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Investigating shrub-encroached mountain grassland using high precision lysimeters

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Zusammenfassung

Die Brachlegung von wenig produktivem Grasland in europäischen Gebirgen führt zu einer Besiedelung durch Sträucher, die durch den Klimawandel voraussichtlich weiter begünstigt wird. Diese Veränderungen der pflanzlichen Diversität und der assoziierten Biota verändern die biogeochemische Funktion von Grasland und die Ökosystemleistungen (ES). Im internationalen Forschungsprojekt LUCSES wird ein besseres Verständnis für Stickstoff- (N) und Wasserkreislaufprozesse in verstrauchtem alpinen Grasland entwickelt. An französischen und österreichischen LTSER-Standorten wird die Variation entlang der Gradienten von Verstrauchung und die Mechanismen, die mit einer Mykorrhizierung verbunden sind, analysiert. Es werden Kleinlysimeter verwendet, um den vollständigen Wasserhaushalt zu analysieren und so die Wissenslücke zu überwinden, wie Veränderungen von funktionalen Merkmalen mit Wasser-Ökosystemfunktionen zusammenhängen.

Schlagwörter: Smart-Field-Lysimeter (SFL), Alpen, Ökosystemleistung, Mykorrhiza

Summary

Fallowing of low-productivity grasslands in European mountains is leading to colonization by shrubs, which is expected to be further favored by climate change. These changes in plant diversity and associated biota are altering grassland biogeochemical function and ecosystem services (ES). The international research project LUCSES is developing a better understanding of nitrogen (N) and water cycling processes in encroached alpine grasslands. At French and Austrian LTSER sites, variation along gradients of encroachment and mechanisms associated with mycorrhization are analyzed. Small-scale lysimeters will be used to analyze the full water balance, overcoming the knowledge gap on how changes in functional traits are related to water-related ecosystem processes and functions.

Keywords: Smart-Field-Lysimeter (SFL), Alps, ecosystem service, mycorrhizal assoziation

Introduction

Across the European mountains, changes in livestock production systems since the 1950s have led to a gradual segregation between more accessible, flatter, and more productive grasslands with intensified forage production through fertilization and sometimes irrigation, and more remote, steeper, and less productive grasslands used for extensive grazing, some of which are being abandoned (Gartzia et al. 2014, Lavorel et al. 2017). These trends are expected to continue to varying degrees under most future scenarios (Kohler et al. 2017b, Lavorel et al. 2019). After grazing ceases in subalpine grasslands, secondary succession is initiated and species- and function-rich herbaceous communities

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are gradually colonized by shrubs (Anthelme et al. 2007). In addition, recent observations and experimental studies have shown that climate warming, sometimes combined with increasing drought, favors shrub expansion (Harte et al. 2015). In addition to resulting changes in plant and associated biota biodiversity, shrub expansion is expected to profoundly alter the biogeochemical functioning of subalpine grasslands and thus the diverse ecosystem services (ES) they provide to local and distant beneficiaries. While previous studies have built mechanistic ES models for alpine grasslands based on plant traits (Lavorel et al. 2011, Grigulis et al. 2013, Kohler et al. 2017a), abandoned grasslands with significant shrub cover may be outside their scope (Schirpke et al. 2017).

Despite the spatial extent of already abandoned grasslands, with, for example, an average of -20% of agricultural land between 1980 and 2000 in Austria-Tyrol (Tappeiner et al. 2008) or -25% in the Spanish Pyrenees (Gartzia et al. 2014), and continuing trends under expected future global changes (Tasser et al. 2017), the functional consequences of scrub encroachment are poorly understood and previous studies have largely targeted the more obvious changes in carbon cycling processes (Tappeiner et al. 2008). In addition to lignification and associated biochemical changes, shrubs have qualitatively different mycorrhizal partners compared to herbaceous plants. These characteristics are expected to affect carbon cycling processes, as well as nitrogen and phosphorus recycling and water balance.

We hypothesize that the functional pathways of traits to nitrogen- and water-related processes will differ qualitatively between herbaceous and shrub communities. This is being investigated in an international collaborative research project called LUCSES. LUCSES is led by the University of Innsbruck, Austria (funded by the Austrian Science Fund - FWF) and the Laboratoire d'écologie alpine (LECA), France (funded by the Agence nationale de la recherché - ANR).

Materials and Methods

Study areas

The two study sites were previously extensively studied for soil properties, plant composition, plant functional properties, and indicators of ecosystem functions and ecosystem services at the plot level (*Figure 1*). The *'Lautaret'* site within the Long-Term Socio-Ecological Research (LTSER) platform of the Central French Alps is located on the south-facing slopes of the headwaters of the Romanche and Guisane valleys (45.03°N, 6.24°E). Field research is supported by laboratory and garden facilities on the Lautaret Pass (2100 m a.s.l.). The area, between 1552 and 2442 m a.s.l., covers 53 km^2 and consists almost entirely of grasslands on the west side of Lautaret Pass (Romanche), while the east side (Guisane) has a significant amount of woody plants due to heavy

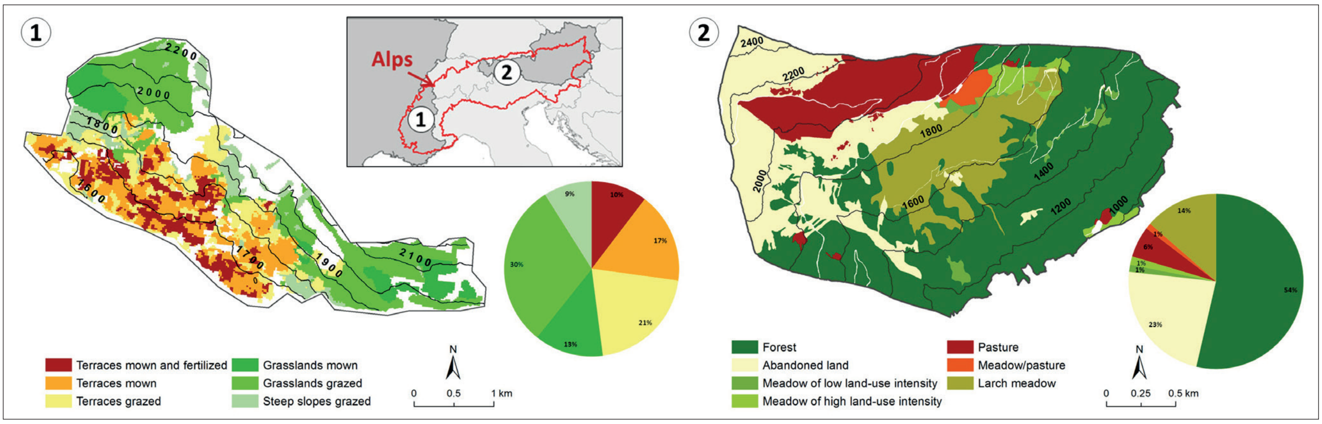

Figure 1. LUCSES study sites: *'Lautaret'* in the Upper Romanche Valley, FRA (1); *'Stubai Valley'* in the Tyrol, AUT (2). Modified after Leitinger et al. (2015).

agricultural extensification associated with the development of the Serre Chevalier ski area. Lautaret illustrates dynamics representative of higher elevation areas in the southern French Alps. The lower part of the site (1552-1800 m) was used for terraced agriculture from the fifteenth century onward and is now hayfields and pastures, while mowing originally occurred above this arable belt and up to a maximum elevation of 2000 m, with the upper slopes devoted to summer grazing. On the Guisane side, 7% of the terraced area and 32% of the summer grassland are currently colonized by woody plants, although some of them are grazed. The 'Stubay Valley' site is part of the LTSER platform 'Tyrolean Alps' in the Central Alps, Tyrol, Austria (47.15°N, 11.25°E) (Leitinger et al. 2015, Frenck et al. 2018). At an altitude of 900 to 2600 m a.s.l. and covering an area of 80 km^2, a long tradition of management systems has resulted in different grassland types, including fertilized meadows in the valley bottom, grasslands with low management intensity and gradients of secondary succession after abandonment above 1500 m a.s.l., and permanent grasslands above 1500 m a.s.l., and permanent grassland above 2000 m a.s.l. In addition, the *'Stubai Valley'* has a unique lysimeter facility with up to 24 high-precision lysimeters (Smart Field Lysimeter-SFL®, Meter Group AG, Munich) (970 m a.s.l.). This facility, maintained by the University of Innsbruck, Department of Ecology, has been used in national and international research projects dealing with climate experiments for herbaceous flora.

Experimental Smart-Field-Lysimeter design in LUCSES

To better understand the nitrogen and water cycling processes of shrubs under expected increasing drought and advanced snowmelt, high-precision lysimeters (SFL®, Meter Group AG, Munich, Germany) are used to analyze the effects and mechanisms of climate change effects on shrub species. For this purpose, two congeneric shrubs exhibiting deciduous (*Vaccinium myrtillus*) and evergreen (*V. vitis-idea*) habit are individually planted in the lysimeters filled with in situ sieved (5 mm) and homogenized soil from original sites. The lysimeters will be used for the analysis of the effects of climate change on shrubs. In a split-plot design of 3.5 m x 3.5 m each, two plots will be subjected to either (1) control, (2) earlier snowmelt, or (3) earlier snowmelt and summer drought. A total of 18-24 lysimeters will be installed, meaning that each of the six resulting treatments (two shrub species * three climate treatments) will be replicated three to four times. The control follows ambient irrigation conditions and snowmelt. Earlier snowmelt refers to snow removal (SR) by shoveling 4 weeks earlier than the end of natural snowmelt. For earlier snowmelt and summer drought, an eight-week dry period during the growing season is added. Natural precipitation will be intercepted for all plots by greenhouse foils (Lumisol Clear AF®, Folitec) installed after snowmelt and removed after the growing season. An irrigation system is used to simulate rainfall. A microclimate station will be installed in the center of each of the six plots to measure relevant micrometeorological factors for ET_0 calculation.

Impact and benefits

LUCSES bridges research areas in functional ecology (vegetation science, soil science, microbiology, biogeochemistry) and social-ecological systems science by extending trait-based ES modeling to bridge the biophysical reality gap in ES models. In the short term, LUCSES will contribute to trait-based ecology by providing missing baseline knowledge and publicly available data (eLTER, TRY) on plant and soil properties and their interactions along gradients from herbaceous to shrub grassland, and their role in nitrogen cycling and the soil-plant-atmosphere continuum (SPAC).

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