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Drought effects on evapotranspiration and productivity of grassland seed mixtures for dry and humid sites

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Zusammenfassung

Ein Lysimeterversuch auf dem sozio-ökologischen Langzeitforschungsstandort (LTSER) ‚Stubaital' in Tirol, Österreich, untersucht die Einflüsse von Trockenperioden auf alpines Grasland. In 2017 wurden Kleinlysimeter (Smart-Field-Lysimeter) mit zwei unterschiedlichen Einsaatmischungen für Grasland (Dauerwiese für trockene bzw. feuchte Lagen) bepflanzt und abwechselnd feuchten Bedingungen und Dürreperioden ausgesetzt. Bei anhaltender Trockenheit in der Wachstumsphase zeigte sich ein Rückgang sowohl der Evapotranspiration als auch der Biomasseproduktion. Wir hatten erwartet, dass sich die beiden Einsaatmischungen aufgrund der unterschiedlichen Anteile an konservativen und exploitativen Arten in ihrer Wassernutzungsstrategie unterscheiden. Die Ergebnisse zeigten allerdings keine signifikant unterschiedlichen Reaktionen der beiden Einsaatmischungen auf Dürreperioden.

Schlagwörter: Grünlandbewirtschaftung, Lysimeter, Wassernutzungsstrategie

Summary

To assess the reaction of Alpine grasslands to drought, we investigated two different types of grassland seed mixtures (permanent meadow for dry and humid sites) in a lysimeter experiment at the long term socio-ecological research (LTSER) site 'Stubai Valley', Tyrol, Austria. Grasland being exposed to extended drought during growth period showed reduced evapotranspiration and reduced biomass production. Due to different proportions of species with conservative and exploitative strategies, we had expected differences in the water-use strategies of the two grassland seed mixtures. But against expectations, the two vegetation types did not differ significantly in their reaction to drought.

Keywords: grassland management, lysimeter, water-use strategy

Introduction

For the European Alps, drought events are predicted to occur more often and more severe in future (Hohenwallner et al. 2011), with the drought stress affecting the ecosystem services provision of mountain grassland including the ecosystem service 'forage production' (Leitinger et al. 2015). To assess the reaction of Alpine grasslands to drought conditions, we investigated different types of grassland seed mixtures (permanent meadow 'humid' and 'dry') in a garden experiment at the long term socio-ecological research (LTSER) site 'Stubai Valley', Tyrol, Austria (Tappeiner et al. 2013). We hypothesize the two grassland communities to reveal a difference in vegetation development and between water-saving and water-spending strategies regarding evapotranspiration due to different proportions of species with conservative and exploitative strategies in the seed mixture.

Materials and Methods

Four sheltered plots of 3.5 m x 3.5 m were established. In each plot, three high precision lysimeters (Smart Field Lysimeters®, SFL, METER Group) with 0.3 m diameter and 0.3 m depth were installed (*Figure 1*).

The lysimeters were filled with the same autoclaved and standardized soils and covered with two different grassland seed mixtures (Schwarzenberger 2018): (1) permanent meadow 'dry' (Type SR012, Nachsaat Dauerwiese TROCKEN) with increased share of *Festuca arundinacea*, and (2) permanent meadow 'humid' (Type SR 037 Dauerwiese FEUCHT) (*Table 1*).

The experiment was characterized by alternating wet and drought periods (*Figure 2*). During the wet periods, the lysimeters on all plots were irrigated regularly and a bidirectional pumping system acted as a groundwater supplier, adjusting the water content at the lower boundary of the lysimeters to maintain a matric potential of approximately 10 kPa. During drought periods (18.05.2017 - 08.06.2017 and 07.07.2017 - 10.08.2017), the two 'control plots' were provided with irrigation water mimicking long-term rainfall amounts and intensities at the site, while the two 'drought plots' were not provided with any water (*Figure 1*). For this, irrigation was stopped and the bidirectional pumping systems were turned off to prevent water supply at the lower boundary (usually mimicking groundwater supply and/or capillary rise).

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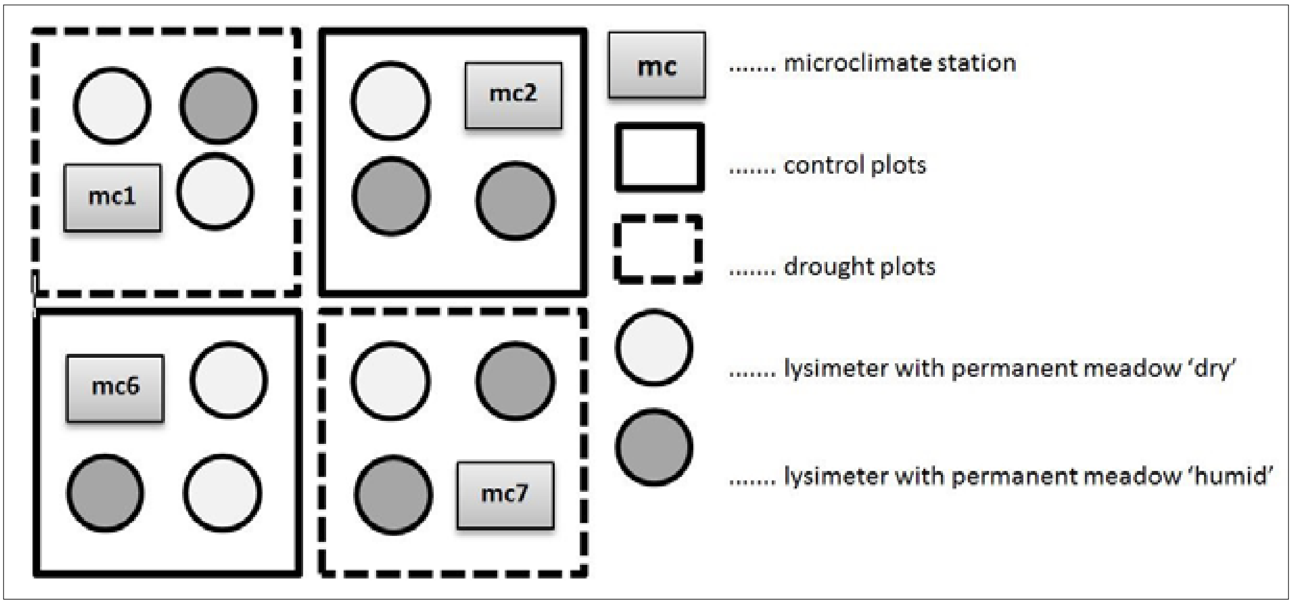

Figure 1. **Experimental design of the garden experiment in Stubai Valley, Tyrol, Austria.**

Table 1. **Seed mixtures (%) of the grassland types 'dry' and 'humid'.**

species	permanent meadow 'humid'	permanent meadow ‚dry'
Agrostis capillaris	4.1	0.0
Arrhenatherum elatius	0.0	4.4
Dactylis glomerata	7.0	6.7
Festuca arundinacea	0.0	50.6
Festuca pratensis	18.1	2.8
Festuca rubra	12.0	5.0
Lolium perenne	13.5	6.9
Lotus corniculatus	2.5	0.0
Medicago sativa	0.0	3.9
Phleum pratense (variety: Timothe)	8.0	5.8
Phleum pratense (variety: Wiesenfuchsschwanz)	6.1	0.0
Poa pratensis	12.1	5.6
Trifolium hybridum	4.0	0.0
Trifolium pratense	2.5	2.8
Trifolium repens	6.0	5.6
Trisetum flavescens	4.1	0.0

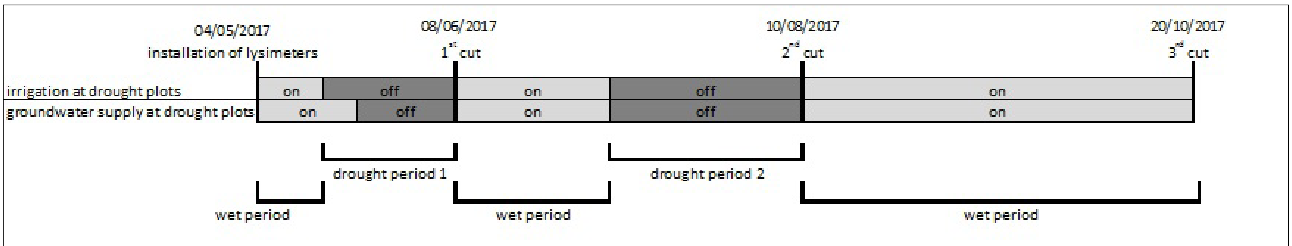

Figure 2. **Time schedule of the garden experiment in 2017.**

The vegetation in the lysimeters was cut at the end of every drought period to analyse biomass production and at the end of the growing season to allow comparison for the annual biomass production. The lysimeter weights, as well as soil matric potential, soil temperature and soil water content in the lysimeters were measured and logged in 1 and 10 min intervals, respectively. The evapotranspiration and seepage was estimated from the weight measurements, with data being processed and smoothed (Peters et al. 2017).

Results

During drought period 1 (21 days in May/June with the pumps being turned off at day 4, *Figure 2*), the matric potential at a soil depth of 15 cm remained relatively low also in the drought plots, with a maximum value of approximately pF 1.5 on the last day of treatment (*Figure 3*). During drought period 2 (30 days in July/August), however, the soil at 15 cm depth dried out. All lysimeters of the drought plots exceeded the mark of pF 4.2, which generally defines

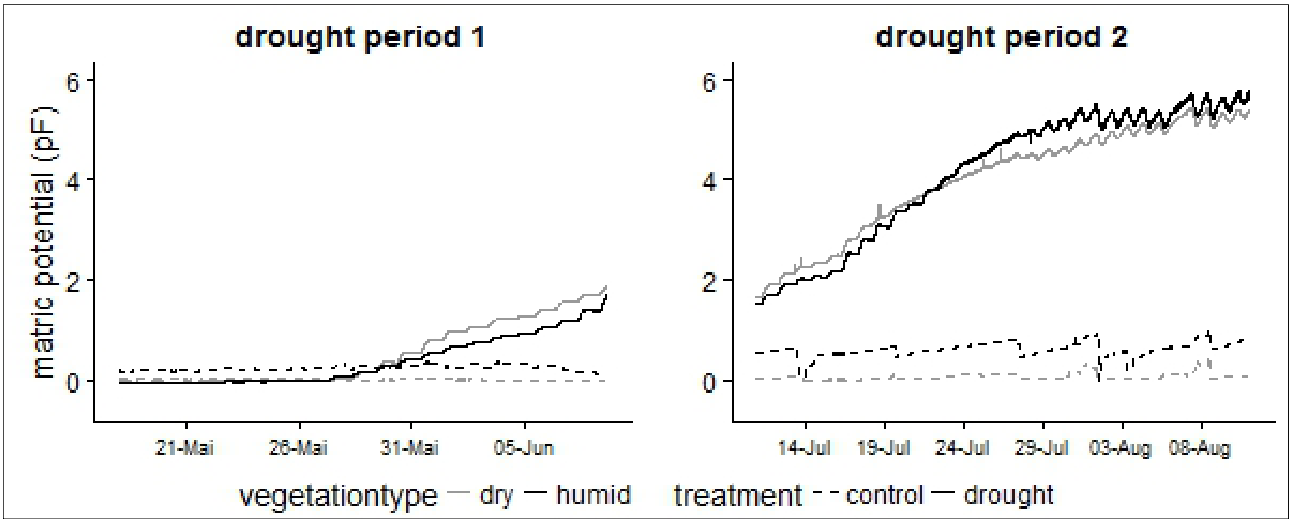

Figure 3. **Mean matrix potential during drought period 1 (left) and drought period 2 (right) in 15 cm depth for all combinations of two vegetation types ('dry' and 'humid') and the two treatments (control and drought). Please note that the accuracy of the matric potential measurements is limited above pF 4.2.**

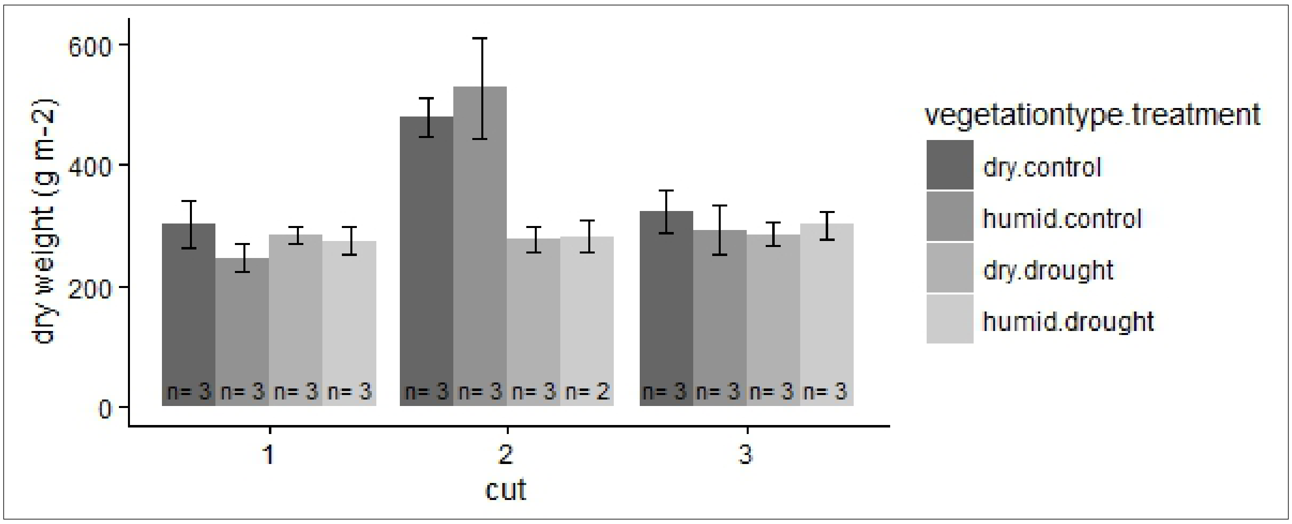

Figure 4. **Mean biomass (± s.e.) dry weight of the cuts 1 (08.06.2017), 2 (10.08.2017) and 3 (20.10.2017) for all combinations of the two vegetation types ('dry' and 'humid') and the two treatments (control and drought).**

the permanent wilting point. No statistically significant difference of the drying behaviour for the lysimeters covered with permanent meadow 'dry 'and the lysimeters covered with permanent meadow 'humid' could be found.

The biomass dry weight of cut 2 (after drought period 2) showed a significant difference between control and drought treatment, but not between vegetation types ('dry' and 'humid') (*Figure 4*). For cut 1 and cut 3, there were no significant differences.

The total evapotranspiration during drought 1 and 2 was similar for both vegetation types 'dry' and 'humid' (46/48 mm in 17 days and 72 mm in 30 days for drought periods 1 and 2, respectively), showing no different water use strategies of the two vegetation types during drought stress (*Figure 5*).

Discussion

Considering the relatively high matric potential values during drought period 1, it is not surprising that the dry weight of above-ground biomass in cut 1 did not show any significant differences between control and drought plots. We conclude 1) that during sufficient water supply, the two vegetation types do not show differences in biomass production and 2) that after a high initial saturation of the soil a short drought period in May/June does not affect biomass production, neither of the permanent meadow 'dry' nor of the permanent meadow 'humid'.

During drought period 2, a clear drying out of the soil in the drought plots could be noticed in the matrix potential data. As a consequence, vegetation in the drought plots produced significantly less biomass than in the control plots. Our hypothesis that the water-use strategies of the two grassland communities during water stress would differ, however, could not be confirmed, as the total evapotranspiration during drought period 2 was the same for both vegetation types. Also, the same amount of above-ground biomass was produced by both vegetation types until cut 2. This finding is not in line with Frenck et al. (2018) who showed for the

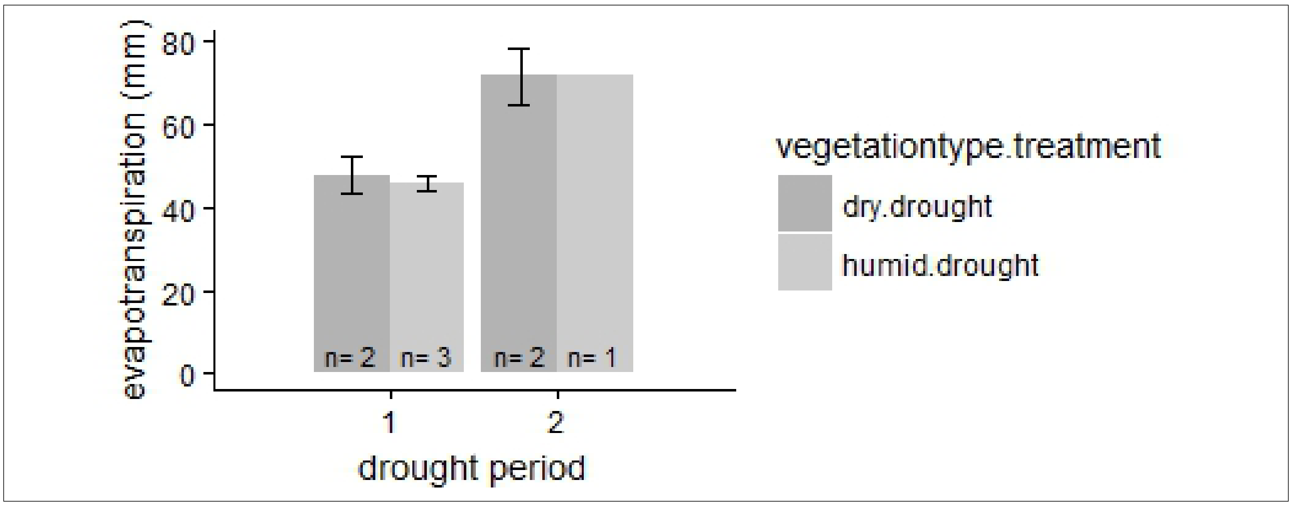

Figure 5. **Mean evapotranspiration (± s.e.) of drought periods 1 and 2 for the two vegetation types ('dry' and 'humid') for the drought treatment.**

differently drought-adapted grassland communities having a water-spending strategy (i.e., no or little reduction of transpiration during drought periods until close to the wilting point) or a water-saving strategy (i.e., continuous decrease in transpiration with decreasing plant-available water). Plant species in the 'dry' and 'humid' grassland of the seed mixtures in our study are almost the same than those determined in Frenck et al. (2018). However, vegetation composition could have changed in the course of the experiment, leading to similar behaviour of all plots. Moreover, in contrast to our experiment with seed mixtures on standardized soil, Frenck et al. (2018) did a transplantation experiment with location-specific soil monoliths and vegetation cover excavated from two field sites differing in environmental setting and climatic conditions. Therefore the differences in the plants' water use found by Frenck et al. (2018) can possibly be explained by differences in physical soil properties, ecotypes of the plant species or the mycorrhization of plant roots.

Between cut 2 and cut 3, all plots were provided with sufficient water. Both vegetation types showed a high resilience as the vegetation in the drought plots was immediately able to come back to its usual productivity in the third growth period without water stress.

Conclusion and outlook

Drought conditions during growth period reduce biomass production of both grassland communities ('dry' and 'humid') to the same extent. This is not in line with our expectations, that the seed mixtures with different proportions of exploitative and conservative species would reveal differences in their water-use strategy, and requires further investigations.

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