by influencing processes like evapotranspiration, interception and water uptake from the soil. The project presented used a total of 220 deep seepage collectors (DSCs, diameter 25 cm, depth 30 cm) with different plant functional composition at three different sites across the Alps (Lautaret/France, Furka/Switzerland, Stubai/Austria) to determine deep seepage and soil moisture content. As precipitation was measured among other meteorological parameters and surface runoff was eliminated by the design and horizontal placement of the DSCs, evapotranspiration could be calculated as the residual in the water balance equation. In order to relate water balance to the plant canopy, species composition as well as cover, height, phytomass of functional groups were measured for each monolith. First results indicate that in short herbaceous and shrub-rich communities evapotranspiration is reduced by 20 to 60% compared to the on-site average. This effect is larger in homogeneous and smaller in more diverse canopies. In communities dominated by graminoids no pronounced difference in evapotranspiration was found between short and high vegetation. We conclude that plant functional composition and diversity may affect the water balance in mountain grasslands. Thus, by influencing plant functional diversity, land management bears the potential of regulating water balance and water yield in mountain environments.

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Biodiversity and erosion control

Alpine plant diversity and species identity are likely to be key parameters to stabilize soil in steep alpine terrain. Although frequently discussed, this hypothesis has rarely been tested explicitly.

We tested in several experiments the effects of alpine plants on the soil aggregate stability and on surface erosion at disturbed Swiss alpine sites where it is particularly important to prevent soil erosion.

1. The number of plant species was positively correlated with soil aggregate stability, and species number was a better explanatory variable than any other variable related to soil or

vegetation. Higher plant diversity was associated with a higher number of different root types.

2. Rainfall simulation experiments demonstrated that surface erosion was strongly driven by the percent of vegetation cover. At a vegetation cover of approx. 60%, an increase in plant diversity significantly reduced surface erosion.

3. Belowground traits of alpine plant species showed large differences e.g. in root length, horizontal and vertical spread and root tensile strength, illustrating that below-ground diversity of functional root types is crucial for slope stability.

Our experiments demonstrate a positive relationship between species diversity or functional type diversity and soil physical properties. Not only percent vegetation cover is crucial to prevent soil erosion but also the diversity of plant growth forms. A high diversity of belowground growth forms is the most likely mechanism for the positive effect of plant diversity on soil properties.

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Alpine plant diversity and function in the Central Caucasus

Biodiversity is a guarantee of ecosystem stability. Functional significance of biodiversity is especially important in alpine regions, where it alleviates many negative exogenous processes and serves as the principal regulating water balance factor. Highly productive plant communities (tall perennial herb meadows, scrubland, fertilized meadows) contain low numbers of species (< 20), while unfertilized meadows are the most diverse ecosystems (> 45-50). Overgrazing has different consequences on slopes and plain areas. In both cases, but more pronounced on slopes, biodiversity is reduced. On plain areas grasses disappear and forbs increase, while on slopes xerophilous grass species forming dense turfs (e.g. *Festuca sp.*) 'win' along with cushion plants with strong root systems, and both growth forms play a key role in stabilization of eroded steep southern slopes. When grazing is ceased on plane areas, specific diversity is recovered by 90% in 1-2 years after 30-40 years of grazing; this fast rate of recovery cannot be reached on slopes. Decrease in plant diversity causes simplification of community structure. Biomass (98%) is concentrated in the 0-2 cm layer close to soil surface. Concentration of detritus in the same layer diminishes PhAR consumption by 30-35%. All these lead to disturbance of community 'protective effect'. Plant diversity reduction causes pauperization of plant functional 'strategies', which is especially harmful during droughts and may lead to community degradation and intensification of erosion processes on the background of on-going global climate change.

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Traits patterns indicate that increased production and isolation due to global change will impact functional diversity in the alpine.

Mountain systems are currently threatened by increasing habitat fragmentation and changes in precipitation, temperature, and nitrogen (N) availability; all of which may alter the structure and function of plant communities. Our objective was to examine trait patterns along naturally occurring gradients and to relate these results to the different processes

suggested to affect species coexistence within plant communities. We analyzed trait patterns in areas of the alpine tundra that differed in aboveground primary production (which may relate to the impact of changing temperature, precipitation and/or N availability) and geographic isolation (which may relate to impact of habitat fragmentation). We hypothesized that 1.) as productivity increases, coexisting species within a site would have less similar traits, suggesting an increased role of competitive exclusion via limiting similarity, and 2.) with greater geographic isolation, there would be greater divergence among sites suggesting decreased dispersal to isolated sites. We found that coexisting species within a site differed more in their traits in more productive communities, indicating that the strength competitive exclusion may increase with increasing productivity. Additionally, we found greater divergence among isolated sites suggesting that dispersal cannot counteract the effects of competition at higher geographic isolation, but may counteract some competitive exclusion when there is greater connectivity between sites. Our results suggest that changes in productivity associated with global change may lead to stronger competitive exclusion, which may lead to the loss of rare or subordinate species. Additionally, dispersal may not be able to counter these effects if geographic isolation increases.

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Seed traits dancing in subalpine grasslands: from convergence to divergence under mowing and environmental filters.

Plant community abundance patterns are often well explained by environmental filtering of seed traits, selecting few species that manage to establish. However, seed trait can also diverge in a community, and the understanding of the role of this divergence of seed traits in the coexistence of species is still limited. We searched for convergence patterns of seed mass and number in subalpine grasslands under diverse mowing regimes and compared it to abiotic conditions. Then, we analysed functional divergence of these seed traits, to know if divergence can also be a response to environmental filters or if divergence was observed when filters were released. Contrary to our expectations, mowing did not filter seed traits. Convergence on heavy seed masses was observed in mown grasslands in response to drought. In parallel, divergence increased when small seeded species entered the communities and decreased average seed mass. We conclude that seed traits constraint probably species establishment when water is limiting, but allow diversity in other cases.

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The importance of facilitative interactions on the diversity of alpine plant communities of the southern Andes

Alpine habitats are expected to be prone to facilitative interactions among species. Although the consequences of facilitation at individual and population levels are well known, the community-level consequences of these processes have received much less attention. In this study we sampled 11 alpine plant communities along the southern Andes in South America, spanning from tropical (25'S) to sub-antarctic latitudes (55'S). Plant communities

were dominated by cushion plants, a particular growth form that act as nurse plant for other plant species. Through rarefaction curves we assessed the effectiveness of community sampling, and estimated the number of species present within and outside cushions. Samples from cushions and open areas were combined in a single matrix accounting for the difference in cover between both microhabitat, and through rarefaction curves we assessed how many more species are added to the community due to the presence of cushions. Samples taken within cushions always contained more species than equivalent samples in open areas. Inclusion of samples from cushion and open areas in synthetic analyses - where differences in cover were accounted for - indicated that the presence of cushions consistently increased species richness at the entire community level. The magnitude of these increases in species richness varied with habitat severity, with lower values at both extreme of the environmental severity gradient. Similar positive effects were observed at the genera, family and endemic species level indicating that facilitative interactions are pivotal in the maintaining diversity in these harsh environments.

Session 2: Phylogeny and genetic diversity in mountains

Keynote

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Using molecular phylogenetic construction to deconstruct the high elevation flora of the South American Andes

Gradual accumulation of molecular phylogenies for plant genera represented in the South American páramo, puna and southern andean steppe, opens the door to better understanding of the origin, lineage richness, breeding system trends, and PD in one of the world's major high elevation floras (ca. 6700 species; >800 genera), while at the same time engendering taxonomic instability in biodiversity studies. Several high Andean genera, some monotypic, are nested within clades of other genera, and consequently, eventually will require formal taxonomic reassignment, if not already completed. Examples include: *Laretia* (Apiaceae), *Lasiocarpus*, *Aetheolaena* (Asteraceae), *Bougueria* (Plantaginaceae), *Tovarochoa* (Poaceae), *Hamadryas*, *Oreithales* and *Barneoudia* (Ranunculaceae), *Urbania* (Verbenaceae). To the contrary new genera have been erected on phylogenetic evidence (e.g. *Lomanthus* (Asteraceae), *Zameoscirpus*, *Phylloscirpus* (Cyperaceae), *Mulguraea* (Verbenaceae)). Of interest are additional monotypic genera, spread throughout the three Andean sectors; while some appear to be lingering lineages (e.g. *Calopappus* (Asteraceae), *Saxifragella* (Saxifragaceae)), a majority show recent splits with single representatives of other genera. With better taxon sampling, more monotypic high elevation genera could become submerged, yet it is unclear at this point where the submergence/emergence balance will lie in general. The tendency for several Andean genera, recognized originally under conventional taxonomic principles, to be nested in other genera, might be a reflection of rapid morphological differentiation, a pattern also possibly underlying outstanding speciation rates in some Andean plant genera. More work is needed to determine whether submergence and emergence rates in the high Andes, differ from those in lowland habitats. Funding: ICM-P05-002; PFB-23; Fondecyt-3085004

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Diversity, distribution and evolution of arctic-alpine *Pedicularis*

Inventories and taxonomic revisions are key prerequisites for global mountain biodiversity assessments. Both can considerably bias the precision of diversity estimates for a given region as well as influence the interpretation of biogeographic patterns and the evolutionary history of taxa. Here, we focus on *Pedicularis*, a large genus of >750 hemiparasitic plant species. *Pedicularis* is typical for many wide-spread and diverse mountain taxa because of the absence of a supervised taxonomic checklist, the conflicted infrageneric morphological classifications, and the shortage of distribution maps. As part of an ongoing molecular

phylogenetic revision of the genus we present preliminary maps of species and subgeneric taxa distribution and diversity in relation to the ecoregions of the world. Herefore we data mined regionally available taxonomic and geographic data from numerous publications and archives. In particular, we aim to quantify and compare the taxonomic diversity of *Pedicularis* in the different mountain ranges of the Northern hemisphere, delineate the potential origin of the species, highlight areas of high conservation priority due to elevated levels of endemism, and outline biogeographic artefacts due to incomplete coverage or taxonomic uncertainties.

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Genetic structuring of a rapidly expanding *Larix decidua* population

There is evidence that plant species shifted upwards during the last century due to climate warming. If genetic diversity is maintained during this rapid migration process or if it is lost due to founder effects is of great concern for the long-term persistence of species. I studied the genetic structuring of an expanding *Larix decidua* population along the lateral moraine of the 'Grosser Aletsch' glacier (Switzerland) by sampling adults along the chronosequence at the regional scale (ca. 350 ha) and by sampling all individuals at local scale in a late and an early successional stand (ca. 0.8 ha each). Microsatellite markers revealed that genetic diversity is similar among groups of adults along the chronosequence. Despite an inter-group distance of up to 4.8km these groups were not genetically differentiated. At local scale, kinship relations among juveniles are significant in the late but not in the early succession indicating differential gene flow. In the latter plot rare alleles show propagule dispersal over a few kilometres and private alleles suggest that they might well come from beyond the region. Overall genetic diversity is maintained at the leading edge of the population. Therefore I conclude that even species with restricted propagule flow (*L. decidua* has non-saccated pollen grains and seeds with small wings) migrate triggered by climate change without losing genetic diversity and thereby secure their long-term evolutionary potential.

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Size structure and longevity of arctic-alpine clonal plants

Long-lived clonal plants are believed to enhance community stability and ecosystem resilience in Arctic and alpine ecosystems. It is suggested that populations of clonal plants persisted locally despite past climatic changes. This persistence can be quantified by the assessment of population age structure and dynamics of present populations. We analyzed the size and age structure in several populations of four long-lived arctic-alpine clonal plant species. The number and size of genets was determined with molecular markers (AFLP) using a standardized sampling design in homogeneous climax populations. Age was then estimated by dividing plant size by a mean annual size increment obtained from in situ measurements in several populations. The measured size and age structures indicate that the individuals of clonal plant populations usually are differently aged with a dominance of younger and a low number of large and presumably very old individuals. The presence of large and old individuals is evidence for the persistence of populations during centuries, in

some cases over thousands of years, including past climate change. The presence of age differences among individuals and the dominance of young individuals suggest regular recruitment. Thereby, necessary adaptive responses to rapidly changing climate are feasible. Together, population persistence and genet turnover ensure maximum ecosystem resilience. Our results indicate that some clonal plants in arcto-alpine habitats are extremely long-lived, survived past periods of climate oscillations and have the potential to resist to changing climate in the future.

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Patterns of biodiversity at the species and gene level in Alpine plants: relevance for conservation

Biodiversity has manifold relevance at all its levels, being ecosystems, species, and genes. The latter represents a fundamental component of ecosystem resilience, given that it embodies the adaptive potential of species under changing environmental conditions. However, the genetic level has rarely been considered in the assessment of biodiversity because large-scale multispecies studies have been prohibitively resource-intensive. Therefore, finding efficiently accessible surrogates for genetic diversity could serve for incorporating genetic information in conservation strategies. To date, little empirical evidence is available on relationships between species and gene diversities, whereas ecosystem-species relationships have been widely explored. Here, we compared total vascular plant species richness with neutral genetic diversity of 27 widespread alpine plants. Both diversity levels were assessed on the same regular grid system across the entire Alps. We found clear spatial patterns of diversity at both species and gene levels. But in contrast to expectations based on theoretical models, we found no correlation between these two levels of biodiversity. We attribute these findings to differential effects of drivers, such as ecology and history, of species and gene diversities. As species richness cannot serve as a surrogate for genetic diversity, we advocate that genetic diversity should be separately considered in efforts to conserve total biodiversity.

Session 3: Climate change and mountain biodiversity

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Shifting species spectra in alpine summit vegetation across Europe

An increase in the number of vascular plant species in high-mountain ecosystems of the Alps and the Scandes was repeatedly reported since the 20th century. More recently, both an accelerated rise in species richness as well as a decline of extreme high-altitude species at their lower range margins were observed. An ongoing atmospheric warming is suggested to being key driver of these changes, by supporting an upward movement of alpine species. This presentation focuses on observed impacts of climate warming on alpine vegetation on mountain summits in 17 regions distributed across Europe. Permanent plots in these regions were established in 2001 as part of the GLORIA network (www.gloria.ac.at) and were resurveyed in 2008. Here we show, if and to what extent the vegetation on summit habitats has shifted towards a more "thermophilic" species composition (using percentage cover data of species) over a 7-year period of climate warming.

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Later migration of bogong moths into the Australian Snowy Mountains despite an earlier snow melt causes mismatch across three trophic layers.

Migrating bogong moths (*Agrotis infusa*) are an important food source for a number of vertebrate species in the Snowy Mountains of south-eastern Australia. However, whereas the date of snow melt in the Snowy Mountains has advanced 2.7 days per decade since 1954, the date of arrival of bogong moths has become later, with the result that moths arrived on average 54 days before snow melt in 1979-1996 but 29 days before snow melt through 1997-2009. This later arrival gives less time for moth numbers to build up to a readily exploitable food source. Resident mammals are dependent upon this source of food in spring at a time of high energy demand, and red foxes (*Vulpes vulpes*), bush rat (*Rattus fuscipes*), dusky antechinus (*Antechinus swainsonii*) and endangered mountain pygmy possums (*Burramys parvus*) account for approximately 45% of one billion moths that are consumed annually. A consequence of the late arrival of the moths is that fox diet in spring fell from 62% moth to 20- 32% moth over three years. The shortfall in moths was compensated for by increased predation by foxes on small mammals. Populations of small mammals that are insectivorous (*A. swainsonii*) or predominantly insectivorous in spring (*B. parvus*) crashed in this period, whereas the omnivorous *R. fuscipes* increased. It appears that, with climate change, a situation of matching phenologies between spring migrating bogong moths and hibernating mountain pygmy-possums has been replaced by a mismatch, and this appears to be exacerbated by acting across three interacting trophic levels: moth-possum-fox.

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Increasing plant biodiversity on mountain tops at the upper limit of dwarf shrub heath

We present a new project on the changes of vascular plant composition on mountain tops over the last century. Starting at an elevation lower than most previous studies, our study covers the highest limits of alpine grasslands and dwarf shrub heaths, and therefore covers a zone of dramatic vegetation change. Our core dataset contains full species lists from the early 20th century of 66 mountains in the vicinity of Davos, Switzerland. Their altitudes range from 2600 to 3400 m within a small geographical area. Species locations at lower altitude are moreover known from an extensive floristic study of Davos. On 13 mountains between 2610 and 2750 m covered in 2009, we found an average increase of 40 species (68 to 108) between a 2600m threshold and the top of each mountain. Of the 239 species found, 34 were newly found above 2600m, occurring on average 213 m higher today. Most notable is the high number of small *Larix decidua*, *Picea abies* and *Pinus cembra* trees on several mountains. A total of 181 species are more frequent today than before 1929, most of them typical species of *Nardus* grasslands and dwarf shrub heaths. Thirty species were less frequent in 2009 than in the early 20th century, but none vanished from more than two mountains. We will extend this new dataset in the next summer with the goal to identify drivers of vegetation change and to disentangle the roles of climate change, land-use and population size of herbivores and hikers.

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Potential effects of climate warming on a unique cryo-flora: the endemic high alpine to subnival plants in the mountains of Iran

In Iran, more than 100 mountain peaks with an altitude exceeding 4000 m and support many alpine and subnival habitats. These high-altitude areas, however, have only been poorly investigated ecologically and botanically. This study examines altitudinal and chorological distribution patterns of characteristic subnival vascular plant species and the vegetation of high alpine and subnival habitats in the Central Alborz. Subnival species are concentrated between 3800-4500 m a.s.l. and the upper limit of vascular plants reaches to 4800 m. More than 50% of these species are endemic to Iran and most of them are local endemics with a narrow distribution area. Long-term monitoring sites of plant diversity and soil temperature (according to the GLORIA standard method) were established in 2008 to relate measured soil temperature trends to observed changes in flora and vegetation. Permanent plots, however, are not yet old enough for detection of warming-mediated changes. Intensive grazing over large parts of Iran's mountains is expected to pose additional press on high mountain plants. The fact that many endemic species are restricted to small and fragmented high-elevation areas makes these cryophilic plants particularly vulnerable to the impacts of climate warming.

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Effects of Climate Change Land Use and Land Cover Change in the High-Atlas Mountain, Southeastern Morocco

Moroccan mountain biomes are considered endangered due to climate change that affects directly or indirectly different key features (biodiversity, snow cover, run-off processes, and water availability). The present article describes the strategy for achieving collaboration between natural and social scientists, stakeholders, decision-makers, and other societal groups, in order to carry out an integrated assessment of climate change in the High-Atlas Mountains of Morocco, with an emphasis on vulnerability and adaptation. Here, we provide a robust statistical technique to dynamically downscale outputs from the IPCC climate models to the regional study area. This study, also analyzed spatial and temporal in land use/land cover changes (LUCC) in a typical watershed covering an area of 800 km² by comparing classified satellite images from 1976, 1989 and 2000 coupled by GIS analyses and also investigated changes in the shape of land use patches over the period. Forest cover declined at an average rate of 2.1 ha per year due to timber extraction, cultivation, grazing, and urbanization processes. Historically, cultivation has resulted in such a high loss of plant communities in lowlands that regional diversity has been threatened. Grazing has increased due to low labor costs and economic policies that provide incentives for cattle production in Morocco.

Finally to address the interaction among ecosystem services principles, we used the Integrated Valuation of Ecosystem Services and Tradeoffs tool (InVEST) to identify areas of high and low ecosystem service production and biodiversity across the landscape and illuminate the tradeoffs and synergies among services under current or future conditions.

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Assessing elevational shifts and projecting future ranges for swiss breeding birds as a consequence of climate and land use change

Climate change is affecting biodiversity worldwide inducing species to either 'move, adapt or die'. Within the project ClimBird developed at the Swiss Ornithological Institute, we addressed the spatial dimension of the induced reactions for breeding birds in Switzerland. In particular, we assessed changes in the altitudinal distribution of breeding birds and we made predictions about their future distribution across the country according to the forecasted changes in climate and land use.

The altitudinal assessment was performed using data gathered by the Swiss national

breeding bird survey (MHB), a monitoring program started in 1999 and run on a yearly basis. Differences in the altitudinal distribution between the beginning of the monitoring program and present time were assessed over 267 sampling units. The number of territories per square kilometre of each species was modelled as a function of altitude and significant changes were evaluated at five reference points along the smoothed regression curves. The proposed methodology allowed identifying upward shifts for at least one third of the 95 species considered. The current distribution of breeding birds across Switzerland was modelled within an 'ensemble forecasting' framework using several modelling techniques (GAM, BRT, MARS), different bioclimatic, topographic and land use-related predictors and data from different sources (monitoring, atlases, ornithological databases). The distribution was projected for the 21st century according to combined scenarios of climate and land use change. Results clearly show that climate warming represents a major threat especially for alpine species, for which Switzerland has a key responsibility in the European alpine landscape.

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Impacts of experimentally induced summer drought on ecosystem functioning in alpine grasslands

Human induced climate change is unequivocal and ongoing and the future summer climate in the European Alps is predicted to be drier and warmer, with an increased probability of extreme events such as severe droughts. How alpine ecosystems will react on changing precipitation regimes is unclear. In a field experiment, established in the Swiss Central Alps, we study the impacts of prolonged summer drought on several key ecosystem processes in alpine grasslands. At three sites at 2500 m a.s.l. with contrasting macroclimate and geology we simulate summer drought with rainout shelters. Knowledge is gained on the impacts of drought on above- and belowground biomass production and on changes in structural parameters of the alpine swards. The experiment reveals whether drought will change plant ecophysiological parameters related to water use and whether these responses are species-specific, leading to changes in competitive abilities and, thus, species composition and diversity in the long term. Furthermore we examine whether drought modifies litter decomposition and nitrogen cycling (nitrogen mineralisation rates, nitrogen uptake). Here we present data of the first two years of drought simulation with focus on biomass production, litter decomposition and nitrogen cycling. Our project will contribute to predictions of the consequences of the most likely climate change scenario for the Swiss Alps. Because vegetation integrity of alpine grasslands reduces risk of erosion and secures slope stability, knowledge on vulnerability of these grasslands to climate change is crucial for the welfare and safety of many people.

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Diversity responses to elevated CO₂ in alpine plant communities

An increase in atmospheric CO₂ concentration may directly affect plants by stimulation of photosynthesis or by reduction of the aperture of leaf pores (stomata), or indirectly via

climatic changes. Both, higher photosynthetic rates and water savings due to less transpiration through stomata might potentially lead to a stimulation of plant growth in future climate. These hypotheses have been tested in three in situ CO₂ enrichment experiments on various early and late successional alpine plant communities in the Swiss Central Alps (2450 m a.s.l.). A lysimeter study with undisturbed alpine grassland monoliths has shown that, across the growing season, evapotranspiration is significantly reduced by elevated CO₂, by 3 to 7 % depending on the grassland type dominated by different species and functional types. Counter expectation, CO₂ enrichment has not stimulated, but in a few species slightly decreased plant growth and reproduction in both early and late successional communities, except for some winning species such as *Leontodon helveticus* and *Trifolium alpinum*.

Our results indicate that, in these different high elevation plant communities, biodiversity matters in the view of their responses to future climatic changes, which might affect ecosystem services such as water yield of catchments in the Alps.

Keywords: Climate change, high elevation, alpine grassland, evapotranspiration, catchment yield

Session 4: Improving forecasts of climate change effects on mountain biodiversity

Keynote talk

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Preserving the Tree of Life - Anticipating the functional and evolutionary consequences of climate change on Alpine biodiversity

Alpine biodiversity is predicted to become vulnerable in the next 50-100 years as consequence of projected environmental changes. However, not all species face equal challenges. Some are predicted to decline ('losers'), whilst others are predicted to expand their ranges ('winners'). In order to plan for adequate responses to mitigate impacts of climate-change on biodiversity, there is a need to identify the species that are most likely to become losers or winners, as well as the areas that might witness disproportionate declines in the numbers of species present. In the meantime the evolutionary and functional consequences of projected environmental changes have been neglected so far, although entire clades or functional group could be unequally vulnerable to environmental changes. If losers and winners are not randomly distributed over the tree of life, Alpine biodiversity will certainly lose higher evolutionary history and functional diversity than expected under a random extinction hypothesis.

We present here the first study aiming to estimate the taxonomic, functional and phylogenetic consequences of projected of environmental changes on French Alpine biodiversity (2700 plants). Using an ensemble for projections, a molecular tree and an extended functional trait database, we demonstrate a substantial phylogenetic clustering in species' vulnerability whatever the climatic scenario used, leading to unexpected extra-vulnerability in some clades. We also show that the consequences of projected environmental changes could lead to a non-random loss of evolutionary history and functional diversity.

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Niche Theory, Elevation Range, and Mountain Biodiversity: A Combined Theoretical and Empirical Study

We investigated the effect of elevation range on mountain biodiversity using a combination of theoretical models and empirical data in an attempt to distinguish between the predictions of classical (deterministic) niche theory and stochastic niche theory.

Deterministic niche models predict a monotonic positive relationship between elevation range and species diversity since larger elevation range leads to more diverse environmental conditions and therefore, more diverse communities (the 'habitat diversity' hypotheses). In contrast, stochastic niche models predict unimodal relationship between elevation range and species diversity. We attribute this difference to the fact that an

increase in elevation range increases the potential number of species that can occur in a given area, but at the same time reduces the effective area available for each species and thus, increases the likelihood of stochastic extinctions. We tested the contrasting predictions of deterministic vs. stochastic niche theory using data on the distribution of vertebrate species (amphibians, reptiles, birds, and mammals) in the Iberian Peninsula. All groups of species showed patterns of species richness consistent with stochastic niche theory. A literature review indicates that unimodal and even negative responses of species diversity to elevation range were also documented for ferns, butterflies, beetles, and birds. We conclude that stochastic extinctions may play an important role in determining mountain biodiversity and propose simple predictions about the organisms, environments and scales at which such effects are expected to be important.

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Past and future changes in alpine tundra in the Rocky Mountains

Improving our understanding of climate, snowpack and alpine plant distribution interactions at fine spatial resolutions (meters or 10s of meters) is an enduring goal of alpine plant ecology. Understanding and quantifying these interactions is required to anticipate and predict future species patterns given anticipated temperature and precipitation changes. The 350x500m study area is located at 3500 m elevation on Niwot Ridge, in the alpine tundra of the Colorado Rocky Mountains. To parameterize species distribution models (SDMs), we assessed the spatio-temporal changes of 80 plant species using 81 permanent plots covering 19 years (records in 1989, 1990, 1995, 1997, 2006 and 2008). Partial triadic analysis showed a shift of species structure in vegetation plots from 1989-2006. Correspondence analysis of 1989 and 2006 inventories revealed an important species composition shift in plots located at the interface between wet meadow and snowbed communities. In addition, these two communities changed the most during this time period. Analysis of climate data suggests that these community changes are associated with warmer temperatures during the melting period in late spring and summer. To obtain a predictive capacity for the SDM given anticipated modifications of temperature and moisture, a spatially explicit model of snow accumulation and ablation (SnowModel) was driven by 17 years of daily meteorological data (1989-2006) to yield maps of snow depth and soil moisture. Snow depth and soil moisture explain up to 80% of plant spatial distributions within the study area. Thus, robust projections of SDM are possible using simulated proximal and process-based variables and future projections of temperature and precipitation patterns over the 21st century.

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Can we predict plant assemblages from species responses to topoclimatic factors?

In the last decade, conceptual and technical developments of Species Distribution Models (SDMs) have allowed better assessment of the alpine flora response to climate and its threat against expected global changes. However, little is known to what extent the actual response of species to climate and topography - thought as main drivers of species distribution in space - reflect the full spectra of community assembly processes that shape plant diversity pattern along elevation gradient. To examine such questioning we used a

large dataset covering the full range of the elevation gradient in the Western Swiss Alps and reconstructed plant communities by stacking predictions of individual plant species niche models based on topoclimatic variables. In this talk we will see that above 1350 m stacked individual species models predicted almost unbiased species composition and species richness, giving strong support to the idea that direct or indirect response of species to climate and topography is the main driver of community assembly at highest elevation. Conversely, at low elevation, predicted species assemblages were composed by too many species compare to the observed. We showed consistent relationships between species richness or composition deviance and the functional features of actual communities leading to a better understanding of structuring forces independent from climate and topography effects. We will then discuss potential ways to account for a more complete picture of community assembly, beyond the species response to climate, which could potentially lead to more reliable assessments of global warming effects on plant diversity in mountain ecosystems.

Session 5: Large scale patterns in mountain biodiversity

Keynote talk

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Data Mining of GBIF data with the GMBA Mountain Portal Tool: examples from the third pole

In times of a global crisis (financial, social, biological and atmospheric), biodiversity is the base currency; it's the essence for human well-being, wealth and sustainability. However, our CBD2010 targets got widely missed, presenting us with large problems. Here, a global view is presented that focuses on Mountain Biodiversity, and how the best available science can be used for reaching critical goals in a science-based Adaptive Management framework. An overview is given on synthesis efforts for mountain biodiversity data, and how it can be achieved using data mining and predictions. An example is presented based on the Himalaya Upland database (HUP) by B. Dickoré et al. in the Open Access environment of GBIF and the new GMBA portal. Challenges of mountain biodiversity data are discussed such as taxonomy, three-dimensional geo-referencing, metadata, digitisation, data mobilization, delivery and access. An outlook is given where online mountain data will be heading, and with the advent of the new WEB 2.0 and with in-time webservice. Making efficient use of Mountain Biodiversity Data is essential if the basic ecological services are to be maintained for mankind, and if global sustainability is to be reached.

Keynote talk

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Tropical Montane Cloud Forest biodiversity: General trends and large-scale, latitudinal and altitudinal patterns across the globe

Although the global area of (narrowly-defined) Tropical Montane Cloud Forests (TMCF) is only about 0.26% of the Earth's land surface, these particular forests are amongst the most species-rich and species-dense ecosystems world-wide, in terms of flowering plants, birds, mammals, amphibians, and reptiles. TMCFs also appear to be particularly numerous in at least six of the most important biodiversity "hot spots" around the globe, viz. the tropical Andes and Atlantic Forests in South America, the Caribbean Islands, the Eastern Afro-montane peaks scattered along the eastern edge of Africa, the Asian Sundaland (which includes the high mountains of Borneo), and Polynesia–Micronesia (which includes the islands of Fiji, Hawai'i and Tahiti). Similarly, the eighteen of the most important "Global 200" WWF Ecoregions (i.e. 9% of the total) contain tropical cloud forests. In general, overall diversity in TMCFs tends to decline away from the equator and –at least for vascular

plants— is explained in terms of temperature, moisture availability, and topographic heterogeneity, with the latter becoming particularly important in humid montane areas. The extraordinary diversity of such taxonomic groups as bryophytes, vascular plants, birds and amphibians in cloud forests is often the result of past explosive evolutionary radiation, such as occurred in the Tropical Andes. Because of the high levels of endemism in TMCs, new species are still regularly discovered. For amphibians, cloud-affected forests do not appear to be more species-rich on average than the (much more extensive) non-cloud forest ecosystems, but they are an order of magnitude richer in endemics. As for mammals, species richness in cloud-affected forests is distinctly higher than outside of cloud forests (by more than 40%), whereas endemism richness for mammals in cloud-affected forests is almost four times higher than in non-cloud-affected forests. Finally, endemism richness for birds is over three times higher within cloud-affected forests.

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The floristic division of the south and north parts of Hengduan Mountains, a biodiversity hotspot in SW China

Hengduan Mountains in southwest China is recognized as one of the world's biodiversity hotspots. The southern and northern subregions of the Hengduan Mountains have been recognized as being among the 11 key regions of terrestrial biodiversity in China. However, these areas were poorly analyzed. We explored the division of the region based on gradients in species similarity and richness. The region was divided into 9 latitudinal belts using 1 degree of latitude to define the belts, and the distribution of all seed plants in each belt was recorded. Latitudinal pattern of species similarity was measured by Jaccard similarity index for each pair of adjacent latitudinal belts. NMDS ordination was also used to measure the species similarity among the 9 latitudinal belts. Both species similarity and ordination both showed species similarity between the southernmost, northernmost or across 29°N latitudinal belts presented a visibly low value. Patterns of species richness shown by the c-value of species-area power function and species / area ratio along the latitudinal gradient both showed a sharp decrease at the 1 degree latitudinal belt from 29°0' to 29°59'N. The Hengduan Mountains is divided into a southern and northern subregion along the 29°N latitudinal line. The southern subregion occupied 40% of total area, but contained more than 80% of all the seed plants in this region, and its higher species richness and endemism suggest it is the core of the biodiversity hotspot and deserves priority for conservation in the region.

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The phytogeography of the southern Great Escarpment in southern Africa: Diversity, Endemism and Connectivity

The Great Escarpment in southern Africa is a 4 800 km-long mountain system stretching from Angola south through Namibia into South Africa, Lesotho and Swaziland. The Great Escarpment is rich in biodiversity and endemism, hosting half of southern Africa's centres of floristic endemism. Despite this richness, the Great Escarpment has been poorly studied. Here we report on floristic research on the southern Great Escarpment (the Sneeuberg,

Nuweveldberge and Roggeveldberge), which is 1 000 km long, forms one fifth of the total Great Escarpment, and has a highest point of 2 504 m. A four-year survey involving extensive fieldwork and literature review was implemented to sample all key habitats, and in particular areas that may represent refugia. A database of some 12 000 taxa was created in order to use phenetic methods and Parsimony Analysis of Endemicity to analyse the floristic relationships between the southern Great Escarpment, the Cape Floristic Region (CFR) and the Drakensberg Alpine Centre (DAC). The southern Great Escarpment is shown to rich in endemics (with one new centre of floristic endemism), to be a palaeo-corridor between the western and eastern Great Escarpment, and to support both paleo- and recent connections with the CFR. Connectivity along the southern Great Escarpment is shown to have been broken by the aridification of the Nuweveldberge since the Last Glacial Maximum. The south-eastern connection with the CFR (first purported by Weimarck, 1941) is shown to be the primary conduit of Afromontane connectivity between CFR and the eastern Great Escarpment in southern Africa.

Session 6: Altitudinal trends in mountain biodiversity

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Trends along andean altitudinal transects of Peru: evidence of declines in frog density and diversity

Steep altitudinal transects along montane forests and high-Andean habitats, of Manu Biosphere Reserve, 600- 3700 m, and Abiseo National Park, 3600 -2600 m, were sampled for frogs in 1999, 2008 and 2009 in Manu, and in 1987-89 and 1999-2000 in Abiseo. Through visual encounter surveys and leaf-litter plots (10x10m), we compared diversity and abundance between years. Despite similar sampling effort, the number of species declined in Manu by 36% in stream-dwelling and arboreal species, while species with terrestrial and direct-development reproduction presented minimal changes. Similarly, frog abundances were lower in more recent years than ten (Manu) or twenty years ago (Abiseo), whereas densities in leaf-litter plots did not differ among survey years. Evidence of chytridiomycosis explains at least partially those dramatic changes in two protected areas, with high numbers of endemic species and little direct human intervention.

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Patterns of congruence and diversity along altitudinal transects in N-W Italian Alps by a multi-taxa approach

The ongoing and fast global loss of biodiversity underlines the need to monitor and identify the factors that influence its distribution. In 2007, three alpine parks located in N-W Italy (Gran Paradiso National Park, Orsiera-Rocciavre Natural Park, Veglia-Devero Natural Park) shared a project to determine the relationships between animal biodiversity and environmental factors and test the most appropriate methods for a periodically repeatable monitoring programme. Twelve altitudinal transects (from montane to alpine belt) were chosen. Each transect is composed of 4-7 sampling units separated by an altitude range of 200 meters, for a total of 69 monitored plots. In every station were collected data from 6 taxa (Lepidoptera, Orthoptera, Aves, Staphylinidae, Carabidae, Araneae), census by standardized, repeatable and cheap methods. Each sampling station was characterized by parameters related to topography, environment (by in situ vegetation surveys) and micro-climate (by location of dataloggers). This work allows to assess the coherence in the distribution of different taxa along altitudinal gradients and the influence of geographical, environmental and climatic factors on biodiversity. Data on species richness and community

composition are also useful to identify priority conservation areas and the peculiarities of each vegetation belt.

This project can offer a representative sample of North-Western Italian Alps and it aims to be the first step of a monitoring program that should be repeated every 5 years to highlight the response of alpine biodiversity to climate and land use changes.

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Patterns of plant species richness, diversity and endemism in the alpine zone of the Western Himalaya

The alpine zone spreads over nearly 33% of the Indian Himalayas and represents one of the fascinating biomes on account of distinct landscape and habitat features manifested by peculiar structural and functional diversity of plant communities. Despite a large number of floristic surveys, very few published accounts are available on the patterns of species richness, diversity and endemism across altitudinal and latitudinal gradients. This paper is based on extensive ecological surveys of alpine vegetation in the Western Himalaya (the Indian states of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir) conducted over more than a decade. This part of the Himalaya has been traditionally recognized as a distinct phytogeographic region. Extensive surveys of alpine vegetation were conducted during summer-monsoons of years 1998 to 2007 covering the Greater and Trans-Himalayas (long expeditions, opportunistic sampling, intensive eco-floristic studies at representative sites). Phytosociological data from >530 sampling sites (with 10 random quadrats of 1 m² within a homogeneous vegetation patch at each site), covering all three states were used to estimate species richness, species diversity, evenness and beta diversity across various physiognomic units, habitat types and altitudes. It was found that the number of endemic species decreased with increasing altitude. Most of the endemic species (70%) in the alpine areas occupied mesic and wet habitats and even within the Trans-Himalaya region, majority of the endemic species were found in the sheltered habitats less exposed to wind and dessication, which is contrary to the findings of previous studies.

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How to interpret insect body size patterns along altitudinal gradients?

Body size of organisms has important functional and evolutionary implications. The study of the relationship between ectotherms body size variation and changes in abiotic and biotic features is particularly relevant in mountain ecosystems where, within a short distance and without photoperiodic modifications, a large range of temperatures exists along elevation. As altitude increases, body size of insects may vary, positively or negatively, both between and within species. On one hand, when resources are abundant, body size generally increases as temperature decreases (Atkinson's temperature-size rule). On the other hand, body size generally decreases where the seasonality of resource availability is high, and/or when the resource density decreases. Altitudinal variation in life cycles strategies may also exist, e.g. in the case of ground beetles, shifts from an annual life cycle (lower altitudes) to a facultative or obligatory biennial life cycle (higher altitudes) impact on body size. A review of published data suggests that the complex set of local interactions between temperature,

resources and growth period duration makes a real contribution to the control of insect body size variations with elevation.

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Coexistence of large herbivores in mountains at multiple scales

Large herbivore populations have increased throughout the alpine regions in the last decades. Yet, the role of large herbivore community composed of several abundant species on the dynamics of plant communities and landscape in mountains remains largely unknown. We will present results of a long term multispecific study aimed at identifying how coexisting large herbivores share or compete for common resources (space and food) at several spatial scales, and how they respond to spatio-temporal variation in availability, quality and quantity of food resources.

Session 7: Land use change effects on mountain biodiversity

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Land Use and Biodiversity in the Alps from the genetic to the landscape level

Alpine grasslands are ecosystems with a great diversity of plant species. However, little is known about other levels of biodiversity, such as landscape diversity, diversity of biological interactions of plants with herbivores or fungal pathogens, and genetic diversity. We explored natural and anthropogenic determinants of grassland biodiversity at several levels in the Swiss Alps. Differences between cultural traditions (Romanic, Germanic, and Walser) turned out to still affect land use diversity and thus landscape diversity. Increasing land use diversity, in turn, increased plant species diversity per village. Within grassland parcels, plant species diversity was higher on unfertilized mown grasslands than on fertilized or grazed ones. Different land use types were characterized by a different set of species. Most plants were affected by herbivores and fungal leaf pathogens, reflecting that parcels harbored a great diversity of herbivores and pathogens. Diversity of herbivores but not of fungal pathogens depended of land use and altitude. A common-garden experiment revealed genetic differentiation of the important fodder grass *Poa alpina* between mown and grazed sites, suggesting adaptation. Per-village genetic diversity of *Poa alpina* was greater in villages with higher land use diversity, analogous to the higher plant species diversity there. Our combined results suggest that plant species richness does not always adequately measure biodiversity at different levels of biological integration. Overall, landscape diversity and biodiversity within grassland are currently declining.

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Regional differentiation in life history and susceptibility to grazing in a widespread Alpine monocarp

Glacial history caused regional differentiation in neutral molecular markers in numerous widespread Alpine plant species. Several distinct phylogeographic lineages resulted from the glacial survival in refugia and subsequent recolonisation of different parts of the Alps. These historic processes could also have affected genetic differentiation in phenotypic traits among these regions, either as a result of drift, regional adaptation or both. A two-year common garden experiment with the monocarpic *Campanula thyrsoidea* from 21 populations across the European Alps was performed to reveal differentiation among four phylogeographic lineages in morphological, functional, life-history and reproductive traits. A clipping treatment was applied to simulate the effect of herbivory and to estimate its influence on fitness. A trend was visible showing that clipping did not affect morphology and reproduction in plants from the Western Alps, whereas the other regions were clearly affected. In the Western Alps *C. thyrsoidea* occurs frequently in grassland, potentially explaining this result as adaptation to higher grazing pressure. Plants from the Eastern Alps were differentiated in morphology and life-history: inflorescences were taller but had lower flower density, and plants showed delayed, indeterminate flowering. Compared to the short growing season of the high Alps, this contrasting flowering behaviour of Eastern Alpine plants is adaptive in the long submediterranean summers in the native range in Slovenia.

QST-G'ST comparisons indicated that all investigated traits were subject to unifying selection. This suggests that, although genetic drift during Ice Ages is a strong force affecting phenotypes, natural selection limits neutral differentiation to maintain adaptations. Keywords: *Campanula thyrsoides*, glacial history, common garden, adaptation, indeterminate flowering, unifying selection

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The consequences of grazing management strategies in the uplands and implications for biodiversity

The semi-natural landscape of upland ecosystems has been managed through low intensity grazing for centuries in Europe. Following a period of extensive over-grazing, recent reforms in the Common Agricultural Policy have resulted in severe under-grazing. It is widely accepted that low-intensity grazing can maintain biodiversity, nutrient cycling and productivity. Here we apply empirical and theoretical approaches to examine the ecological and socio-economic drivers of biodiversity change in upland ecosystems. Four upland study regions were selected in south west Ireland on the basis of their potential for continued extensive hill farming. Within each region, three hill farms of varying grazing management intensity were chosen. Habitats were mapped, assigned a grazing impact category and an overall state was then attributed to each farm. Bird, carabid and plant species data provided measures of the biodiversity present. Here we quantify the impact of grazing management on plant, carabid and bird diversity operating at a hierarchy of scales and altitudes, and the resulting effects on functional traits. We find that a suite of factors will determine the state of a habitat and use mixed effects models to study the consequences of land use change on the biodiversity of the uplands. These findings can inform and define policy options that both enhance biological diversity and respond to the needs and aspirations of the people living and working in the uplands.

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Tundra plant diversity and semi-domestic reindeer management in northern Norway

Semi-domestic reindeer are the dominant herbivores in tundra ecosystems of northern Fennoscandia, and their densities are much higher than those of wild reindeer/caribou herds in the rest of the Arctic. These densities have been particularly high during the last two decades for various socio-economic reasons, and some authors have claimed we were facing an ecological catastrophe. We have investigated the impacts of reindeer grazing on plant diversity using a series of study designs at different spatial scales: 1) large-scale survey covering most of the summer reindeer pastures (area covered of the order 40,000 km²), 2) intermediate-scale survey focusing on one specific habitat preferred by reindeer, snow beds, and 3) experimental studies at small spatial and temporal scale focusing on direct effects of reindeer and small mammal grazing using exclosures. Plant diversity was analysed using Chapin's concept of growth forms, refined here by considering the facilitating or retarding ecosystem effect of some species (e.g. mountain crowberry *Empetrum hermaphroditum* slows down ecosystem processes). At large, landscape scale reindeer grazing had a homogenizing effect, such as decreasing the biomass of

palatable/facilitating growth forms in productive habitats down to the level of biomass in unproductive areas, or decreasing the cover of willow/dwarf birch shrubs. At small scales, dependent on type of selected habitats, we find either no herbivore impact or we find that both reindeer and small rodents impact on growth form composition, with small rodents reducing willow thicket recruitment and reindeer facilitating unpalatable grasses. Due to the wide-ranging behavior of reindeer, and its high selectivity, we find that ecological studies at spatial scales from 15 m to 100 km give complementary knowledge of the relationships between reindeer grazing, plant diversity and ecosystem functioning.

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Fire regime as a driver of resilience, functional diversity and ecosystem services in Mediterranean mountains

Mountain areas in Portugal are usually defined as territories with rough morphology, low demographic densities, and peculiar agrarian systems based on cattle raising and husbandry. The use of fire has been a common management practice in traditional land use, mainly to control vegetation encroachment and to promote pasturelands. Therefore, historically fire has been a strong driver of vegetation patterns, soil properties and ecosystem services throughout Iberian mountains. Recently, however, a generalized tendency for abandonment of agriculture and pastoralism is promoting vegetation recovery and changes in fire regimes, driving a shift from small fires in recurrently burnt areas to energetic and largely unpredictable wildfires.

We present results from studies of ecosystem resilience and vegetation dynamics driven by fire regimes, discussing their connection to the provision of ecosystem services. We report strong effects of fire recurrence, distance to the latest wildfire, and geology on scrubland resilience, with potential implications for regulating services. We also evaluated the resistance and resilience of young deciduous forests to fire disturbance and its implications for supporting services. Overall, our results support the idea that fire regime is a major driver of functional diversity in Mediterranean mountains and suggest that land abandonment and related shifts in fire regimes promote unpredictability in the spatiotemporal patterns of several ecosystem services. Finally, we discuss response options for managing changing mountain landscapes.

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Evapotranspiration in alpine and subalpine grasslands under land use change

The Alps form an important source of water for the lowlands. In the Alps land use forms and patterns have undergone significant changes: while we witness intensification and even over-exploitation on the easily accessible and more fertile lands, grounds that are less productive and more difficult to reach with animal herds, have become abandoned. As a result of this, diversity, vegetation structure and ecosystem functioning are altered. For alpine pasture and meadow systems we can expect water relations to change in particular evapotranspiration. Abandonment likely leads to a reduced evapotranspiration while intense grazing is likely to reduce evapotranspiration (the magnitude of these effects does however

depending on altitude). In order to come to predict the effect of land use changes on a catchment's water balance we measured evapotranspiration across a range of altitudes. We will present results from a large-scale lysimeter experiment where we test for the effect of the presence or absence of grazing (clipping) on evapotranspiration for different plant life forms that are characteristic for the alpine and sub-alpine domain.

Key words: Land use change, evapotranspiration, lysimeter, altitudinal comparison, catchment yield.

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Ecological and hydrological consequences of green alder expansion in the Swiss Alps

The European Alps are the most intensively exploited mountain region in the world, inhabited by 13.6 Mio people and visited by c. 120 Mio visitors every year. Primary resources are agricultural production, landscape values (e.g. tourism) and hydroelectric power. In Switzerland, hydropower meets 60% of country's electricity requirements. Regardless this exploitation, the Alps still host Europe's largest pool of plant species in highly diverse landscapes. Ongoing transitions in land use, climatic changes and socio-economic processes are affecting ecosystem goods and services of alpine areas with vital effects for the forelands. Reduced farming activities have led to massive shrub and forest expansion into formerly open habitats. In particular, green alder encroachment leads to nearly mono-species stands in previously species-rich grasslands. These land cover changes affect evapotranspiration and runoff (amount, quality), thus, with hydrological consequences for high- and the adjacent lowlands. We will show how alder encroachment into subalpine grasslands leads to (1) a decline in plant diversity, (2) to altered water balance due to increased interception and higher transpiration, thus, reducing surface runoff and therefore, decreasing the hydroelectric potential. And further, how (3) this species contributes to eutrophication by amplified nitrate leaching due to its enormous N₂-fixing capacity even when it is forming the high elevation tree line in the Swiss central Alps.

Session 8: Invasive species in mountains

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Global comparisons of plant invasions along elevational gradients as a model system for studying niche dynamics

The recurrent introduction of Eurasian weeds into mountains around the world represents a unique natural experiment for testing ecological and evolutionary hypotheses; in particular for investigating whether plant species maintain their climatic niches in new areas of introduction (niche conservatism v. niche shift). We present a comprehensive analysis of the climatic niche of a broad range of Eurasian weeds on different spatial scales (local elevational gradients to continental-scale distribution ranges) and by combining field observational and experimental data with statistical modelling. For some 30 Eurasian weeds we modelled the complete climatic niche in Eurasia and two areas of introduction (Northern America, Australia) based on continental-scale data, and for some 20 of these species we repeated the modelling with high-resolution, regional-scale data in a native (Switzerland) and non-native mountain area (Hawaii) both characterised by steep elevational gradients. Further, such regional-scale data was for some species also available for several other mountain gradients spread across all climate zones (MIREN core sites, www.miren.ethz.ch), which allowed for investigation of the generality of our results. For three species (*Hypochaeris radicata*, *Lactuca serriola* and *Verbascum thapsus*) we used plant fitness data from field observations and/or experiments along elevational gradients to investigate the mechanisms behind climatic limits to niches.

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Biogeographic distributions of non-native plants in mountains

Biogeographic processes operating at multiple spatial scales determine patterns of species richness. As a model system to study these processes, the Mountain Invasive Research Network (MIREN) surveyed the distribution of non-native plants in eight climatically different mountain regions around the world. Variation in species richness and similarity in 100 m² plots was partitioned at three hierarchical levels: between regions globally, along elevation gradients within regions, and locally among sample sites. The global scale explained most variation in similarity because each region had a unique species pool, with 74% of species appearing in only one region. Old World regions had fewer species and were highly dissimilar to the New World regions, because the latter share many non-native species of Eurasian and Mediterranean origin. Non-native species richness peaked in the lowest third of the elevation gradient in all regions, irrespective of climate, and was positively correlated with land-use intensity. Elevation largely explained differences in similarity within a region, as species present at high elevations had broad elevation ranges and were also found in lower elevations. Non-native species richness also decreased away from roadsides, and this was more pronounced at high elevations. Distance from road explained little variation in

similarity, suggesting that spread of non-native species into natural habitats is limited by dispersal. Our results support human-mediated dispersal and ecological filtering as key mechanisms in the formation of elevational non-native species richness gradients.

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Genetic and plastic responses of non-native plants along altitudinal gradients

Non-native plant species are typically expected to have high phenotypic plasticity which enables them to invade across a broad range of environmental conditions, such as along altitudinal gradients. However, adaptation of non-native species can be very rapid and might contribute to their often rapid spread. We begin by documenting clinal trait variation of alien species in mountain regions in both their native and introduced ranges (Valais, Switzerland; Wallowa Mountains, OR, U.S.A.). Despite very short introduction histories, there has been a re-establishment of clinal patterns in the introduced region which are very similar to those observed in the native range. In order to separate the relative contribution of phenotypic plasticity and local adaptation to these clinal patterns, we grew native and introduced populations of one species, *Lactuca serriola*, in common gardens along an altitudinal gradient in Switzerland. This experiment showed that while genetic differentiation of native populations was often related to altitude, introduced populations tended to be more phenotypically plastic in their responses to altitude. We then move beyond comparisons of plants from two mountain regions to investigate the generality of these patterns using multi-regional studies, including a further two species (*Hypochaeris radicata* and *Verbascum thapsus*), conducted by groups from the Mountain Invasion Research Network (MIREN; www.miren.ethz.ch). We suggest that while genetic adaptation might frequently play a role, phenotypic plasticity is most important for enabling non-native plants to spread along environmental gradients.

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Non-native plant species richness along elevation gradients: the interplay of climate matching and time since introduction

Climate matching has emerged in many studies as a consistent predictor of invasion success. However, there is evidence that the climatic niche of some non-native plant species is different in the area of introduction. In a comparison of ruderal roadside plant communities in two mountain systems in different climatic zones (Swiss Alps and Tenerife, Spain) we could show that climate matching is particularly important during the phase of establishment at low elevation sites. Due to this lowland introduction filter, species occurring at high elevations were also present at low elevations. When spreading into higher elevations species are confronted with changing climatic conditions and all plant species reach their climatic limit somewhere along elevation gradients. In our field survey we found that old-introduced species were able to reach higher elevations than recently introduced species. This might reflect the time required for species to disperse to high elevations. However, another explanation might be that old-introduced species have had more time to

adapt genetically to the unfavourable climatic conditions. We conducted a multi-species experiment including some 30 non-native herbaceous plant species from both regions to test for local adaptation and plastic responses to altitude. Most species reacted plastically to different climatic treatments, but for many species there was also evidence for genetic differentiation between low and high-elevation populations. Our results suggest that climatic niche modeling may be useful to predict potential areas of first establishment, but that from there ongoing adaptation might enable species to extend their ranges upwards along elevation gradients.

Session 9: LTERs in the Alpine and their influence on biodiversity research

Keynote talk

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NWT LTER as a prototype for understanding the controls on alpine biodiversity: the challenge of converting long term monitoring into science.

Niwot Ridge is the only multidisciplinary, long-term field site for high-elevation areas on the North American continent. As such, the site is an essential benchmark for regional, national, and global networks that measure biological changes and feedbacks and experimentally determine mechanisms for these relationships. Our ongoing attempts to meet the challenge of converting long term monitoring into process-based understanding on the controls of biodiversity at the NWT LTER is shaped by the interface of two conceptual models a) the Landscape Continuum Model and b) the novel ecosystems concept that arises out of the Panarchy Model. The interplay of these two models argues that amplification of drivers such as climate change, N deposition, and dust deposition in high-elevation catchments may be “tipping” these ecosystems into states not experienced in modern times. A major component of our activities over the last six years has been to develop NWT LTER as a research platform to broaden the scope of science by a) bringing in new scientists, b) collaborating with new environmental observatories such as the National Ecological Observatory Network (NEON) and the Critical Zones Observatory (CZO) program, and c) collaborating at regional to international scales.

I'll illustrate these ideas with the following items: a) evaluate the quality and quantity of organic carbon deposition to high-elevation landscapes, b) test how plant-soil feedbacks and directional environmental change influence community dynamics, extending previously developed theory on threshold effects or tipping points to alpine ecosystems, c) evaluate the potential of biotic disturbances such as species invasions and infectious diseases to tip ecosystem properties and dynamics into novel ecosystems in both terrestrial and aquatic environments, d) build on a new conceptual framework and global meta-analysis to test the ways in which a stoichiometric perspective may better predict N accumulation along the hydrologic continuum both within and beyond the NWT region, e) explore ecohydrological feedbacks over the NWT LTER and the surrounding region through the next century by improved synthesis, integration and model development, and (f) work with social scientists and economists to increase our understanding of the impact of these and other perturbations such as the mountain pine beetle invasion on ecosystem services in high-elevation areas.

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Coupling of snow cover and vegetation structure in Sierra Nevada (Spain)

Sierra Nevada is the second highest range of Europe, after the Alps. Its singularity lies in its geographical situation at the southern border of Europe. It can be considered the southernmost mountain in Europe in which snow cover determines the structure of alpine vegetation. On the other hand, climate change predictions show that Mediterranean ecosystems will be affected by alterations in temperature and rainfall patterns. Both issues make interesting the analysis of the relationships among snow cover and vegetation structure in Sierra Nevada. We have assessed the relationship among snow cover behaviour (duration, snow cover onset date, snow cover melting date) and two ecotones (treeline and woody vegetation limit). Snow cover has been analyzed using the snow product of MODIS satellite images, from years 2000 to 2009. Ecotones have been obtained by photointerpretation of present day aerial photos. To analyze the coupling among both variables, we have assessed the similarity of snow cover in the pixel occupied by the ecotone and in the pixels immediately above and immediately below from this ecotone. That is, we have assessed how different are the snow cover patterns in locations situated right above and right below from the ecotone. If we consider only ecotones not created by human land use (i.e. pine plantations, farmlands), we can conclude that uncoupling among both factors means that snow cover has changed and vegetation structure is still adapting to it. So we expect changes in vegetation structure (altitudinal movements) in next decades due to changes in snow cover.

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LTER in the Austrian Central Alps: scientific relevance and outlook

Among the Austrian LTER/LTSER several central Alpine areas in North Tyrol form the platform 'High Alps'. Each of these regions (Gossenköllesee, Oetz Valley, Stubai Valley, Mt. Patscherkofel) hosts monitoring programmes on different scales, process and/or organism levels, including different time periods. Glacier and rock glacier research as well as climate and timberline analyses cover several decades up to recent years whereas ecological monitoring - using permanent plots - was carried out consecutively during the last two decades. Changes of the North Tyrolean glaciers were regularly monitored since the end of the 19th century. Time series of glacier mass balance measurements in the inner Oetz Valley are available since 1952/53. A long monitoring sequence with continuous recording since 1938 also exists for a rock glacier in the same area. Climate, timberline and land use changes are among the most important data recorded by ecologists. Climate warming appears as essential factor governing growth stimulations of timberline trees as well as species enrichment along the altitudinal gradient from the subalpine to the subnival zone. Long-term grazing exclusion experiments in the inner Oetz Valley showed remarkable effects on species composition and strategy types. All in all the Austrian LTER/LTSER platform 'High Alps' offers good examples of long-term studies providing basic biodiversity data but also essential data input for models and future observations. A continuation of the monitoring programmes is indispensable in order to analyse trends and to predict ecological consequences.

Abstracts of poster presentations (alphabetic)

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Promoting sustainable human settlements and eco-city planning approach: southeastern anatolia region and southeastern anatolia project in Turkey as a case study

In the recent years, there have been many opportunities flourishing through the development of Turkey. One of these is unvalued rich agricultural and hydro-sources in the Southeastern Anatolia Region. The Southeastern Anatolia Project (GAP), one of the most important projects to develop the remarkable natural resources of the world, is considered as a chance to make use of rich water and agricultural resources of the Southeastern Anatolia Region. In the recent years, the concept of promoting sustainable human settlements and eco-city planning approach have been included into the GAP Project. And by applying these concepts in real projects caused remarkable results through development of the region. The aim of this study is analyze the concepts of promoting sustainable human settlements and eco-city planning approach in the GAP Project that has been still processed. In the first section, the region of Southeastern Anatolia and the GAP Project will be introduced briefly. In the second section, the stages of GAP Project and the project existing will be analyzed. In the third section, the projects and sub-projects used for promoting sustainable human settlements will be introduced. In the last and fourth section, a series of policies and strategies for providing the process of settlements which is optimal and harmonizes with eco-system will be given.

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Projection of the butterfly diversity in Switzerland considering climatic changes until 2050

We modelled the butterfly species richness in Switzerland at the landscape scale until 2050. The model was based on data from the Swiss Biodiversity Monitoring (BDM), which records butterfly species richness over the whole country. We assumed an increase in annual mean temperature of 2 °C until 2050. We found by model projections that future butterfly species increased above 1200 m. At lower altitudes such as in the Plateau and in the Jura, however, we predicted a decrease in butterfly species richness.

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Polylepis forests of the northeastern Cordillera Oriental of Ecuador: Cover loss and genetic diversity

Scattered patches of *Polylepis* forest that occur within the 3000 to 4500m altitudinal belt of the Andean Cordillera from Venezuela to Argentina have been hypothesized to be remnants of continuous forests whose range became fragmented through anthropogenic activities that probably preceded the Spanish conquest. The southern part of the northeastern Cordillera Oriental of Ecuador is one of the few regions in the Andes where *Polylepis* forests exist as both patchy and continuous forest, and are still influenced by Andean people. The synergistic combination of these factors provides a unique opportunity to cast light on environmental versus human controls of the *Polylepis* forest present and its historical distribution, and to explore the associations of its current range with its genetic diversity. The area studied encompassed three adjacent river basins in the southern part of the Cayambe Coca Ecological Reserve and farther south, the Oyacachi, Chalpi and Papallacta river basins (491 km²). The investigation aimed to assess the magnitude of loss of *Polylepis* forest over the past four decades of agricultural intensification in the area, and to evaluate the consequences of fragmentation on genetic diversity of the dominant tree species (*Polylepis pauta*). Isolation by distance and spatial attributes of forest patches were incorporated into the study to increase our understanding of genetic differentiation among subpopulations of *P. pauta* in the area and assess the potential of *Polylepis* stands as sources for restoration.

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Converting field data into knowledge: towards adaptive management in Sierra Nevada LTER site

The main objective of the Observatory of the Sierra Nevada is to study the effects of global change in this protected mountainous LTER site. We are monitoring more than 100 environmental variables that are surrogates of ecosystem functions. A large amount of information is being created during the data collection. This information must be maintained within an information system so that it can be useful both to managers and scientists. The basic idea that has inspired the design of this system is to enhance the creation of useful knowledge from raw data collected in the field. We have considered the need to implement adaptive management of natural resources in Sierra Nevada. We show results obtained when including the above concepts in designing the information system. Thus, the data input to the system is performed through one web interface per data collection methodology. However, queries can be made at an ecosystem scale of all variables measured. Data are collected by means of transects or permanent sampling points and results are shown to an ecosystem scale (i.e. Data from dispersing birds are collected in permanent transects. Processed information expressed as diversity or relative abundance, is assigned to the ecosystems where those transects are located. This requires the use of interpolating techniques). To achieve this, spatial interpolations are performed regarding the ecosystem type in which the data were collected. These and others modelling algorithms are performed through workflow management software. Processed information is converted to knowledge about the ecosystem functions, expressed as a set of pressure-status-response indicators. These indicators are shown with a temporal perspective; their values are shown in the past, present and future (forecasts). Both raw data and the information generated are properly documented by a metadata system that meets international standards.

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Got Climate? Current Vegetation Changes in the Alpine Region

Species lists established on 900 sampling areas of Biodiversity Monitoring Switzerland since 2001 show changes in plant communities that may be attributed to the effects of a warming climate. The mean altitudinal distribution of typical oreophytes has been shifting further upward in the past ten years, while lower altitudes are increasingly being colonized by heat indicators.

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Forest infection in space: point patterns of trees affected by mistletoe (*Viscum album*) and pine processionary moth (*Thaumetopoea pityocampa*) in Mediterranean woodlands

Ecologists and foresters are becoming increasingly aware of the importance of spatial information in ecosystem analysis and resource management. An analysis of forest pests was conducted to characterize the spatial characteristics of mistletoe (*Viscum album*) and pine processionary moth (PPM) (*Thaumetopoea pityocampa*) incidence in a 4-ha pine forest plot located in Sierra de Baza (1,700 m.a.s.l.), southern Spain. The study was designed to develop an approach for assessment of the spatial patterns of these two pests separately and investigation of potential associations between them in two pine species (*Pinus nigra* and *Pinus sylvestris*), which are widespread in Mediterranean mountain ecosystems. To address these goals, 1,546 pine trees were geo-referenced and the number of PPM winter nests and mistletoe bushes counted in each tree. Random labelling and random thinning tests were employed to analyze the data. The results show a clustered pattern of both infections in *P. nigra*, whereas random patterns were observed in *P. sylvestris*. There was also a positive association of mistletoe and PPM, indicating that pines infested with mistletoe are more prone to be infected by PPM. Our study provides a characterization of the spatial patterns of two common forest pests in Mediterranean woodlands and new insights into the ecology of forest pest interactions. Further research and more complex models are, however, needed to explain the variables that cause their spatial distribution.

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How much is the biodiversity loss due to the *Deschampsia caespitosa* increase in an Alpine pasture?

Italian Alpine and pre-Alpine pastures, which were traditionally used for grazing livestock - mainly dairy cows- are particularly rich in plant species, especially forbs. Agricultural intensification, including the improvement of cattle diet that is often supplemented by feed concentrates in order to sustain their milk production during the summer months, is responsible for the decline in grazing intensity. In the Cansiglio forest pastures (NE Italy), like other large pastoral areas of the Italian Alpine region, one of the effects of the lower

stocking-rate due to the presence of less hungry grazing animals is the increase in the abundance of less attractive food plants that are negatively selected by livestock, such as *Deschampsia caespitosa* (L.) Beauv. Nowadays, as a consequence of this process, in the pastures of the Cansiglio forest, which -on the basis of 75 botanical surveys- are referable to the class Molino-Arrhenatheretea, order Molinietalia caeruleae, the *D. caespitosa* coverage goes from 0 to 76%, with a proportional decrease in number of species ($R^2=0.86^*$). The pastoral value also lowers when *D. caespitosa* increases ($R^2=0.9922^{***}$).

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Land use changes affect water yields of subalpine grasslands

Mountains ecosystems provide freshwater to approximately 50% of the world population. In the context of global changes this ecosystems service is threatened. At the Lautaret pass we investigated the effect of climate and land use changes on the water budget and quality of subalpine grasslands. Soil plus vegetation were sampled from five grasslands differing in their land use and were inserted into deep seepage collectors (DSC) allowing soil water percolate volumes to be measured and analyzed for nitrogen contents. Half of our 100 DSCs were transplanted at a different altitude to simulate climate change and land uses were also manipulated. Climatic parameters and soil moisture and temperature were monitored for each DSC. First analyses showed that precipitations and last days temperature explained a large part of percolated volume variability. We expect that analyses on water nutrient contents, plant phenology and functional compositions will help us to depict processes involved in the observed water budget changes.

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Modelling speceis richness: a comparison between two approaches

Species richness is a widely used measure of biodiversity. Its empirical modelling allows studying the drivers of biodiversity pattern, predict its future under global change or help establishing conservation strategies. Two modelling approaches are currently used in this research field. The first one, called hereafter direct modelling, relates measurements of species number to environmental variables, with a statistical model assuming a Poisson distribution. This technique relies on macro ecological hypothesis. The second approach, called cumulative approach consists in stacking independent species distribution models. For each species, presences and absences are linked to the environmental predictors, giving a potential distribution map. These maps are then summed to generate a species richness map. In this study, we used both techniques to model the plant diversity in the Western Swiss Alps and compared their respective performance. We show that the cumulative approach clearly over predicts the species number, when the direct approach provides prediction around the observed mean but is less well correlated with observed richness. We conclude that both approaches are complementary. Better species richness prediction could consequently be obtained by using the direct method to help constrain the cumulative one.

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Integrating genetic diversity and phenotypic plasticity into plant population responses to climate change in the Alps

Climate change scenarios predict a considerable rise of global mean temperature by 2100. As reactions to this, plant populations in mountain habitats are expected to migrate upwards, show phenotypic plasticity, adapt to the new climatic conditions or go extinct. We seek to determine the potential responses to changing climatic conditions of low central and upper peripheral populations of three common grassland species (*Ranunculus bulbosus*, *Trifolium montanum* and *Briza media*). Several approaches are applied including common gardens at different altitudes and climate chamber experiments to determine adaptation and phenotypic plasticity as well as population genetic analyses and investigations of contemporary gene flow. Along an altitudinal gradient, transplanting plants from higher to lower altitudes simulates climate warming and determining the degree of gene flow along altitudinal transects indicates the potential of gene movement from the nowadays to the expected future favourable locations. First results show differences in the relative growth rate of *R. bulbosus* originating from 1200 m and 1800 m a.s.l. Genetic analyses of population pairs of *B. media* and *T. montanum* did not reveal any effect of altitude on either the genetic diversity or the differentiation among populations. However, differentiation was found over short geographic distances in *T. montanum* but not in *B. media* most probably due to wind pollination in the latter. Gene flow among populations was stronger at lower than at higher altitudes. Ultimately, all results will be integrated to derive a scientific basis for conservation strategies to foster plant persistence under climate change.

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Quantitative genetic differences in growth and reproduction mirror phylogeography in a widespread Alpine plant

From the perspective of preserving biodiversity, it is important to understand how historic processes affect contemporary genetic pattern in widespread plant species. Numerous studies demonstrated the impact of glacial history on molecular geographic structure in alpine plants. However, studies testing whether regional molecular differentiation at the large scale of the Alps is mirrored as well in quantitative genetic differentiation in phenotypic traits are lacking so far. Here, we studied molecular differentiation and in parallel quantitative genetic differentiation among 16 populations of the widespread Alpine plant *Geum reptans*. In a common garden experiment including 592 plants, we recorded quantitative genetic differences among regions, populations and genets. In parallel, the 128 genets used in the common garden were analysed with RAPD markers to detect a putative molecular geographic structure, to measure genetic diversity and to estimate gene flow among regions and populations. A distinct molecular differentiation splitting the Alps in three phylogeographic regions was detected indicating highly restricted gene flow particularly among regions. A strong isolation by distance indicates the importance of neutral drift during isolation in glacial refugia. In the common garden regional effects on quantitative traits concerning growth, reproduction and leaf morphology were consistently larger than differences due to populations and genotypes, thereby indicating that glacial history has also effected phenotypic differentiation. Results suggest, that besides drift, adaptation to climatic and other environmental conditions in present-day habitats maintain strong fitness

related differentiation as evidenced for instance by trait variation correlated with the altitudinal origin of populations.

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Impacts of cushions on plant community diversity at different elevations the Rocky Mountains (USA)

Vegetation at high altitudes in harsh conditions is often organized in patches, and these patches are often dominated by cushion plants. Cushions offer refuge to many other plant species. By ameliorating abiotic conditions through temperature buffering, protection from wind, soil stabilization, or resource enrichment, cushions appear to substantially increase the local richness and evenness of communities. We compared the effects of cushion species on plant community richness at five sites in the northern Rocky Mountains at different altitudes. These included the Glacier National Park, Scenic Point (2600 m) where we sampled *Potentilla nivea*, the Beartooth Mountains (3000 m), where we studied the circumboreal *Silene acaulis* and *Trifolium nanum*, Rogers Pass (1600 m) where we sampled *Antennaria umbrinella*, Mount Jumbo (1200 m), and Waterworks Hill (1200 m). At the latter two sites we measured the effects of *Eriogonum ovalifolium*. By creating species-area curves for each site, with and without cushions in the model, we found that cushions increased local species accumulation, and thus diversity, at four of five sites, and saw no general pattern for the effects of cushions on diversity related to elevation. At the highest altitudes, *S. acaulis* and *T. nanum* increased species richness by 20.6% and 19.2%, while *P. nivea* increased diversity by 24.5%. At mid altitudes *A. umbrinella* increased richness by 20%. At low altitudes *E. ovalifolium* increased richness by 19.8% in Waterworks Hill, but there were no effects of *E. ovalifolium* on Mount Jumbo. However, multivariate analyses indicated that community composition was more similar between cushions and in the open at higher elevations than lower elevations, suggesting that cushions have stronger effects on community organization at higher elevations.

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Plant diversity along an altitudinal gradient in the Northern Apennine (Italy).

The study was conducted in the Northern Apennine along an altitudinal gradient from 1500 m to the mountain top (1935 m) and according to Western and Eastern aspects. Aim of our study was assessing the biodiversity and the possible effects of climate change on it. 122 plots for the two opposite aspects (61 for each ones) were sampled. A plot was 5x5 m large and divided in sixteen subplots of 1,25x1,25 m large. For each plot, all the vascular flora was sampled and the cover value for each species was evaluated by mean and continuous scale from 1 to 100%. Distribution of plots was chosen randomly stratified according to the altitudinal gradient considering five belts of hundred meters for each one. Phenological data were sampled and analyzed in comparison to the altitude and the seasonal data of temperature. For the whole area, the temperature at 1,60 m and 10 cm under the surface was recorded by mean of five datalogger. Richness, alpha and beta diversity and functional diversity (life forms and Grime strategies) along an altitudinal gradient were analyzed. Structural and functional data diversity was analyzed in correlation with station features (elevation, exposition, slope, etc.), temperature, plot heterogeneity and other factors.

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Climate-change effects on structural and functional plant diversity in the Northern Apennines

In order to investigate the floristic diversity and the ecological niches of the more important species and to study the effects of temperature increase on vegetation, we used a data set collected from the Alpe delle Tre Potenze, in the Northern Apennines. The study area concerns the Western and the Eastern slopes of the mountain, from 1500m up to the crest and the summit (1940m). A total of 122 plots, 61 for each slope, were randomly sampled and stratified according to a 100m altitudinal range. Each plot position was established using a GPS. The 5x5 m (25m²) plot was built up by orientating its sides in North-South and East-West directions. It was then divided into 16 sub-squares of 1.25m. For each plot we recorded the stational data, the vegetation cover and the species presence, assigning them a coverage value using a sliding scale of 1 to 100. A few sampled points were finally chosen to monitorize the phenology of some species during specific time periods (approximately every 10 days) of their growth season, using a general BBCH scale. In this way the main phenological stages of various species were detected, relating them with the climatic parameters of the area. Using five dataloggers we recorded both air and soil temperatures. Rainfalls during the growth season were recorded by a simple pluviometer.

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Protected Area Gap Analysis (part of the CBD's PoWPA WWF Dinaric Arc Ecoregion Project)

Dominated by the Dinaric Alps and the Dalmatian coast and sea, the Dinaric Arc ecoregion is one of the most important European biodiversity hotspots. Although the natural environment is relatively well preserved, after years of political instability the region urgently needs a good plan for the management of its natural resources, both within and outside protected areas. Gap analysis is a method for identifying the degree to which biodiversity is represented in a mosaic of conservation lands in order to provide land managers and policy makers with the information they need to make appropriate decisions. In its simplest form, a gap analysis involves comparing the distribution of biodiversity with the distribution of protected areas and finding the localities where species and ecosystems are left unprotected or under-protected. Species and communities that are not adequately represented in the existing network of conservation lands constitute conservation 'gaps'. On basis of existing data, range map of each biodiversity target were made. Gap analysis is based on three main sets of data components: Spatial orientation of various habitats, distribution of biodiversity components and map of areas already protected. Gap analysis was executed using GIS. Distributional maps were overlaid with shapes of protected areas. The result was the statistical representation of targets in protected areas within counties. Gaps among countries were analysed and discussed, according each group of biodiversity targets. Further, maps with relevant hotspots of animal groups were built and interpreted.

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Effects of grassland fragmentation and management on functional traits of ground beetle assemblages

The Italian montane ecosystem is characterized by a mosaic of different managed grasslands from meadows to pastures. This kind of human management belongs to the historical and cultural process of the montane agroecosystem evolution towards the centuries. In the last year the abandonment and neglect of this agricultural practice is determining grasslands colonization by the forest with an increasing of fragmentation with hypothetical consequences on the functional biodiversity. The Eastern part of the Stelvio National Park has been chosen as study case while ground beetles as study model due to their well known ecology and sensibility to the environmental changes triggered by human management. More than twenty grasslands with different patch size, management and elevation has been analyzed comparing the frequency of carabid functional traits (feeding habit, dispersion ability and body size) and richness. Three hypotheses have been tested with multivariate models: 1. the most stable grasslands like the abandoned ones are those where there is the highest frequency of carabids with low dispersal ability, predators and large size; 2. the grasslands size do not determine changes in the species richness, but in the frequency of functional traits; 3. the grasslands management determine changes in the assemblages composition.

The results obtained suggest the importance of the knowledge of the functional traits in the functional biodiversity: the predator carabids are able to eat pest insects, wingless carabids are not able to react to human impact due to the low dispersion ability and the biggest species are those mainly eat by little mammals and birds. Thus, the functional traits of the single species in the assemblages may be more useful than species richness as an indicator for habitat management.

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Linking landuse change with invasive plant species and assessing their impacts on mountain biodiversity in southern Indian montane forests

Invasive plant species have been known to cause massive damages to mountain ecosystems, and hampering its biodiversity in Indian montane forests. Increasing demand for raw materials from forests, and conversion of forest-land for human habitation has resulted in massive landuse changes. These anthropogenic disturbances have resulted in drastic fragmentation of terrestrial ecosystems, which has caused the invasive species to find an easy 'inlet' into mountainous areas. In southern Indian montane forests the prominent invasives include: *Lantana camara*, *Hyptis suaveolens*, *Parthenium sps.*, *Ipomoea sp.*, *Cassia tora*, and *Eupatorium spp.* These invasive plant species (often called as 'weeds') can drastically decrease tree growth and result in reduced carbon storage capacity of mountain trees. They vigorously proliferate on any available patch of mountainous land and compete with naturally occurring seedlings for space, nutrients and sunlight. The reasons for the prolific spread of invasive species are the aggressive modes of their propagation and specialized physiological adaptations, rendering them resilient and more competitive than their counterparts. In order to achieve sustainable management of tree resources on mountainous forests and preserve its biodiversity, it is mandatory to

assess the impacts of weed species on the forests. The present paper is an attempt to assess the impacts of invasive plants in the mountain forests of Mudumalai wildlife sanctuary in India. The study highlights the ecological impacts of invasive plant species on mountain biodiversity and explores possibilities for controlling their spread.

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Are mountains immune to invasions? Research insights from plant invasions in Kashmir Himalaya, India

In the globalised world, with the increasing trade and travel, the breaching of biogeographic barriers has accelerated the rates of biotic invasions - one of the major anthropogenic drivers of global environmental change. The world's montane ecosystems - previously believed to be relatively immune to biotic invasions - are now increasingly experiencing the spread of invasive alien species introduced, intentionally or unintentionally, by humans over the recent past. Like other montane regions of the world, the Kashmir Himalaya, nestled in the north-western extremity of Himalayan biodiversity hotspot, is facing a higher risk of plant invasions with potential ecological and economic costs as evidenced from our recent research studies. This Himalayan region is endowed with a rich repository of endemic biota that is critically linked to the sustainable provision of precious ecosystem goods and services, which in turn supports the survival of both the high- and low-land human population. In this backdrop, the present paper provides a synthesis of research insights gained over the last decade while studying alien plant invasions in the region. The taxonomic composition of invasive alien flora, biogeographical affiliation, altitudinal patterns, and socio-economic correlates of plant invasions are presented. The differences in the distribution patterns between native and alien flora and the ecological impacts of invasive species on native biodiversity are also discussed. Finally, a multi-pronged management strategy is proposed to stem the tide of plant invasions in this Himalayan region.

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Wrong ski piste construction enhances species numbers, but also the danger of erosion

Anthropogenic impacts on vegetation at high altitudes provide a high risk of failure for re-vegetation. The alpine countries, to a large extent economically dependent on a flourishing winter tourism, have undertaken numerous efforts to minimize these risks by improving not only the technology of ski piste construction, but also by developing adapted seed mixtures. Since 1986 we have performed phytosociological research on ski pistes in the Central Austrian Alps and from 2000 to 2005 on test plots at the world championship site St. Anton. Our results show that at altitudes above 2000 m species groups with life traits different from the adjacent natural vegetation take their chance to immigrate into ski pistes, especially when neither construction nor seed mixture match the state of the art. Small, erosulate

species, partly with high seed production and big soil seed pools, replace inadequate seed species, thus provoking a higher risk of erosion.

Key words: grading, seed mixture, autochthonous immigrants, erosion control

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Land use effects on evapotranspiration of subalpine grasslands

Mountains ecosystems provide freshwater to 50% of the world population. In the context of global changes this ecosystem service is threatened. We investigated the difference in rates of evapotranspiration among different land-use regimes in subalpine grasslands and we assess similarity and accuracy of evapotranspirative rates predicted by meteorological models. The models were ones we created from evapotranspiration measured on the study site and from the FAO-56 Penman-Monteith, and were compared to weighing method data for accuracy assessment. It was found that, of the meteorological factors analysed, evapotranspiration correlates most strongly with photosynthetically active radiation (PAR). In their relationship with PAR all terraced grasslands were significantly different from un-terraced land types and the abandoned terraced grassland was significantly different from the two maintained terraced grasslands. Evapotranspiration values predicted by our models were more strongly correlated with the observed values than with the predictions by the Penman Monteith. However a paired sample t-test showed that in all cases except the mown prairie the model values were significantly different from the observed values. This indicates that the models were inaccurate. The main reasons for this are unreliability of meteorological data and insufficient data to create refined models.

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Good practice for academic research with biological samples from abroad

Whenever scientists intend to use organisms or parts thereof from abroad for research purposes, they have to adhere to regulations as by the Convention on Biological Diversity CBD. The convention aims at conserving and sustainably using biodiversity. It's less known third fundamental objective consists of the fair and equitable sharing of benefits that arise from the use of genetic resources. This includes the use by academic non-commercial science. The historical 'free' use of genetic resources from plants, animals and microorganisms has in many cases led to the development of important drugs for the improvement of society's well being. However, this 'free' use of genetic resources is being perceived by many as a new form of bio-colonialism: Biodiversity rich countries are being used as a treasure chest for genetic resources and related traditional knowledge. Yet, the development of the commercial products usually happens in industrialized countries with more technological advancements and without the participation, remuneration or acknowledgment of the country of origin of the genetic resources used. The mistrust has become more acute since intellectual property rights are increasingly being claimed also by academic researchers. With a view to help scientists in Switzerland carry out research in an ethically and legally best way, the Swiss Academy of Sciences has elaborated tools on Good Practice. The paper illustrates the convention's background and illustrates the necessary steps academic researchers have to take in order to correctly access genetic resources and how to share benefits resulting from non-commercial research.

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Biodiversity changes in Mediterranean mountains induced by experimental climatic change

Mediterranean mountains present an elevated diversity of species as a result of migrations during glacial periods. Climatic variability induced by the climatic change is expected to affect in a different way to species from every successional stage cohabiting in the diverse ecological scenarios. In Mediterranean ecosystems, rainy summers are rare, appearing with a low frequency and irregular time intervals, but would represent a window of opportunity for the recruitment of many species, especially for long-lived woody species. A 30% rainfall reduction during summer is predicted for the coming decades in Mediterranean region, and is expected to have important consequences on the regeneration of those species with higher water requirements, and therefore on community diversity. In this study we evaluated the effect on the natural woody seedling bank during three consecutive years in experimental areas where three climatic scenarios were simulated: dryer, current, and wetter summers. This experiment was replicated in the three principal Mediterranean mountain habitats: open areas, under shrubs, and under tree canopy. Results obtained presented a strong effect of the habitat type and climatic scenario both on the number of seedling and species emerged and established. Woody canopy (tree or shrub) increased seedling emergence, as well as boosted survival. Dry summer scenario significantly reduced the number of seedlings and species, increasing community dominance, whereas under the wet summer scenario the pattern was the opposite, resulting in a more diverse community. These results indicate that climatic change has the potential to change the structure of the natural woody community.

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Variation in the communities of insect herbivores along altitudinal and latitudinal gradients in the Ural Mountains

The Ural Mountains offer an excellent case to study both altitudinal and latitudinal gradients, that provide the main source of variation in plant communities and in associated consortia of herbivores as well. Insect herbivores enable to track through the changes in composition of their consortia any trends in their functional significance. Although it was not easy to do this before as only separate guilds from the whole consortia have been surveyed so far. For this purpose in the North, South and Polar Urals in the years 2006-2008 several plot-based transects were laid down, where 100-m altitude belts were used for sampling with the permanent plots on each. Coniferous trees demonstrated very low species diversity of herbivores and almost no altitudinal variability. And for deciduous trees (birch, willow, mountain ash) all insect herbivores were collected and percentage of canopy damage was parallel recorded. The latitudinal gradients in composition of consortia were tracked along the mountain range (Polar - North - South Urals). Compositions of miners and gall-formers are very similar throughout the Urals. And in general consortia are similar in Polar and North Urals, while in South Urals some common species are absent. The consortia include five guilds (chewers, miners, suckers, gall formers and leaf rollers) and all these guilds demonstrate different latitudinal trends. Miners obviously disappear in alpine zone, but in gall formers several species with high abundance add in subalpine and alpine zones. Both suckers and leaf rollers demonstrate altitude related increase of percentage in the higher

belts. Chewers have clear maximum of percentage representation in the lower alpine belt. This situation may be one of the causes restricting tree regeneration in treeline ecotone.

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Mycographical analysis of climate change and conservation attempts of some threatened macromycetes of Ayubia National Park, Pakistan.

In the wake of rapidly increasing tourist activity, global warming and demand of medicinally important items, a number of macromycetous fungal flora of Ayubia National Park is highly threatened. Besides human induced changes, climate variability is resulting into cascading impacts on macromycetous diversity. The climate is turning unfavorable for the native flora and ultimately leading towards their extinction. This variability is also inducing dramatic upsets in ecological settings which are resulting into the introduction of exotic species. The present proposal is planned to identify threatened species of these fungi in Ayubia National Park and also focus for an integrated approach to conserve them. Another task of the proposed study is to develop awareness among local people and present an alternative strategy to promote cottage industry of edible and medicinal mushrooms for local inhabitants to minimize human interventions.

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Are the medicinally important resources of our mountainous regions threatened? Throwing light on the dark side of the story.

The use of plant materials for medicinal, cosmetics and therapeutic purposes dates back to civilizations in memorial. Through the process of trial and error man has acquired knowledge about a variety of uses of natural herbs. Pakistan is rich in plant resources with more than 6,000 plant species of higher plants and a number of medicinally important fungi. Our country is endowed with a variety of these medicinal resources due to a diversity in geographical, topographical and climatic conditions. However this wealth is being overexploited in view of increasing demands and lack of developing cultivation protocols. The irrigated areas of plains of Punjab and mountains are rich in phyto-diversity, containing a wealth of cultivated crops, natural vegetation and wild flora including macromycetous fungi. This also includes plants used in traditional herbal medicines, cosmetics and other therapeutic uses. Research on medicinal plants and fungi and those used in cosmetic industry in Pakistan has been generally ignored in respect to developing an understanding of the dynamics of natural resources, organization and evolution of human systems. This apparent lack of attention on these aspects has resulted in a scarcity of scientific data and an over exploitation of selected ones. There are however scanty reports of enlisting these special resources from the region. The pressure on these wild plants is going to increase in the coming future due to increasing tourism, agricultural, urban and industrial activities and rapidly accelerating and cascading global climate change scenarios. The natural vegetation of these areas of the country is severely degrading and there is an immediate need to protect and preserve these plants. It is therefore highly necessary to built a knowledge base and disseminate this knowledge among masses to save the plants and other medically important resources from overexploitation and extinction. Another vital option is to select plants in order of priority and standardize their cultivation protocols at large scales. This would not only inculcate research activities but would also save million of dollars of foreign exchange being spent on the import of these plants or active ingredients of interest. The

present paper throws a light on causes and consequences of these anthropogenic activities and climate changes on the medicinal wealth of the country. It also highlights suggestions to achieve towards finding possible solution to this problem.

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Vegetation cover changes in Sierra Nevada Mountains (Spain) during the past 50 years and relation to land use and climate change

Photointerpretation and analysis of 1956 and current aerial photographs allow us to show major changes in vegetal covers of the Sierra Nevada Mountains (Andalusia, Spain) in the last 50 years. This period is characterized by a generalized revegetation process as a consequence of the agricultural and the firewood use abandonment, the decrease of the livestock pressure and the extensive plantations of conifers, carried out as a way of control erosion and flooding during last decades. This land use evolution has led to advance of shrubs and densification and expansion of holm oaks forest, especially on Meso and Supra-Mediterranean belts, range of potential distribution for these species.

Moreover, diachronic analysis of elevational transects revealed a small increase in the altitudinal limit of oaks forests, holm oaks forests and juniper shrub fringe (*Juniperus communis* ssp. *hemisphaerica*), in some areas. These changes could involve the replacement of high-mountain grassland communities with large numbers of endemic and endangered species, typical of the Cryoro-Mediterranean belt, by shrub patches of *Juniperus communis* ssp. *hemisphaerica* and *Genista baetica* from lower altitudes (Oro-Mediterranean belt). These changes in altitude seem to be more influenced by climatic variations than by land use changes. Also the relief and the different orientations play a key role in explaining these variations. In definitive, we have observed that major changes in vegetation cover in Sierra Nevada are due to drastic changes in land use by human action. The small altitudinal observed shifts, especially in the highest areas, could be due to climate change.

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Crop diversity in the farmers' field of central Nepal; Opportunities for in-situ agrobiodiversity management

A study on the spatial and temporal dimension of crop diversity in the Jutpani village in central Nepal indicates that farmers cultivated 96 different types of annual crops and perennial fruit trees with an average of 26 crops per household. The number of crops per farm varied from 11 to 45. Fruit trees, vegetables and spices used for household consumption are concentrated in the home gardens while cereals, legumes and oilseed crops are grown in other available ecosystems based on their adaptive characters. However, few market oriented farmers grow vegetables and fruits in large scale. In this study we examine inter-household variation in cultivated crop diversity among different land use types and seasons by surveying 134 households. Our survey reveals that substantial difference exists in crop composition and crop diversity across households. Home gardens (total n = 78) among ecosystems, and winter season (total n = 60) by crop growing seasons have highest crop diversity on farms. Crops on the farms move progressively from one land

use to another based on their economic and cultural importance and their use value. Increasing use values counteract the bottlenecks associated with the small number of crops limited to smaller areas and thereby support in maintaining crop diversity through increased market demand. We also examine what factors account for maintaining crop diversity on farms. The statistical analysis shows that household crop diversity is strongly related ($p < 0.05$) with the number of different ecosystems available, wealth status and the size of cultivated land.

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Herbaceous species diversity in tall tussock grassland of the Bolivian Altiplano

The semi-arid, high Andean grassland of the Bolivian altiplano (mostly 3800-4300 m a.s.l.) is dominated by tall tussocks of *Festuca orthophylla* covering 30% of the plateau, with a tiny biomass fraction but high diversity in herbaceous species in the inter-tussock space. Land degradation affects 41% of Bolivia's surface, mainly in the altiplano, and leads to a decline of biodiversity, largely due to the impact of overgrazing and trampling by camelids on small herbaceous taxa. Herbaceous species are much richer in nutrients than the tussock grasses, but they are present during the wet season only. Here we explore the abundance and diversity of these threatened minor species under various management regimes, including fencing, fire and nutrient (llama dung) addition. In our study area in the Sajama National Park at 4200 m a.s.l., plants species richness and abundance were reduced under heavy grazing pressure and wide precipitation intervals related to the climatic oscillation ("el Niño"). Although inter-tussock species have high concentrations in nitrogen and non-structural carbohydrates, llamas do not appreciate many of these species, perhaps, due to their ephemeral nature or because their dietary needs are adjusted to the poor quality of the ever-present tussock foliage. Though, llamas do prefer and feed on the species that develop "hidden" or facilitated by *Festuca orthophylla*, but have lower nitrogen concentration than the open growing, inter-tussock species. The emergence of inter- and intra-tussock herb-species coincides with the camelid's birth season, hence these species may still be very important because they can provide protein, sugar and starch supplements rapidly metabolized and available as fat and milk. We also studied the seed bank size and seed quality as well as seed and dust deposition in response to wind. Both, the quantity and quality of seeds in the soil was found to be rather low, too low to allow fast regeneration after disturbances. Overgrazing and the use of fire as land management practice are causing a reduction in vegetation cover, which in turn increases the wind erosion and diminishes the productivity and plant species diversity in this area.

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Assessment the state of conservation of Mountain Ecosystem in Sierra Nevada-LTER site in a global change context

We present a concise and synthetic evaluation of the conservation status of mountain ecosystems in Sierra Nevada, a natural protected area located in southern Spain. This area is considered one of the most important biodiversity hotspots in the Mediterranean basin. To characterize the state of the main ecosystems we have used different workflows that include standardization, integration, processing and analysis of information generated within

of Sierra Nevada Global Change Observatory, a long term monitoring programme to assess the effects of global change in this LTER site. We used biotic and abiotic variables as well as processes involved in ecosystem dynamics. We performed a spatial and temporal analysis of key biophysical variables under three different scenarios representing past, present and future conditions and emphasizing the main factors that have conditioned the actual natural status of each ecosystem. The main ecosystem services provided by each ecosystem type were identified following the Millennium Ecosystem Assessment. We show some case studies that demonstrate adaptive management actions in relation to each ecosystem type. With this approach we have provided useful information for future management actions of natural resources in this protected area.

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A conservation index for evaluating Alpine species-rich *Nardus* grassland (code 6230, Natura 2000)

Many of the indices usually used to analyze biodiversity apply only to counts of individuals. They very often lack meaning when applied to the whole community, as an evolving system (M. O. Hill, 1973). A method for calculating the conservation level of mountain plant community types was considered. The index (Floristic Quality Index -FQI) was calculated for two Alpine species-rich *Nardus* grasslands (code 6230, Natura 2000) sited on Monte Grappa, NE Italy: 70 sample areas of 100 m² differing in *Nardus* percentage cover were analyzed. The FQI was compared with number of species and Shannon Index in order to evaluate its capacity to explain cenosis biodiversity. According to Oldham et al., 1995, the FQI takes into account a coefficient of conservatism and phytosociology,. This study underlined a high conservation capacity when typical *Nardus* grassland species cover amounts to 20-50%. FQI displayed a unimodal pattern passing from zero to 80% *Nardus* grassland species cover, with a peak value increase of 12%. According to this trend, species-rich *Nardus* grassland (code 6230, Natura 2000) could be considered well-preserved when the cover value of typical *Nardus* grassland species is between 20 and 50%. The FQI defines biodiversity in terms of a measurable indicator. It has a good capacity to describe the evolution and degradation of habitats to be retained.

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Catalogue of forest invaders of the Kashmir Himalaya

Mountain ecosystems throughout the world are undoubtedly facing an alarming and accelerating risk of plant invasions. Despite huge ecological and economic stakes involved with invasions, management of plant invasions in mountain environments has remained an international challenge. At present, most alien biota in these fragile ecosystems remain confined to lower elevations, but will most likely ascend to higher elevations with increasing human disturbance and global climate change. In developed countries, such invasions occur due to increasing urbanization, tourism, globalization of ornamentals, and climate change. Additionally, in developing countries, agriculturally driven land-use changes are occurring at an accelerated rate because of increasing human populations. Such anthropogenic influences along with wanton axing of virgin forests, promote biological invasions throughout world and the Kashmir Himalaya, located in the northwestern extreme of the Himalayan biodiversity hotspot, is no exception. Recognizing that inventory of alien species is an important resource for managers of any biodiversity reserve and should be a

priority for mountain areas which face a growing threat from invasions, a catalogue of the worst forest invaders of the Kashmir Himalaya has been prepared. This shall not only give researchers and managers the unique opportunity to respond in time to the emerging threat of plant invasions in the area, but will also help us to understand the basics of invasion ecology.

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Alpine marsh meadows of Indian Trans-Himalaya: Floristic structure, species diversity and aspects of conservation

The Indian Trans-Himalaya, located in the rain shadow zone of Great Himalayan massif adjacent to Tibetan plateau, represents a distinct cold arid ecosystem characterized by sparse vegetation cover, relatively low species diversity and specialized growth forms adapted to extreme environmental conditions. The major physiognomic classes of vegetation in this region include desert steppe, scrub steppe, riverine scrub, marsh meadows and alpine fell-fields dominated by cushionoid growth forms. Of the various categories, alpine marsh meadows are of high ecological and conservation significance. These meadows occupy less than 2% of geographical area in the entire Trans-Himalaya yet they harbor more than 30% vascular plant species reported from the region. These meadows serve as critical habitat for a large number of wild mammals and birds. In addition, they support a considerable biomass of domestic livestock including yak, sheep, goat, horse, donkey, cow, and dzo (hybrid between yak and cow) especially during autumn and winter. Excessive use of marsh meadows for livestock grazing, tourism and diversion of water for reclamation of land adjacent to marsh meadows are the major threats. We conducted a rapid survey of alpine marsh meadows in north-western parts of Indian Trans-Himalaya especially in Zaskar ranges and Changthang plateau of Ladakh, Jammu & Kashmir. The major objectives of the study were to assess the floristic structure, plant species diversity and use of marsh meadows by various species of wild mammals and birds. The patterns of species diversity, unique features and conservation implications are presented.

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Variation in diversity along environmental gradients in eutrophic mountain vegetation in Southern Norway

The aim of this study was to estimate the variation in vascular plant and bryophyte species diversity between vegetation plots sampled from different mountain communities, and to identify which of the sampled environmental factors had the highest explanatory power for this variation. In total, 117 quadrates (4m²) were selected by a stratified random sampling procedure (stands including eutrophic species) to represent major gradients in snow layer duration and altitude. In addition the following environmental variables were sampled: topography variables, soil variables and cover of different plant life-forms. Vascular plant species richness varied from 4 to 41 with a mean of 21.1 ±7.6, and bryophyte species richness varied from 2 to 25 with a mean of 11.1 ±5.1. Bryophyte and vascular plant species richness were weakly positively correlated ($r = 0.21$, $p < 0.05$). Significant unimodal

responses were found between vascular species richness and the cumulative cover of different plant life-form groups ($p < 0.0001$). Species richness showed significant polynomial response to snow layer duration, and soil variables (amount of calcium, magnesium, potassium, amount of soil water, loss-on-ignition, and amount of carbon). Richness was not significantly related to the variation in altitude, slope degree, pH and amount of phosphorous. The variation in bryophyte species richness was poorly explained by the studied environmental variables. Highest explanatory power was found by a polynomial relationship between bryophyte species richness and total bryophyte cover ($p < 0.0001$). Bryophyte richness increased with altitude ($p < 0.0031$) and with increasing pH ($p < 0.0224$).

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The origin and diversification of the Alpine Flora

Phylogenetic reconstruction is a useful tool to study the origin of biodiversity, the relationships between species, the functional relationships; moreover, the phylogenetic diversity indices are credible and useful tools to measure biodiversity. However, despite its utility, there are still very few comprehensive phylogenies for an entire biogeographic area. We present here the first extensive phylogeny of Alpine Flora (Alpine Arc), resolved to the genus level, which has been obtained with a mixed approach of supertree and supermatrix methodologies, using DNA sequences extracted from the database Genbank, including 98.2% of the genera of the Alpine Flora. This phylogeny has allowed us to study the patterns of diversification of this flora, the relationships between diversification rates and paleoclimatic and geological events, and analyse temporal changes on diversification rates in relation to the evolution of functional traits and niche.

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Plant functional diversity decreases with abiotic stress in alpine ecosystems

Functional diversity, the extent of functional differences among species in a community, is an important determinant of ecosystem processes. In alpine ecosystems predicted climate change will be disproportionately strong and will have effects on abiotic stress factors. However, knowledge about variation of functional diversity under differing abiotic stress conditions is sparse. The aim of this study was to test the relationship between abiotic stress and plant functional diversity in alpine ecosystems. We have chosen nine contrasting plant communities along an altitudinal gradient from 2200 to 3000 m a.s.l. For each community we calculated a functional diversity index based on 16 functional plant traits. To quantify abiotic stress we developed a stress index based on micrometeorological and edaphic variables. We could show that (i) there are considerable differences in functional diversity of alpine plant communities, (ii) there is a strong negative correlation between functional diversity and abiotic stress and (iii) functional diversity significantly decreases with altitude. Thus, altitude can be used as an easily measurable surrogate for causal factors determining functional diversity. This study highlights general patterns about the relationship between functional diversity of alpine plant communities and recent abiotic stress conditions and allows predicting some potential modifications of functional diversity under future climate. It points out that functional diversity of alpine plant communities is

stress-limited. Under the assumption that future climate changes will result in a reduction of stress conditions, functional diversity of alpine ecosystems will most likely increase.

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Subalpine ecosystems of the Swiss Jura Mountains in a changing climate

Subalpine silvopastoral systems are influenced by human activities, combining long-term timber and fuel-wood production with the annual production of forage for livestock. Vegetation response to climatic change may vary with the level of human impact and under different forms of management. Land use activities may either accelerate or moderate vegetation response to climatic changes. Climatic changes resulting from anthropogenic activities over the passed century are repeatedly reported to alter the functioning of ecosystems worldwide, and especially those in cold biomes. Little is known, however, about the interaction between climate change and man induced land use change, such as in the case of extensification or intensification of historically sustainable subalpine wooded pastures. We set up a full-factorial design with several levels of climate warming and reduced precipitation intensities interacting with different land use practices typical for the Swiss Jura Mountains (pastures, wood-pastures, and forests). To this end, mesocosms of soil turfs with characteristic vegetation types were transplanted to lower altitudes along a climatic gradient ranging from the Jura Mountains to Lake Geneva. This allows studying the resilience of subalpine ecosystems to climate change in terms of capacity for carbon storage, forage biomass productivity, tree seedlings establishment and overall above- and below-ground biodiversity. First results of this ongoing project will be presented.

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Founding the LTSER platform Alps: reactivating long-term data sets to monitor impacts of land-use and climate changes on mountain biodiversity

The creation of the platform for long-term socio-ecological research in the French Alps (LTSER Alps) provided a challenging opportunity to reactivate unique data sets on vegetation composition and land use spanning over a period of more than 40 years. The main objective of the LTSER platform Alps which is research on coupled dynamics of alpine ecosystems, their uses and the climate is constructed around topics on which all partners have already worked for several years. Moreover, a great amount of data has already been produced but is not yet available to all partners. Through the organisation of the LTSER platform, collaborations already envisaged which remained for many years in the state of drafts (e.g. projects on transformation of the coupling of functioning of farm holdings and mountain summering pastures and on mutations of alpine tourism in the face of climate change) were finally fostered and formalised. Other long-term data sets initially recorded to describe the status quo of diverse alpine ecosystems are now used to respond to urgent question on the impact of climate change and more precisely of drought on the mountain biodiversity. Moreover, the creation of the LTSER platform is facilitating the emergence of new approaches. This finally led to a new project in which the process of construction of the LTSER platform is becoming itself subject of a study by sociologists.

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Phenotypic plasticity of functional traits in mountain grasslands: consequences for biodiversity

How do species adapt to changing environments, and what is the consequence for biodiversity? Adaptation to a new environment proceeds from two independent (but not exclusive) mechanisms: genetic variability (different genotypes are adapted to different environment and natural selection sorts out the most adequate genotypes) or phenotypic plasticity (a single genotype produces different phenotypes in different environments). Our aim was to determine the importance of genetic variability and phenotypic plasticity in the response of alpine grassland species to environmental change. We hypothesized that, because of their long life span and wind pollination, phenotypic plasticity would be more important. In two separate experiments studying the effect of variable levels of nutrients, water or light on different genotypes of *Dactylis glomerata* and *Festuca paniculata*, we found that phenotypic plasticity was indeed the main source of variation of functional traits (such as SLA, LDMC, LNC and biomass) and that genetic variability was limited. This means that most of the variability of functional traits observed in the field is due to phenotypic plasticity while only little genetic differentiation occurs. Moreover, environmental changes will thus lead to a change in functional diversity, with little change in specific and genetic diversities.

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The incidence of egg parasitoids on the population dynamics of a forest pest, the pine processionary moth *Thaumetopoea pityocampa*, along an elevational gradient

The pine processionary moth (PPM, *Thaumetopoea pityocampa*, Lepidoptera: Notodontidae) is one of the main forest pests in circummediterranean pine woodlands. In part of its distribution area, PPM shows a cyclic dynamics, alternating severe defoliations with years of very low incidence. The drivers of this cyclic dynamics, either abiotic, biotic, or both, are not clearly identified, but a relevant role is usually attributed to the egg parasitoids that attack the PPM egg batches. In this work, we evaluate the incidence of the egg parasitoids of PPM in an elevational gradient (0-2000 m) in the mountains of the Sierra Nevada National Park (SE Spain). During two consecutive years (2008-2009) we collected PPM egg batches once larvae hatched, in nine localities differing in altitude, exposure, and main pine species. Egg batches were examined in laboratory and the incidence of parasitoids was recorded. Our results show a clear decrease of incidence of parasitoids as altitude increases. Since the pine species living at higher altitudes are more susceptible to the attack of PPM, its progression in altitude due to the climatic change represents a severe threat for these pine woodlands that parasitoids do not seem to be able to control.

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Management Oriented Multidisciplinary Research and Monitoring in the Great Himalayan National Park Conservation Area: Sustainable Livelihoods Based Approach

The Great Himalayan National Park Conservation Area (GHNPCA) covering an area of 1,171 sq km makes a significant protected area site for the conservation of biodiversity in the north western Himalayan biogeographic zone. The GHNPCA received substantial international funding for improved PA management adopting sustainable livelihoods as a strategy. The project had an integral component of multidisciplinary research and monitoring. Prior to this initiative very little research information was available for this priority CA area. The project supported integrated multidisciplinary research dealing with varied themes viz. landuse / landcover assessment, plant and animal diversity, resource dependence and socio-economics, transhumance, eco-development and ecotourism. The project was launched after participation by all concerned in a planning workshop. Multidisciplinary research resulted into resource inventories; holistic understanding of floral and faunal resources, conservation threats, development of a GIS based spatial database and approaches to be used for management of GHNPCA. The research output included a six volumes report containing 30 technical reports dealing with physical, biological, ecological, socioeconomic and management aspects. Research findings have been extensively used in the preparation of management plan for GHNPCA. Integrated research efforts allowed development of a long term ecological monitoring (LTEM) programme using select taxa for monitoring. The paper highlights accomplishment, constraints, gaps and lessons learned in the organization and conduct of major research.

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How vulnerable are mountain landscapes and their services to invasion by alien plant species?

Alien species invasions threaten ecosystems worldwide and are considered hazardous for native biodiversity. Their consequences are not well understood, but it is assumed that they depend on functional attributes of invaders and differ among ecosystem and ecosystem services. Understanding and anticipating biological invasions can focus either on traits that favour species invasiveness or on features of the receiving communities, habitats or landscapes that promote their invasibility. Recently, we modelled invasibility at the regional scale in Northwest Portugal, found that some landscape types are more sensitive than others and identified critical drivers of alien plant richness.

Based on these findings, we now assess spatial and ecological patterns of alien invasions in fragmented landscapes along an elevation gradient, using an ensemble modelling approach. We identify common responses (“rules”) among altitude belts, and project these to high-elevation areas that are currently scarcely invaded. Specifically, we address the following questions: 1) How do invasions affect different types of ecosystem services, namely supporting, regulating and provisioning services? 2) Are landscape susceptibility and vulnerability to invasion related to particular functional groups / plant strategies? 3) How do climate and/or land-use changes influence landscape invasibility? We provide evidence on the location and ecological features of the most vulnerable areas, and discuss how mountain landscapes should be managed in order to prevent negative impacts on ecosystems and their services. This study was financially supported by FCT (Portuguese Science Foundation) through PhD grant SFRH/BD/40668/2007 to J. Vicente.

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Post-fire recolonization of plants in the central-alpine Valais, Switzerland

Climate change will result in a shift of environmental conditions among which effects of increased drought are likely to aggravate the risk of forest fires in regions where forests are not adapted to repeated fire. Surprisingly little is known about factors influencing re-colonisation speed and the balance of plant species richness. In 2003, a fire destroyed 300 ha of forest along an elevational gradient from 900 to 2100 m a.s.l (treeline) in central-Alpine Valais (Switzerland). The burn traversed belts of Scotch pine, Norway Spruce and European Larch forest. We examined early succession of plant species assemblages with respect to richness and its explanatory variables on permanently installed sample plots (n=150, 200 m² each) along a rectangular grid with 125 m mesh-size. From 2004 to 2007, species composition was assessed annually. Species richness evolved rapidly, exceeding numbers of adjacent undamaged forests already after three years. Numbers were highest towards higher altitudes and in proximity to forest edges. Fire intensity was only relevant in the first and second year after the fire. In conclusion, post-fire re-colonisation is quick whether the forests are fire-adapted or not. Post-fire effects on species richness are therefore positively valuated.