



# FIRST MOUNTFOR PhD - DAY

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# ORAL PRESENTATIONS

**Francesco Giammarchi[1], Paolo Cherubini[2], Enno Uhl[3], Hans Pretzsch[3], Giustino Tonon[1,4]**

**EFFECTS OF CLIMATE CHANGE ON FOREST PRODUCTIVITY OF TWO ALPINE NORWAY SPRUCE CHRONOSEQUENCES**

An increase in forest productivity has been widely reported in Europe and several methodologies have been proposed to study it. However, knowledge on its causal relationships with climate change is scarce, though this is crucial to understand the mitigation potential of forests and to adapt forest management according to changing forest dynamics. In this framework, two Norway spruce chronosequences located in Northern Italy and in Southern Germany were studied, hypothesizing an increase in forest productivity of younger stands in response to climate change. A retrospective approach consisting of stem analysis of dominant trees was adopted, as it allows to reconstruct past growth trends and their relation with environmental drivers while avoiding bias introduced by age-related factors. Stem analysis was performed on dominant trees, dominant height being a more reliable proxy of forest productivity than radial growth. Obtained data were modelled and age-height relationship compared among different aged stands. Height increment temporal trends were also measured and compared. A significant increase in growth potential of younger stands was detected in both sites as proved by height-age curves. A shift of trees height increments was also found. Furthermore, the role of several environmental drivers, such as atmospheric $CO_2$ levels, temperature and precipitation regimes and nitrogen depositions in determining the forest productivity increase was investigated. We applied a multi-stable isotope analysis, including $\delta^{13}C$, $\delta^{18}O$ and $\delta^{15}N$. $\delta^{13}C$ inferred iWUE (intrinsic water-use efficiency) trends were assessed and their correlation with climate factors evaluated. Results point out a significant increase of iWUE in both sites. Stable isotope data suggest that this was mainly triggered by increased photosynthetic capacity rather than by a reduction of stomatal conductance, even though in older stands size-related hydraulic limitations could have partly triggered the increase. Moreover, iWUE was strongly correlated with CO2 and temperature, not with precipitation. Nitrogen stable isotope data instead did not show any clear trend. Overall, the observed increase in forest productivity appeared to be linked to a $CO_2$ related increase in iWUE and to higher temperatures, that could have also extended the growing season, whereas water availability was not a crucial factor. In addition, increasing historical deposition values do not allow us to exclude this factor as a possible driver in the two studied sites, and suggest that further knowledge on this issue should be acquired.

**Keywords:** forest productivity, climate change, chronosequence, stable isotopes, water-use efficiency, Norway spruce

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## DROUGHT CONDITIONS IN THE ALPINE FOREST OF SOUTH TYROL – ASSESSING EVOLUTION OF VEGETATION STATUS WITH MODIS DERIVED NDVI AND NDII TIME SERIES

Observed nowadays global changes in temperature and precipitation patterns are especially concerning for the Alps. The overall meteorological trends result in increasing frequency and severity of the occurring drought events, which become a serious peril to the well-being and of the alpine forest ecosystems. Through our analyses performed for the area of South Tyrol, we addressed the arising need for medium to large scale long-term drought related vegetation stress monitoring in the complex and diverse environment of the alpine forest. Firstly, the real drought conditions in the region were estimated through the on-station based 2001-2012 time series of scPDSI (self-calibrated Palmer Drought Severity Index). Next, related stress induced vegetation variability was obtained through the EOF (Empirical Orthogonal Functions) analyses performed on 16-day, 250 m resolution MODIS (Moderate-Resolution Imaging Spectroradiometer) derived NDVI (Normalized Difference Vegetation Index) and NDII (Normalized Difference Infrared Index) time series of 2001-2012. Areas identified as affected by drought conditions were subsequently further scrutinized with respect to the yearly phenological indicators of an approximation of the Gross Primary Productivity, Cyclic Fraction, Season Length, Season Begin Day, as well as, averaged high-season values of NDVI and NDII. Obtained results allowed us to identify subtle drought footprint in the complex and diverse environment of the alpine forest, and provided an additional insight into the local phenology development. Recognized stress related variability revealed two types of vegetation response: an abrupt decline triggered by the onset of drought conditions and followed by vegetation recovery, as well as, levelled deteriorated forest vitality observed over the whole period of water scarcity conditions. Moreover, phenological indicators inspected for the drought affected sites showed statistically significant trends towards an earlier start of the season and increasing CF productivity. Further investigation of detailed environmental information provided a comprehensive understanding of drought affected regions with respect to their location, as well as, species composition. This additional insight allowed us to specify forest stands potentially prone to the future drought stress conditions. Applied synergy between meteorological and remote sensed time series provided a complex and detailed insight into the subtle drought impact on the alpine forest. Obtained results not only confirmed high utility of the EOF approach for the NDVI and NDII time series analyses, but also captured the long-term variability being in line with the state of the art of the climate change models available for the Alps.

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## A SIMULATION STUDY FOR EVALUATING ADAPTIVE MANAGEMENT IN SLOVENIAN SILVER FIR-EUROPEAN BEECH MOUNTAIN FORESTS UNDER CLIMATE CHANGE

Evaluating Business-As-Usual management strategies (BAU) under future climate change is essential to examine if they are able to maintain the provisioning of multiple forest ecosystem services (ES), and if adaptive management is required to counteract adverse effects of climate change. In this context, forest succession models are valuable to assess the sensitivity of ES to climate change under BAU. We enhanced and evaluated a climate-sensitive forest succession model (ForClim) across the Alps, and implemented new algorithms for capturing specific harvesting regimes and assessing ES. The model was subsequently applied according to specific management prescriptions and different climate change scenarios in several representative Silver fir-European beech stands in the Dinaric Alps (Slovenia). These forests have a long tradition regarding small-scale system management, and they were managed for the last 200 years to promote conifers due to their higher productivity and economic value. Simulation results for a rotation period, i.e. ca. 130-140 years, reveal that the most important ES at the stand scale (timber production) would be maintained under BAU, but climate change will have negative effects on conifers regeneration. This was especially strong for Silver fir due to its sensitivity to both browsing and increasing winter temperatures, while European beech demonstrated vigorous growth and abundant regeneration, as confirmed by measured data. At the end of the rotation period, most of the simulated stands showed a dominance of European beech, favoured by the decline of Silver fir and Spruce due to the combination of BAU and climate change. Our results suggest that foresters should reconsider their BAU management and adapt their management strategies if they wish to maintain species diversity and preserve Silver Fir in these forests. A set of simulations under adaptive management are proposed as a suitable alternative to current forest planning**.**

**Keywords**: mountain forests, climate change, forest gap model, Business-As-Usual management, Adaptive management

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**PROXIMAL SENSING OF $CO_2$ UPTAKE IN TERRESTRIAL ECOSYSTEMS**

Linking remote sensing with carbon fluxes and vegetation biophysical parameters is critical to exploit spatial and temporal extensive information useful for validating model simulations at different scales. Proximal sensing is fundamental to quantify and understand the seasonal dynamics of ecosystems and to upscale the observations carried out at the ground level. In this study, we present chosen activities of an ongoing international PhD project granted by Fondazione Edmund Mach, Italy. Principal aim of this research project is the investigation of the relationship between $CO_2$ uptake from terrestrial ecosystems (measured by the eddy covariance technique) with ground multi- and hyperspectral spectral observations, as well as quantitative estimation of vegetation biophysical variables from proximal sensing. Within this study we present in particular:

1) the potential of a commercially available proximal sensing system – based on a 16-band multispectral sensor – for monitoring mean midday gross ecosystem production (GEPm) in a subalpine grassland of the Italian Alps equipped with an eddy covariance flux tower

2) a new tower-based hyperspectral system designed for the estimation of $CO_2$ fluxes and biophysical parameters (fAPAR, total chlorophyll content, green herbage ratio) in a subalpine grassland ecosystem

3) the ability of ground spectral signal for capturing the temporal changes in the green herbage ratio of the grassland ecosystem (the percentage of green biomass with respect to the total phytomass) and for determining the phenology delay inside the ski run in the grassland ecosystem as regards to the areas not used for sports

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**METHODS AND MAPPING TOOLS FOR FOREST ECOSYSTEM SERVICES ASSESSMENT: A CASE STUDY AT REGIONAL LEVEL IN ITALY**

Forests are one of the most important providers of ecosystem services on Earth. Globally, forest ecosystems (i) provide timber and other non-timber products to local communities, (ii) mitigate climate changes, (iii) conserve natural habitats integrity and biodiversity, (iv) protect human settlements against erosion and other abiotic hazards, and (v) preserve spiritual and cultural heritages. In Italy, forests sustain local economies in many fragile environments, such as mountain and countryside ones. However, forest management is increasingly called to face with future climate uncertainties, anthropogenic impacts (i.e. land use changes), and other disturbances (i.e. fires), while maintaining health, resistance and stability of forest ecosystems. Generally, the aim of this study is to propose alternative supporting tools for improving forest services provision in both local and broader management and planning contexts. Accordingly, two alternative methods for assessing and mapping forest ecosystem services – by upscaling the approaches from landscape (process-based) to regional level (scenario-based) – are showed and discussed. The first approach is based on the implementation of a semi-automatic algorithm to map forest ecosystem functions according to the related ecologic features, such as stand parameters (basal area, tree height, tree species composition) and environmental characteristics (aspect, slope, elevation). By the second approach, a large scale scenario model (i.e. InVEST) is implemented at regional scale to map future-oriented land uses and assess forest ecosystem services, according to alternative forest management scenarios. Broadly, results demonstrate that: (i) the integration of forest stand parameters and environmental characteristics provide useful estimations of forest landscape potentialities to provide goods and services; (ii) the ecosystem services mapping reveals that the tradeoffs between services are largely influenced by human-induced interventions, in terms of frequency and intensity; (iii) if integrated, the proposed approaches can be used in other contexts to systematically improve the assessment of ecosystem services from forests, thus enhancing forest sustainability and resilience in forest management and planning. At conclusion, the assessment and mapping of forest ecosystem services at different scales can be suitable to support decision makers towards improving the stability of forests in fragile environments.

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## CARBON SEQUESTRATION AND FERTILITY AFTER CENTENNIAL TIME SCALE INCORPORATION OF CHARCOAL INTO SOIL

The addition of pyrogenic carbon (C) in the soil is considered to be a strategy for C sequestration. The PhD project investigates the long term effects of charcoal addition on C sequestration and soil physico-chemical properties by studying a series of abandoned charcoal hearths in the Eastern Alps of Italy where charcoal was produced in 1858. This natural setting can be considered to be an analogue of an experimental setting with replications. Carbon sequestration was assessed indirectly by comparing the amount of pyrogenic C present in the hearths (23.3 ± 4.7 kg C $m^{-2}$) with the estimated amount of charcoal that was left on the soil after the carbonization process (29.3 ± 5.1 kg C $m^{-2}$). The latter value could be estimated thanks to historical references, measurements performed on a modern charcoal hearth, laboratory tests, ortophotos and LiDAR data. After taking into account uncertainty associated with parameters' estimation, we concluded that 80 ± 21% of the C added to the soil more than 150 years ago can still be found there and that the overall Mean Residence Time of charcoal is 650 ± 139 years, proving that charcoal is an effective way to sequester C into soil. An overall change in the physical properties (hydrophobicity and bulk density) of charcoal hearth soils was observed compared to control adjacent soils without charcoal, as well as an accumulation of nutrients. The impact of these properties on the plant growth is investigated at the moment.

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## CLIMATE CHANGES EFFECT ON MARGINAL POPULATION UNDER MEDITERRANEAN ENVIRONMENT: THE CASE OF *PINUS NIGRA*

*Pinus nigra ssp. nigra* var. italica is naturally distributed only in Abruzzo Region around the small town of Villetta Barrea as an altitudinally marginal and geographically isolated population. Marginal and Peripheral (MaP) forest population, because of its nature of small group of trees living at the edges of species' ecological niche, are a very important resource to be investigated and preserved. Very important are their genetic structure, their adaptability to particular local climate conditions and ecological dynamics, which could play a key role to understand adaptability of forest ecosystems. Anyway, many of them are located in Mediterranean area, a very important basin of biodiversity and they could seriously be endangered by climate change effects. With the aim to study the more likely interactions between the MaP and the effects of Global change, dendrochronology was used to assess the climatic tolerance of the species. From the population of Villetta Barrea, thirty cores were sampled from straight, dominant and old trees, with and increment borer and measured with LINTAB6. Then, after crossdating and standardization, general correlation function and moving correlation functions with a 30 years windows were performed between tree-ring series and climate data. Averaged annual minimum and maximum temperature and total annual precipitation were derived from ClimateEU database and, to consider the whole year, October of the year before the ring formation (t-1) and up to September of the reference year (t) were used as climate input data. Using general correlation function for the whole considered period (1903-2009) black pine demonstrated to be more sensible to temperature factors than precipitations. Positive correlation was found with minimum and maximum temperatures of previous winter (December, February and March) whereas negative correlation was detected with minimum temperatures of current July and September and maximum temperatures of May. Subsequently, moving correlation functions confirmed that, in the recent decades, the population has react mainly to changes in temperatures, especially minimum temperatures of previous October, and maximum of previous December and September. The increased temperature will be one of the major effects of global change and will probably be stronger at high elevations than elsewhere. For that reason, Black pine of Villetta Barrea could need specific in situ adaptive management. At the same time, a selective collection of the seeds and breeding nursery activity will certainly help to preserve the genetic wealth of the MaP of Abruzzo.

**Key Words**: *Pinus nigra*; dendrochronology; climate change; Mediterranean area; Forest Genetic Resources; Marginal and peripheral forest populations

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## BIOENERGY PRODUCTION FROM ORCHARD WOODY RESIDUES – A LCA CASE STUDY IN SOUTH TYROL (N ITALY)

In Italy, the use of biomass for energetic purposes has increased enormously over the past years, promoted by international and national policies enhancing the production of energy from renewable sources. The alpine Autonomous Province of Bozen-Bolzano (South Tyrol, N Italy) is characterized by intensive apple tree cultivation. Currently, about 37,6 % of the biomass used in the province for production of bioenergy is imported from inter-regional trading, and this share is expected to further increase in the near future owing to growing renewable energy needs. The residual biomass harvestable from the local agronomic sector based on the cultivation of apple (*Malus domestica*) therefore stands out as a promising option able to supply relatively cheap bioenergy feedstock. Orchards require annual and cycling operations (i.e. annual pruning and tree removals at the end of the fruit producing cycle) and produce woody biomass materials such as branches, trunks and rootstocks (apple woody residues, AWRs) on a regular basis, at approximately 46,500 t per year. Pruning residues are, up to now, left on the field for decomposition, whereas the removed plants are used in house-heating facilities or sent landfills or to compost plants.

The goal of this study is to assess the environmental sustainability of using woody agricultural residues as bioenergy feedstock in South Tyrol. We perform a life cycle assessment (LCA) of a hypothetical bioenergy system based on woody residues from apple orchards cultivated in this region. The system boundaries include activities on the field, e.g., the harvesting and chipping of the woody biomass, transport of the feedstock to the energy plant, conversion into heat and power in a combustion plant with an electrical capacity of 1MWel (megawatts electricity). The inventory dataset relies on real field data for the operations of biomass harvesting, chipping and transport, and for the quantification of the amount of available woody biomass. The functional unit used is the amount of bioelectricity produced in 1 year. Different allocation procedures are applied. We quantify the impact in different environmental impact categories like climate change, acidification, fossil depletion and others. The environmental impact from conventional fossil fuel systems are used for comparison. Our results show that production of bioenergy from woody agricultural residues generally performs a lower environmental impact than the reference systems and can be considered more sustainable, although some tradeoffs exist.

**Key Words**: bioenergy, LCA, CHP, agricultural residues, sustainability

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**Gianluca Grilli[1,2] Marco Ciolli[1], Giulia Garegnani[2], Alessandro Paletto[3]**

## A GIS-BASED DECISION SUPPORT SYSTEM FOR BALANCING RENEWABLE ENERGY PRODUCTION AND NATURE CONSERVATION

The development of renewable energy (RE) is going to increase in the next years. In particular, European countries are particularly committed in enhancing their share of RE production, in order to achieve the targets established by the European Union's climate and energy package (Directive 2009/28/EC). This situation will be extremely beneficial for reducing the dependence on oil fuel but, on the other hand, it will increase the pressure on the ecosystems and the goods and services they provide. In particular, mountain regions may be severely depleted, because of their fragile habitats. Moreover, any decision of natural resources exploitation may be a source of conflict with the local population, that are directly affected by the projects of development. Within this context, it is fundamental to take into consideration the effect of any project on the environment, in order to reduce as much as possible the anthropic pressure on the ecosystems. At the same time, it is also important to involve the stakeholders in the decision-making process, so that each group of interest may express their needs before the decisions are taken. Starting from these considerations, the present phd project is aimed at creating a spatially explicit GIS-based decision support system (DSS) for the renewable energy production. The energy sources considered are solar photovoltaic, hydro-power, wind power and biomass energy with a specific focus on forest biomass. For each energy source, the DSS will be able to take into consideration technical, economic and ecological constrains occurring while planning RE exploitation. Such an analysis shows the most suitable sites where the withdrawal of RE is effective in conserving the multi-functionality of the mountain ecosystems. The procedure will be tested in different case studies in the Alpine space: Triglav National Park (Slovenia), Parco Naturale delle Alpi Marittime and Mis and Maé Valley (Italy), Leiblachtal (Austria). Moreover, stakeholders will be involved in the decision-making. At the beginning, a stakeholder analysis is carried out in each pilot area, so that the most important groups of interest can be identified. Then, the DSS will produce several scenarios of RE development, so that the identified stakeholders have the possibility to undertake a participatory approach, in which they can reach a shared solution for the future RE development. The final result should lead to a solution of RE development, able to supply the local population with the energy they need and, at the same time, effective in maintaining the health of the mountain ecosystems.

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**BIOMASS-BASED ENERGY AT LOCAL SCALE: AN AHP-SWOT ANALYSIS**

As a result of increasing issues related to using fossil fuel energy, interest in biomass-based energy development has grown in the recent decades on national and regional level. Bioenergy is seen as important strategy in order to fulfill energy security mandates and reduce greenhouse gas (GHG) emissions in the near future, especially when adjusted to include its primary stakeholders' opinions and acceptance. This case study provides an analysis of stakeholder perception of biomass-based energy development as a part of the forest-wood-energy chain in an Alpine valley (Sarentino Valley, South Tyrol, Italy). A combined SWOT (Strength, Weakness, Opportunities, and Threats) analysis and AHP (Analytical Hierarchy Process) framework for this purpose was used. Outcomes of a semistructured questionnaire administered to 30 external stakeholders (NGO and associations, Public administrations and Academia) and 20 forest-wood chain actors (forest and farm owners, forest enterprises, sawmills, and district heating plants) were statistically compared. The results show interesting differences between the groups of stakeholders. In particular, the representatives of the academia perceived the use of wood residues from sawmills for bioenergy generation - in addition of the use of forest residues - as an important opportunity for energy self-sufficiency of the valley. Public administrations noted that the use of local wood for bioenergy generation was major strength factor. Instead, forest-wood chain actors pointed out the possibility of additional income for the private forest owners as strength of this biomass value chain. NGO members individuated the increasing biomass extraction and negative environmental impacts due to possible upgrading of the district heating systems (into co-generation) as potential threat. Overall, all stakeholder groups are in favour of forest biomass-based energy presence and further development in Sarentino Valley. SWOT-AHP methodology could be useful in the development of potential bioenergy policy and implementation of participatory decision making process in forest-wood-energy supply chain.

**Keywords**: bioenergy, forest-wood chain; sustainability; SWOT analysis, Analytic Hierarchy Process (AHP); Sarentino valley (Italy)

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## FOREST STRUCTURE, INDICATORS OF NATURALNESS AND SAPROXYLIC FAUNA: A CASE STUDY IN THE "ABETI SOPRANI" SILVER FIR FOREST (MOLISE, ITALY).

The conservation of biological diversity has become one of the important goals of managing forests in an ecologically sustainable way. The relationships between potential forest structural indicators and biodiversity are not well established. Carefully designed studies are required to test relationships between the presence and abundance of potential indicators and the maintenance of critical ecosystem processes in forests. In this study, forest structure, deadwood amounts and microhabitats occurrence were considered indicators for conservation issues at stand level. We described the stand structural attributes, deadwood characteristics and microhabitats occurrence, evaluating their role on the abundance, distribution and diversity of saproxylic beetle fauna. The study was realized in Central Apennines (Italy), in a silver fir stand that has been unmanaged since several decades. A systematic aligned sampling method was realized on 240 ha, examining 50 plots of 530 square meters each. Data were collected to assess forest structural parameters and deadwood volumes, and the relative abundance of different deadwood components in decay classes. Saproxylic beetles were sampled using window flight traps and emergence traps, with the aim of obtaining data on abundance and species richness at plot level and dead wood level. The heterogeneity in types and frequency of microhabitats, and the link between structure-based indicators and saproxylic species were also analyzed. Geostatistical analyses were conducted in order to highlight the spatial variability of the parameters investigated and the beetle pattern distributions. Results showed how the saproxylic community is influenced by the deadwood amounts, size and decay, but also by the forest complexity and microhabitats presence. Gaps dynamics and natural disturbances had effects on deadwood amounts and microhabitat abundances in this unmanaged forest stand, that were significantly higher than in managed and structurally simplified forest stands. With the aim of describing the complex saproxylic ecological network, the species of beetles were classified according to the type of interactions with wood and other insects and to trophic guilds. The results implied the importance of deadwood traits and microhabitat amounts as monitoring tools for assessing and forest attributes for preserving biodiversity in these forests. New indicators, such as microhabitats, should be implemented in the traditional forest inventory approaches as a measure of nature conservation. Finally, In order to preserve biodiversity, forest management should reproduce certain environmental characteristics of unmanaged forest in managed forests through the conservation of diverse stand structure and species composition, and increasing deadwood amounts.

**Keywords**: *Abies alba*, Forest structural features, Deadwood, Microhabitat, Saproxylics

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## SECONDARY METABOLISM IN MEDITERRANEAN EVERGREEN SPECIES WITH HIGH TOLERANCE TO OSMOTIC STRESS: WHAT'S THE ROLE FOR THESE PLANTS AS BIOFACTORIES?

Mediterranean plants face with excess light stress on daily and seasonal basis. Photooxidative stress is particularly severe during the summer season when plants also suffer from high temperature and drought stress. Plants possess an extraordinary number of 'antioxidant defenses' that must cooperate to maintain a ROS level for efficient signaling, but avoiding cell death. Our project explores the relative significance of various components of the antioxidant machinery in three species, widely distributed on the Mediterranean coasts, which differ for their strategy to cope with drought. We examine indeed *Pistacia lentiscus* and *Phillyrea latifolia*, two evergreen sclerophylls that display classical isohydric and anisohydric strategy behavior in response to drought. We also examine the responses of *Cistus incanus* a semi-deciduous species, the drought response strategy of which has not been explored in depth. Our experimental plan consists of physiological and biochemical analyses conducted on both seasonal and daily basis. It is of interest to assess the daily variation of different components of the antioxidant defense network: (1) antioxidant enzymes undergo marked daily variation, and their activity is severely depressed under high light conditions (exacerbated by the drought-induced reduction in the usage of radiant energy to photosynthesis) and high temperature (2) carotenoids, which also vary much during the day, are however more stable to high temperature (3) phenylpropanoids that are more stable to drastic variations in environmental conditions. The choice of the three species also depends on their relative phenylpropanoid composition. *P. lentiscus* displays a very low 'phenylpropanoid plasticity', as more than 95% of the whole phenylpropanoid spectrum consists of hydrolysable tannins (galloyl derivatives), whereas flavonoids are often at trace level. *P. latifolia* has a phenylpropanoid composition to respond promptly to changes in environmental conditions, as hydroxycinnamates occur together with mono and dihydroflavones (apigenin and luteolin) and flavonols (kaempferol and quercetin). *Cistus incanus* is an interesting study case, as the species display a wide range of phenylpropanoids, ranging from ellagitannins (hydrolysable tannins) together with at least 16 flavonoids with different glycosylation pattern, mostly quercetin and myricetin skeleton. The concentration of phenylpropanoids is particularly high in *P. lentiscus* and *C. incanus* ranging from 20-25% of lead dry matter. Then *P. lentiscus* and *C. icanus* will be assessed as source of bioactive compounds. Relevant compounds will be isolated (preparative HPLC) and fully characterized through HPLC/MS-MS and NMR. Compounds will be preliminary evaluated for their antioxidant activity using electron spin resonance spectroscopy. Most promising metabolites will be further evaluated for their ability to behave as signaling molecules, the most important function they play in humans. There is a close link between the antioxidant potential and the ability of polyphenols to interact with proteins that regulate cell growth and differentiation. Such analyses will be conducted in collaboration with the Department of Molecular Medicine and Development at University of Siena, where it will be possible to explore the ex vivo activity of our individual molecules. In detail we will investigate their role as: (1) protective agents of a cholesterol receptor (SR-B1), important for the defense of the cutaneous tissue against cigarette smoking damages; (2) inhibitiors of the parisited derived antigen PfEMP1, a virulence factor of the human malaria; (3) anti-spasmogenic agents of gastrointestinal and vascular smooth muscles, for the prevention of tissues from ischemia-reperfusion injury.

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# POSTER SESSION

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**MANAGEMENT OF UNDERSTORY LIGHT FOR CONTROLLING REGENERATION DYNAMICS**

Alpine forests represent a precious resource and a social heritage of the Italian and European landscapes. The numerous socio-economic, political, and climatic developments occurred in the last decades, have radically changed the role and the functions fulfilled by these forested areas, sometimes compromising the ecosystems stability. New sustainable silvicultural strategies for managing forest ecosystems are being developed also using new concepts from the complexity science to foster the enhancement of biodiversity, resilience and resistance of stands and ensuring the availability of a variety of ecosystem services. Most of the recent proposals, aimed to get multi-aged, mixed forests with heterogeneous structure and temporal continuity of natural regeneration of trees. Transition from theory to practice can be achieved by different silvicultural systems referable to general categories such as partial cuttings or variable retention cuttings that emulate natural disturbance regimes, modifying overstory cover and creating spatially differentiated microclimate conditions within the stand, particularly in terms of understory light availability. Being understory light availability a key factor in driving and controlling dynamics, especially for the establishment, growth and survival of regeneration, a better understanding of how to control it by manipulation of the spatial arrangement of forest canopy structure is fundamental for silviculturists to select which and how many trees to cut. Modelling light beneath forest canopies could be a valid supports to explore a wide range of silvicultural strategies on light distribution and regeneration establishment, but the large data requirements and the restricted field of application often limit the use. The present contribute expects to improve the current knowledge concerning the processes (competition and growth) involved in the natural regeneration of silver fir (*Abies alba*) and Norway spruce (*Picea excelsa*), paying specific attention on the relationship between established regeneration growth and understory radiation conditions and taking into account the influence of stand structural attributes, readily available from field data, on understory light availability.

**Keywords:** understory light, regeneration, forest management, silver fir, Norway spruce

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**COMPARING BUD PHENOLOGY WITH XYLEM DEVELOPMENT ON TWO CONIFER SPECIES IN BOREAL FOREST**

A comparison of the phenology of the apical and lateral meristems could add new clues in order to understand mechanism of the growth dynamic in conifers. This study investigated six phases of bud phenology and analyzed xylem development in two boreal species in the Monts-Valin National Park (QC, Canada). Primary and secondary growth were monitored weekly from May to September during the growing seasons 2010-2014 in balsam fir (*Abies balsamea* Mill.) and black spruce (*Picea mariana* Mill.). Three trees per species were randomly selected in two sites between the healthy dominants or co-dominants individuals. Two north-facing and two south-facing branches per tree were selected in the bottom part of canopy. In each branch, the phases of bud break were recorded observing the terminal bud of the main stem with the naked eye to determine the different stage. Wood microcores (2 mm in diameter) were collected on the stem using Trephor. Microcores were dehydrated in ethanol and D-limonene. Transverse sections of 7 µm thickness were cut from the samples with rotary microtomes, stained with cresyl violet acetate and examined under bright-field and polarized light to differentiate the developing and mature xylem cells. In each sample, cells in the cambial zone, as well as cells in the radial enlargement, secondary cell wall thickening and mature phases were counted along three radial rows. All data were computed in days of the year (DOY). Species considered showed different timing in bud development phases, while in xylem differentiation not different dates occurred. However, within each species first phase of bud development occurred in same days of first phase of xylem differentiation, and there showed a strong correlation between these two phases. Know that phases of beginning of bud break and first phases of xylem differentiation occurred in same days and are correlated, will allow in future studies to know the different phases of secondary meristems only watch the phases of apical meristems, without invasive practices on stem.

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**VALIDATION OF WRF-ARW MODEL FOR FUTURE BIOGENIC PARTICLES DISPERSION STUDIES: A COMPARISON WITH HIGH-RESOLUTION AIRCRAFT DATA**

Forested areas are a source for a wide array of biogenic particles, some of which have ice nucleation capabilities and, therefore, may potentially influence precipitation patterns. There are still no certainties about their effective abundance in the atmosphere and, therefore, their actual impact on atmospheric ice nucleation: in this context it becomes greatly important being able to simulate their dispersion in and above the PBL, but reliable tools are needed for the task. The WRF-ARW is the most widely utilized weather model with a huge user base and outstanding flexibility (being applicable to scales ranging from large eddy simulations to the whole globe). WRF-ARW output fields are also widely used as inputs of dispersion models either of passive scalars or particulate matter: for such applications it becomes of paramount importance a validation of the simulated wind-field (along with air temperature). These outputs depend strongly on model configuration and especially on chosen parameterizations and initial and boundary conditions. While for the former a certain literature exists, for the latter, instead, there are not many works done in comparing model forcings. Moreover all the papers employ punctual ground measurements as references with a certain loss in spatial resolution. The aim of the present work is not only to conduct a sensitivity analysis of WRF-ARW to different initial and boundary conditions, but also to validate the results against a spatialized highly-resolved airborne dataset obtained by an aircraft-carried wind and turbulence probe (Mobile Flux Platform). Multiple WRF-ARW simulations had been run over different intensive observation periods (IOPs) were aircraft data were available employing different initial and boundary conditions (ERA-Interim and CFSR data). The IOPs span all the seasonal variability and are flown across different terrains including coastal, flat and elevated environments . Outputs from the simulations are compared to the airborne dataset after an optimization-based spatial matching: results show that WRF-ARW is generally well capable of simulating wind speed and air temperature across the whole domain. Differences between the initial forcings are mainly visible when different data subsets are analyzed, but the analysis show a coherent behavior of the two datasets. The finding of an appropriate statistic for the evaluation of wind direction matching between model and aircraft is still problematic, but the first results suggest that the model is also able to assess domain-wide wind direction to a reasonable degree, increasing the confidence in using WRF-ARW outputs for simulating atmospheric dispersion.

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**RESULTS OF INTERNATIONAL COMPARATIVE TRIALS OF MEDITERRANEAN PINES (*P. HALEPENSIS* AND *P. PINASTER*) AFTER 57 YEARS OF EXPERIMENTATIONS**

*Pinus halepensis* and *Pinus pinaster* are Mediterranean conifers scattered distributed around Mediterranean basin. Many different trials were made around Europe especially with the "IUFRO 2.02.13 Breeding and Improvement of Mediterranean Conifers". The provenance test of Cecina was established in 1956 with a 2.5 x 2.5 m planting pattern and an experimental design of randomized blocks. In total, 5 *p. halepensis* provenances and 10 *p. pinaster* provenances were tested. Aim of this study is to measure performances of Mediterranean provenances to support forest management activities in Mediterranean forest, especially in population used to contrast seaside erosion and reforestation activities. To asses interaction between provenances and environment, diameter at 1,30 m and height of each tree were measured and used to calculate volumes and average increment using INFC2005 formula. To evaluate phenological traits and to add more information for Principal Component Analysis, scores for basal deformation, sinuosity of the stem, inclination of the branches and inclination of the stem were given. For Aleppo pine, Italian provenances demonstrate to be more productive than others with an average increment of 6.86 $m^3$/ha for the Terni provenance and 5.83 $m^3$/ha for the Taranto provenance. PCA separated Italian provenances from each other and also from others provenances, especially for basal deformation and sinuosity of the stem. For maritime pine, Spanish and Algerian provenances had better results with respectively 7.91 $m^3$/ha and 7.60 $m^3$/ha. PCA grouped Algerian and Spanish provenances together and main differences were in branches inclination and stem volume. As reported in many studies, in Mediterranean area many differences are present in Aleppo and maritime pine's provenance and a network of common gardens must be encouraged to create an useful tool for sharing experiences across the whole basin area.

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## STRESS-INDUCED SIGNALING: INTRASPECIFIC PLANTS COMMUNICATION MEDIATED BY VOC EMITTED FROM S. LYCOPERSICUM PLANTS

Plants release volatile chemicals into their surrounding air space that can affect the physiology of neighboring plants and influence the behavior of insects. Herbivores, for example, induce a class of VOC, called herbivore-induced plant volatiles (HIPV) that are involved in mediating tritrophic interactions; in fact these chemicals mediate the attraction of natural enemies of herbivores, so they act as an indirect signal of defense. In this context, an impressive body of evidence now exists that VOCs can act as signals for the communication of stress for the intact neighbor plants, in the sense that stressed plants can warn their intact neighbors of danger by emitting VOCs. In the present project, the effects of multiple stress factors on *S. lycopersicum* (cv. Micro-Tom) plants will be studied on VOC emission and on the transcript levels of characteristics genes involved in the synthesis of VOCs, but it will be also investigated the effect of the signalling on intact plants from the same species that will share the same physical space of the stressed plants. So it will be used a communication system that allows the study of the signal transmission, mediated by VOCs, between plants stressed by multiple factors and intact plants. This system will be a modified "push-pull" dynamic system for collecting VOCs from aerial parts of plants. Teflon-coated guillotine-like blades close the base of a chamber around the stem of the plants allowing trapping VOCs from the upper part of the plant. The multiple stress factors chosen are an abiotic stress (water stress) and a simulation of an herbivore attack (biotic stress) through the application of the phytohormone jasmonic acid. Jasmonic acid plays a central role in induced plant defense by regulating the biosynthesis of herbivore-induced plant volatiles, so exogenous application of jasmonic acid can be used to elicit plant defense responses similar to those induced by biting-chewing herbivores and mites that pierce cells and consume their contents. The application of different biotic and abiotic stress factors simultaneously could have synergistic, additive or opposing effects on VOC emission. Drought stress should act as a priming of defense mechanisms, so that, with the addition of jasmonate, it is expected an additive or synergistic response on VOC emission, on the transcript levels and a higher effect on the activation of defensive mechanisms in the intact plants. Understanding of this fascinating communication system is only rudimentary; our results may add new knowledge about VOCs role in communication between species and about the behavior of these signal molecules under multiple stress factors.

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**MODELING ENVIRONMENTAL CHANGES IN THE UDZUNGWA MOUNTAINS OF TANZANIA, THROUGH IMPACTS ASSESSMENT ON RAIN FOREST PRIMATES.**

Udzungwa Mountains of Tanzania is a very remarkable site for biological diversity and endemism, known also as the "Galapagos of Africa", increasingly endangered by anthropic pressure. Assessing the impacts that the environmental changes and the anthropic pressures have on the shifts in the distribution and abundance of animal species can be crucial when planning for potential faunistic management and conservation actions. In this perspective, our project is aimed to integrate the use of GIS, geostatistics and remote sensing analysis techniques with the existing field based program of the evaluation of distribution and abundance regarding selected target species of primates in the area. On the already available data we performed several statistical analysis. The R libraries Distance and mrds were used to derive estimates of primates density and abundance, fitting detection functions to distance sampling data on primates clusters that were collected along line transects. Generalized Linear Models –GLMs, allowed us furthermore to explore and identify the relationships between primates presence and abundance with vegetation and other habitat variables. Using the results of these analysis we will carry out a new data collection campaign on the field that will further extend the significant database already available that comprises animals records as well as vegetation sampling results. A field sampling campaign is scheduled for the next year. After having defined the habitat requirements of the species, we are adopting a spatial analysis approach. The attempt is to extrapolate the same specific environmental variables from the satellite and the aerial imagery, trying different modules and tools for the image analysis and mainly those linked to indexes of vegetation richness and diversity. To perform these tasks we are processing all the available spatial data sets with the free and open-source software GRASS GIS and R (spgrass and dsm packages). We use then field sampled data to test the validity and consistency of the method. At last we aim to derive spatial explicit models containing density surfaces of the species. These models will be useful in order to predict animals distribution also in those areas that are not directly sampled. The results will thus help to identify and control possible drivers of variation in the species occurrence inside a large area, as well as their origins that could be of both natural and anthropic derivation.

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## FOREST PROTECTION FUNCTION AND UNEVEN-AGED MANAGEMENT: A CASE STUDY ON THE EVOLUTION OF ROCKFALL HAZARD FOR DIFFERENT FOREST OPENING SIZES

In mountainous areas forests play often a significant role in mitigating the rockfall hazard. This protective effect against rockfall can be influenced also by forest management and therefore, silvicultural interventions should aim at maintaining and improving the protection effect. The objectives of the present study are to analyze the variation of the protective function in three rockfall-prone zones within a selected study area considering different harvesting scenarios and an evolution period of 60 years. The study area covers approximately 10 $km^2$ and is located in South Tyrol (Italy) in a subalpine forest environment. The digital terrain model and tree locations were obtained by analyzing LiDAR data from an airborne survey carried out at a point density of 10 points/$m^2$. The 3D rockfall simulation model Rockyfor3D was then used to identify three zones in which there is an evident role played by forest in reducing the hazard at the forest road, element at stake in this study. Within the selected areas a forest evolution was simulated using the Samsara2 spatial explicit and individual-based forest dynamics simulation model. Firstly a forest growth without any interventions was chosen and then also different harvesting scenarios following an uneven-aged management were applied according to a single-tree or a group cut approach. Horizontal distribution of trees was known during the forest dynamics simulation and this allowed an accurate over time rockfall hazard assessment using tree positions as input for Rockyfor3D. Mean energy and reach probability of falling rocks were analyzed at the road for each forest growth simulation at a 10-years' time step and used to investigate the influence of the different silvicultural interventions on the protective function played by forest in the considered stands. The use of LiDAR data as input, from which accurate tree positions can be derived, has the potential to enable the study of the protection provided by forest in many small-scale rockfall-prone areas located above objects at stake within a region of interest. Preliminary results show an increase in the rockfall hazard on the road just after forest interventions during which trees are removed. The authors believe that the outcomes might contribute to forest planning and support practical silvicultural guidelines in forests having a protective function.

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**EFFECTS OF FOREST EXPANSION ON MOUNTAIN GRASSLAND: CHANGES IN SOIL ORGANIC CARBON STOCKS AND FRACTIONS**

Grassland abandonment followed by progressive forest expansion is the dominant land-use change (LUC) in the European Alps. Contrasting trends in soil organic carbon (SOC) storage have been reported for mountainous regions following forest expansion on abandoned grasslands. Fractions sensitive to LUC can be indicative of changes in SOC and they can allow a better understanding of SOC stabilization processes. Our aim was therefore to explore the impact of LUC on SOC stocks, focusing on the effect of grassland abandonment and forest expansion on physical SOC fractions. Four successional stages were investigated in a pre-alpine region of Trentino (Southern Alps, Italy): managed grassland, two transitional phases in which grassland abandonment led to colonization by *Picea abies* (L.) Karst., and old forest dominated by *Fagus sylvatica* L. and *P. abies*. Organic and mineral soil layers were collected down to 30 cm at eight points within three plots for each successional stage. Soil samples were fractionated following two procedures: 1) aggregate size fractionation, separating aggregates based on their dimension through wet-sieving, and 2) size-density fractionation, separating stable aggregates from particulate organic matter (POM) non occluded in aggregates. Mineral SOC stocks were lower in early-stage and old forest (-28% in the top 10 cm of mineral soil) than in managed and abandoned grassland, however the inclusion of organic layers offset mineral SOC stock difference. The dimension of aggregates assessed by aggregate-size fractionation tended to increase, whereas SOC allocation to stable aggregates assessed by size-density fractionation decreased following conversion of grassland to forest (e.g from 78 to 59% in the 0-10 cm layer). The amount of SOC stored in POM increased by 3.8 Mg $ha^{-1}$ in the 0-20 cm layer from managed grassland to old forest, but it did not compensate for the decreased SOC accumulation in stable aggregates. The decline in SOC storage in stable aggregate fractions was indicative of the decrease in mineral SOC stocks after forest expansion on subalpine grasslands. Higher SOC allocation to POM fraction in the mineral soil and changed carbon distribution between mineral and organic soil layers suggest an overall decrease in SOC stability and a concomitant shift to more physically labile SOC fractions.

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**GREENHOUSE GAS EMISSIONS FROM ALPINE LAKES**

Most of the studies on greenhouse gasses, methane ($CH_4$) carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$) emissions from freshwater ecosystems were focused on tropical and boreal areas for their high organic matter occurrence and their significant biological activity. Regarding temperate areas, research has been focused on $CO_2$ from land ecosystem suggesting a sink in this region. Freshwater ecosystems systems in temperate areas were first considered as pipes of carbon transporting it from land to the ocean, ignoring their role as bio-reactors and emitters of terrestrial carbon. Lakes, with their anoxic and reductive conditions, could be overlooked methane emitters. The overall aim of this study is to understand if alpine lakes are potential emitters of GHG. Is there any difference in terms of emissions over a gradient of elevation? Or over a gradient of latitude? To know if Alpine lakes would be potential emitters, the first year has been focused on the dissolved concentration of GHG at the surface taken as a proxy of potential diffusive emissions. To do so, 79 lakes distributed in Trentino and South Tirol (Italy) and North Tirol (Austria), have been selected according to different elevation (from 240 to 1700 m a.s.l.) and latitude. To date, 43 of them have been already sampled to determine dissolved content of methane as well as carbon dioxide, and dissolved $O_2$. Only water surface samples were considered. Two samples of 60 mL each were sampled using a gas tight glass bottle. A headspace was then created to exsolve GHGs from the water and 0.5 mL was injected into a Gas Chromatographer. A Flame Ionization Detector (FID) was used to determine the CH4 compound whereas a Thermal Conductivity Detector (TCD) is used for the $CO_2$ compound. The first results of dissolved methane concentration show that some lakes could lead to potential diffusive emissions, with a range of concentration from 0 to 5.89 µmol/L with mean value of 1.11 µmol/L. Further steps will be to focus on them with micrometeorological equipment to study the evolution of those potential emissions over a certain period of time.

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**CARBON DIOXIDE EXCHANGE IN COMPLEX TOPOGRAPHY**

On a global scale the budget of carbon dioxide ($CO_2$) bears a quite substantial uncertainty, which is commonly understood to be mainly due to land-surface exchange processes. In this project we investigate to what extent complex topography can amplify these land-surface exchange processes. The hypothesis is that, on the meso-scale, topography adds additional atmospheric mechanisms that drive the exchange of $CO_2$ at the surface. Simulations with the atmospheric numerical model Weather Research and Forecasting (WRF) coupled to the community land model (CLM) are conducted to study the effect of complex topography on the $CO_2$ budget compared to flat terrain. The magnitude of differences in $CO_2$ exchange ranges between ±2 ppm per day. The sign of the valley effect and the magnitude are strongly dependent on the CLM plant functional type, the initial temperature, the initial relative humidity and the latitude, but are independent from local circulations.

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## DELINEATION OF INDIVIDUAL TREE CROWNS FROM ALS AND HYPERSPECTRAL DATA: A COMPARISON AMONG FOUR METHODS

Forest structural properties are traditionally acquired during extensive fieldwork campaigns. A great potential for time saving is given by remote sensing assisted inventories. Recently great attention has been devoted to individual tree crowns (ITC) level forest inventories. In ITC inventories a key step is the delineation of the tree crowns. Thus, in this study we will compare four methods for the identification of individual tree crowns (ITC) based on high density airborne laser scanning (ALS) and hyperspectral data. The study area is an alpine forest located in Lavarone at 1400 m (Trento Province, Italy) above sea level. 600 trees were inventoried in a plot of 4800 $m^2$, of which 58% Silver Fir (total basal area: 37 $m^2$/ha), 23% European beech (total basal area: 2 $m^2$/ha), 19% Norway Spruce (total basal area: 22 $m^2$/ha). ALS data were acquired by an Optech ALTM 3100EA sensor, with a mean density of 8.6 points/$m^2$ for the first return (laser pulse wavelength 1064 nm, laser repetition rate 100 kHz) and with up to four recorded returns for each laser pulse. Methods 1 and 2 exploit both a CHM in raster and point cloud formats. The main difference among them is that method 1 uses a watershed segmentation to delineate the ITC, while method 2 uses a region growing algorithm. In detail the two methods can be summarized as follows: i) a raster CHM is created from point cloud; ii) the CHM is properly filtered to avoid inclusion of non-vegetated objects; iii) a watershed segmentation (method 1) or a region growing (method 2) is applied; iv) ITCs are reshaped using a morphological filter and their raw ALS point cloud distribution. Method 3 is based on raw ALS cloud and focuses on the delineation of intermediate and suppressed trees. In particular: i) the point cloud is divided into horizontal layers to which a 3D K-means clustering is applied; ii) K-means clusters are grouped using a prolate ellipsoid shape along all the layers; iii) the distribution of points in the clusters is estimated along x and y axes and the uneven distributed clusters are separated into two new 3D clusters; iv) clusters are eventually merged along all layers, in 2D space, and grouped into final 3D clusters representing ITCs. Method 4 is based on hyperspectral data. ITCs are delineated on a single raster band (band at 810 nm). In particular: i) the raster image is filtered with a low pass filter, and with a thresholding filter in order to highlight only the tree crowns; ii) a watershed segmentation algorithm is applied; iii) a morphological filter is used in order to reshape the final ITCs. The above described methods will be compared with the field inventory data for the identification of individual trees and their canopy sizes.

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## VALORISATION OF AGRICULTURE FOR THE WATER SUPPLY IN CONTEXT WITH CLIMATE CHANGE (CLIMAGRO PROJECT PRESENTATION)

Almost 90% of agricultural land in South Tyrol is composed of extensively and intensively used meadows und pastures. Land-use, such as managed grasslands, in mountain environments has strong influence on water supply in the lower regions, soil stability and hydro power. With the alpine region not only being influenced by large-scale changes in land-use during the last 60 years, but also being subject to climate change more than the global mean, it is essential to further understand the hydrological mechanisms of alpine grassland ecosystems. This abstract reports the conceptual idea of the "ClimAgro" project, a research cooperation of the European Academy Bozen-Bolzano (EURAC), the University of Innsbruck and the Free University of Bolzano sponsored by the the Province of South Tyrol (Autonome Provinz Bozen – Südtirol, Abteilung Bildungsförderung, Universität und Forschung). The project aims at analysing the impact of different agricultural management types of grasslands (intensification and extensification) and changing climate (higher mean temperatures, lower precipitation) on water use efficiency (WUE) of grasslands in alpine environments. The experimental sites are the Stubai Valley in Tyrol, Austria, and the Matscher Valley in South Tyrol, Italy, chosen for their different climatic conditions, with the latter one displaying lower precipitation and being artificially irrigated. The WUE is evaluated by performing a common garden experiment in the Stubai Valley, where local soil monoliths together with others from the Matscher Valley are transplanted into smartfield lysimeters on the valley floor. These monoliths will be sheltered to allow the control of environmental parameters such as precipitation and temperature. To quantify water use efficiency in this experiment we use stable isotope analysis of carbon ($^{12}C$ and $^{13}C$). Concurrently we investigate the sources of water for grasslands in relation to location, altitude and vegetation type. We analyse the Hydrogen ($^{1}H$ and $^{2}H$) and Oxygen ($^{16}O$ and $^{18}O$) isotopic signature to trace the supply of water from the different possible sources (ground water, rain, snow and irrigation water) into plants. With our approach of combining proven ecological techniques such as species transplantation experiments, continuous micro climate and hydrological measurements and state-of-the-art technology like smart-field lysimeters and stable isotope analysis, we will contribute to a better understanding of the future development of agricultural ecosystems in mountain environments in a changing world.

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**FORESTS: A POTENTIAL DRIVER OF WARMING MITIGATION IN SOUTH EASTERN ITALIAN ALPS**

Forests manifest a complex role on climate through bio geophysical feedbacks that affect the energy flux, hydrological cycle and the atmosphere composition. Compared to other types of vegetation, forests influence directly or indirectly the air temperature via increased $CO_2$ storage capacity, lower albedo and enhanced emission of biogenic volatile compounds. The climatic data of 24 weather stations from the Province of Trentino (South Eastern Alps) ranging between 203 and 2125m a.s.l, were analysed together with eddy covariance and land use change data in order to understand the potential influence of forests on the air temperature in mountainous compared to lower elevation sites. Studying the response of air temperature to increase in elevation, a significantly negative trend of the warming rate has been found. Different drivers like changes in atmospheric moisture content of the planetary boundary layer, modified surface albedo as well as changes in the ratio between sensible and latent heat fluxes driven by fast urbanization that occurred at low elevation may have induced an accelerated warming in lower elevations. But at the same time, rapid reforestation of formerly mountain pasture land (+13%) that occurred at high elevations and that was associated to a large and significant increase in mountain forest stocks may have determined cooling through enhanced evaporative capacity and emission of organic vapours which lead to higher aerosols and cloud droplets formation and increased reflected solar radiation. The Eddy Covariance data of three towers was analysed for assessing differences in climatic and energy balance parameters and cloud events frequency between low versus high elevation and forest versus grassland ecosystems. The comparison between grassland and forest ecosystems, both located in mountainous areas, suggests that, averaged over a 10 years period, the forest site was colder than the grassland especially during summer. In addition a higher cloud formation is recorded over the forest site and a higher frequency of cloud events is registered in a high compared to low elevation site. Although not a very clear evidence of forest cover induced cooling has been found, considering our findings, we can argue that the increase of forested area may have led to a cooling effect in the mountains by changing the energy balance through enhanced reflected radiation as a result of a higher cloud formation.

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