

Effects of extreme weather events on Apennines grasslands productivity

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Abstract

Extreme weather events are expected to increase in frequency and magnitude due to climate change especially on Mediterranean chains, but their effect on ecosystem services and vegetation processes are widely unknown. Prediction of future impacts has become critical to conservation planning and management, particularly in protected areas.

Our research has been carried out in the Torricchio Nature Reserve (Central Apennines, Italy), 317 ha under strict protection since 1970, owned and managed by the University of Camerino.

Two contrasting grassland ecosystems under different environmental conditions (North and South facing slopes) were selected to simulate extreme events. The magnitude of a given recurrence interval (1000 year) were estimated by the application of extreme value distributions on climate data series covering 50 years.

In both slopes, the weather manipulations consisted of extreme drought (D), additional rainfall (R) and ambient conditions for control (C). The experiment covered 2 years (2011 and 2012). Once a year, at the end of the treatment period, the above-ground biomass was collected.

No significant differences between treatments were found in the productivity of the stony terrain of the S facing slope, while significant results were detected between the climatic extremes (D vs R) in the N facing slope with dense plant cover. In any case, the experimental treatments of the S facing slope, show a high level of biomass variability, demonstrating the importance of the fine-scale environmental heterogeneity.

The effects of climatic alteration on productivity of montane grasslands, underlines the crucial importance of future research on the outcome of climate change in these systems.

Keywords

Extreme weather events; Sub-Mediterranean grassland; Drought; Above-ground productivity; Torricchio Nature Reserve.

Introduction

Climatic and land use changes are considered to be major drivers of biodiversity loss in terrestrial ecosystems (THOMAS et al. 2004; FISCHER & LINDENMAYER 2007). In particular, global climate change will likely cause profound effects shifting terrestrial ecosystems outside their historical range of climate variability. (GORDON et al. 1999; THOMEY et al. 2011). In this context, prediction of future impacts has become critical to conservation planning and management (SUTTLE et al. 2007), particularly in protected areas.

Associated with a changing global climate, alterations in the distribution and abundance of animals and plants are already occurring (e.g. PENUÉLAS & FILELLA 2001; PARMESAN & YOHE 2003; ROOT et al. 2003; THOMAS et al. 2004). This is due to changes in the mean and spatiotemporal patterns of temperatures and precipitation, as well as an increase in the frequency and magnitude of weather-related extreme events (IPCC 2007; JENTSCH et al. 2007; KREYLING et al. 2008b).

The ecological effects of extreme events have been identified as one of the main gaps of knowledge in community ecology (AGRAWAL et al. 2007; JENTSCH et al. 2007).

The Mediterranean area is characterized by a climate of transition between the temperate mid-latitude and tropical dry climate, therefore it is considered to be potentially very sensitive to climate change (CUBASCH et al. 1996; LAVOREL et al. 1998).

For SALA et al. (2000), Mediterranean grassland ecosystems likely will experience the greatest proportional change in biodiversity because of the substantial influence of all drivers of biodiversity change (land use change, climate change, biotic exchange, etc.). For instance, changes in timing and amounts of growing season

precipitation and variations in temperature, are likely to cause long-term changes in grassland plant community composition and structure, with consequences on ecosystems functioning from the point of view of provision of habitat, biomass, water interception, nutrient cycling and carbon storage (GRIME et al. 2000; SANDEL et al. 2010).

Several studies of climate manipulation were recently carried out in Central and Northern Europe grasslands (GRIME et al. 2008; KREYLING et al. 2008a); however, experimental data on the effect of extreme weather events on montane sub-Mediterranean grasslands are lacking.

Here we evaluate the effects of certain induced extreme weather events (namely, drought and additional rainfall) on the above-ground biomass of two contrasting Apennines calcareous perennial grasslands, located in a protected area.

Methods

The Torricchio Nature Reserve (Central Apennines, Italy, Figure 1) provides areas of montane grasslands under different environmental conditions. The ones considered in this study are located at contrasting, north and south-facing slopes along a SW-NE orientated valley. Mean annual precipitation reaches 1250 mm and mean annual temperature is around 11 °C (HALASSY et al. 2005). Jurassic-Cretaceous limestone (scaglia rosata) prevails in the area. The Reserve, owned and managed by the University of Camerino, is under protection regime since 1970 and it is included in the Natura2000 and LTER networks.

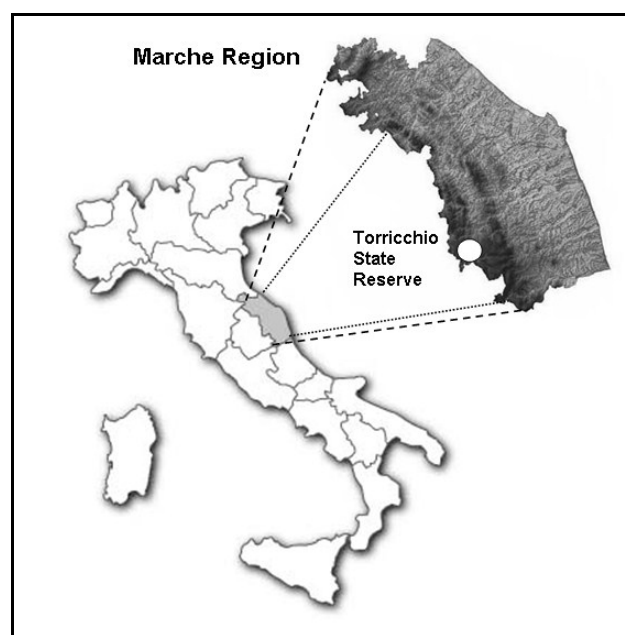


Figure 1: Location of Torricchio State Reserve in the Central Apennines, Marche Region. Italy

We selected two study sites with an area of about one hectare each, representing the contrasting environmental conditions of the north and south slope (Figure 2). The north-facing slope (site N) is covered with a dense grassland assigned to the association *Seslerio nitidae* – *Brometum erecti*, here a secondary community originated by the destruction of a former beech forest. The south-facing slope (site S) hosts an open grassland with a more scanty cover, assigned to *Asperulo purpureae* – *Brometum erecti*. Due to erosion associated with the presence of rocky outcrops, a poorly developed, shallow and skeletal soils occur which are characterized by strong instability (KWIATKOWSKI & VENANZONI 1994).

In both sites, the weather manipulations consisted of extreme drought (D), additional rainfall (R) and ambient conditions for control (C). Magnitudes of climatic extreme events of a given recurrence interval (1000 year event) were estimated by the application of extreme value distributions on climate data series (JENTSCH et al. 2007) covering 50 years. For Torricchio Nature Reserve, the 1000-year event resulted in 58,5 days of drought.

At each site, five plots were established with three 1x1m sub-plots: one sub-plot with a 4m² roof to simulate extreme drought, one sub-plot downstream the shelter to simulate additional rainfall and one control plot. Roofs were constructed with a steel frame and covered with transparent 3 mm plastic foil that permitted over 93% penetration of photosynthetically active radiation (PAR).

Soil temperature and soil relative humidity were measured each two hours (Maxim- Hygrochron Temperature/Humidity Logger – DS1923) during the entire period, in roofed and non-roofed plots, at two different soil depths: 0 and 10 cm. General meteorological data was provided by a local meteo station.

The experiment covered 2 years (2011 and 2012). Once a year, at the end of the treatment period, in each sub-plot, the above-ground biomass was collected.

Data from loggers were compared among treatments using the non parametric Mann-Whitney U-test.



Figure 2: Pictures of the North facing slope (Site N, on the left) with a dense and closed grassland, and South facing slope (Site S, on the right) characterized by an open grassland with poorly developed and shallow soils.

The effects of the treatments and time on mean above-ground biomass values for both sites, were tested using the univariate repeated measures ANOVA (test of within-subject effects). Therefore, per each site and year, the One-way ANOVA with “Bonferroni” post-hoc test was performed to check for significant differences on mean biomass values of the three treatments. Additionally, we used the coefficient of variation (CV; standard deviation divided by the mean) as a measure of above-ground biomass variability in each treatment for both sites and years.

Results

Soil moisture content measurements exhibited that the applied weather manipulations significantly differed from control conditions. As shown by table 1, for both sites and depths, drought treatments registered the lowest mean values of soil moisture, significantly different from the control; while the additional rain ones experienced the higher mean values, significantly different from the control only at the soil surface.

Table 1: Mean soil relative moisture (%) at both sites and depths (0 cm and 10 cm) for the three treatments. Different letters in the same line, indicate significant differences in mean values (Mann-Whitney U-test; $P \leq 0.05$).

		Control	Drought	Additional rain
Site N	0 cm	93.88 a	89.98 b	96.19 c
	10 cm	101.94 a	101.44 b	102.05 a
Site S	0 cm	90.03 a	83.84 b	93.21 c
	10 cm	97.98 a	96.74 b	99.13 c

As expected, significant effect of the shelters were noted also on soil temperature. The mean difference between roofed and non-roofed plots in the site N at 0 cm and 10 cm depth was respectively 0.66°C (4.1%, $P = 0.009$) and 0.95°C (7%, $P = 0.000$); while in the site S the mean difference was respectively 1.02°C (5%, $P = 0.014$) and 0.67°C (3.6%, $P = 0.004$).

In both sites the lowest values of total above-ground biomass were registered in the drought treatment, while the higher values in the additional rain one. This is true for both the vegetative seasons analysed.

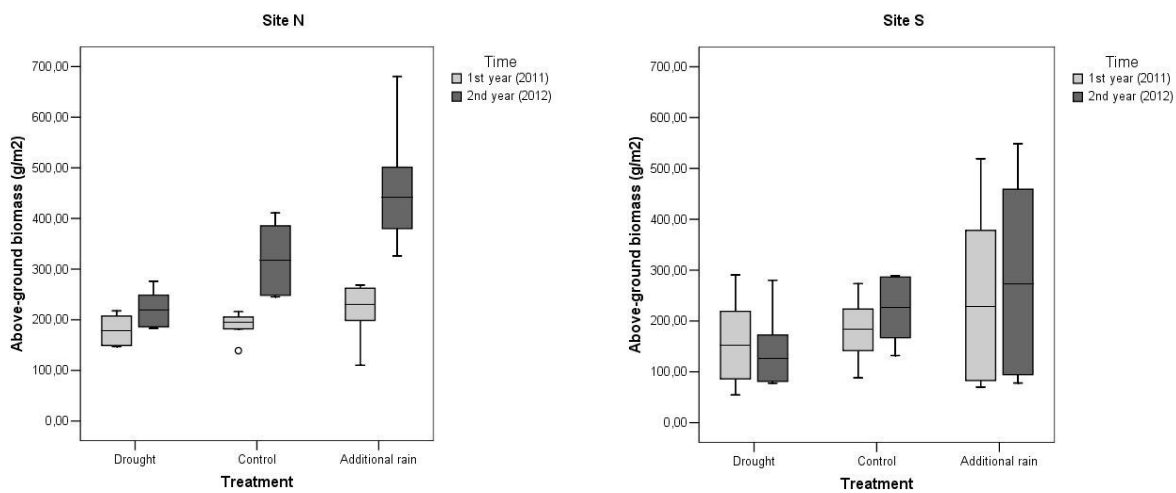
With respect of the effect of the treatments and time on mean above-ground biomass values, the repeated measures ANOVA shows for the site N a significant effect of the treatment ($p: 0.003$) and of treatment*time ($p: 0.020$). While, for the site S, not significant effects are registered.

Analysing separately each year, only the second one (year 2012) in the site N shows significant differences in mean values between the two experimental treatments (drought and additional rain) (Table 2, Figures 3a and 3b), but there are not significant differences between each experimental treatment and the control.

Table 2: Mean values of above-ground biomass (g/m²) per treatment and year. Different letters in the same line, indicate significant differences between means (p≤0.05).

		Mean values of above-ground biomass (g/m ²)		
		D	C	R
Site N	1st year	182.00 a	189.25 a	215.25 a
	2nd year	226.25 a	332.00 ab	474.50 b
Site S	1st year	149.75 a	186.50 a	240.75 a
	2nd year	139.25 a	216.25 a	299.25 a

With respect of the biomass variability, the CVs indicate a surprisingly high variation in the experimental treatments (drought and additional rain) of the site S in both years; while the biomass variability in the three treatments of the site N is low (Table 3).



Figures 3a and 3b: Mean above-ground biomass values (g/m²) in both sites per treatment in each year (2011 in light grey, 2012 in dark grey).

Discussion

During the two seasons of weather manipulation, fixed shelters proved to be effective tools for altering the amount of rainfall. Anyway it is likely that, especially during the major rainfall events, a certain quantity of rain penetrated below the shelters due to the water runoff.

GRIME et al. (2000) states that different plant communities, when exposed to changes in temperature and precipitation, will respond in different ways and, crucially, at different rates. Our results confirm this statement.

Table 3: Coefficient of variation (CV, standard deviation divided by the mean) as a measure of above-ground biomass variability.

		CV biomass	
Site	Treatment	1st year	2nd year
N	D	0.18	0.18
	C	0.16	0.24
	R	0.30	0.29
S	D	0.67	0.63
	C	0.39	0.33
	R	0.83	0.71

The stony south-facing slope (site S) shows no significant differences in above-ground biomass for treatment, indicating a certain resistance of this system. According to the exposition and soil features, this environment frequently experiences dry conditions in summer, and it is likely that this plant community is buffered to a certain

degree of drought. In any case, for both years, the system shows a high level of biomass variability (CV) in experimental treatments (D and R) demonstrating the importance of the fine scale soil heterogeneity in the response to extreme events.

In the north-facing slope, after two years of recurrent extreme drought and increased rainfall, the biomass production differed significantly between the climatic extremes (D vs R). However, surprisingly, differences were not significant against the control. This means, that similar as in temperate grassland systems (GRIME et al., 2008; KREYLING et al., 2008b), sub-Mediterranean systems prove to be buffered to a certain degree.

In any case, we should consider that functional groups or individual plant species may differ in their responses to environmental change (KLANDERUD, 2005); changes in the performance of one species or a functional group may change any current relationship between positive and negative plant-plant interactions, i.e. changes in competition between co-occurring species or growth forms.

Conclusion

The results after two years of extreme event experiment, show that the climate change (i.e. rainfall variability) can have important implications for sub-Mediterranean grassland mountain communities. The effects of climatic alteration on productivity, and thus ecosystem services of grasslands, underlines the crucial importance of future research on the outcome of climate change in these systems.

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