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Effect of grassland vegetation type on the responses of hydrological processes to seasonal precipitation patterns

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SUMMARY

Under future climate scenarios, rainfall patterns and species composition in California grasslands are predicted to change, potentially impacting soil-moisture dynamics and ecosystem function. The primary objective of this study was to assess the impact of altered rainfall on soil-moisture dynamics in three annual grassland vegetation types. We monitored seasonal changes in soil moisture under three different rainfall regimes in mesocosms planted with: (1) a mixed forb-grass community, (2) an *Avena barbata* monoculture, and (3) an *Erodium botrys* monoculture. We applied watering treatments in pulses, followed by dry periods that are representative of natural rainfall patterns in California annual grasslands. While rainfall was the dominant treatment, its impact on hydrological processes varied over the growing season. Surprisingly, there were only small differences in the hydrologic response among the three vegetation types. We found significant temporal variability in evapotranspiration, seepage, and soil-moisture content. Both Water Use Efficiency (WUE) and Rain Use Efficiency (RUE) decreased as annual precipitation totals increased. Results from this investigation suggest that both precipitation and vegetation have a significant interactive effect on soil-moisture dynamics. When combined, seasonal precipitation and grassland vegetation influence near-surface hydrology in ways that cannot be predicted from manipulation of a single variable.

1. Introduction

In Mediterranean climates such as those that define grassland ecosystems in California, soil moisture usually originates as precipitation from seasonal rainfall events and is then often rapidly lost from the root zone by transpiration (Loik et al., 2004). Increasing evidence of global climate change suggests that the hydrology of ecosystems found in these relatively dry climatic regimes is, and will be, impacted in complex ways (Gerten et al., 2007). General circulation models predict trends with increased climatic variability, where the frequency of rainfall events may be reduced while the magnitude of these events increase (e.g., Easterling et al., 2000). Further, inter-annual variation in precipitation patterns is projected to increase, with longer periods of drought (Easterling et al., 2000; Groisman et al., 2005; Sun et al., 2007). Other studies point to water becoming scarce in certain regions of the world, a scenario that would affect the amount of water recharged to groundwater and soil moisture (e.g., IPCC, 2007).

Soil moisture plays a key role in interactions within the climate–soil–vegetation system (Rodriguez-Iturbe et al., 1999). In semi-arid climates, limited water availability over extended periods frequently forces vegetation to persist in a state of water stress, resulting in significant changes to the rates of transpiration, carbon assimilation, and biomass production (e.g., Ludlow, 1976). Besides impacting essential physiological processes, water stress in plants can also drive competitive mechanisms between plants (Ridolfi et al., 2000) and microbial activity (Stark and Firestone, 1995). An improved understanding of soil-moisture variability is crucial for accurately predicting the consequences of climate fluctuations for ecosystems (D'Odorico, 2007).

The status of soil moisture in California's grasslands has been altered over the last two centuries with the introduction of non-native plants (Holmes and Rice, 1996). As in most of western North America, plant invasions in California have resulted in the replacement of native perennial grasses with Eurasian and Mediterranean annual grasses (Beatley, 1966; Burcham, 1956; Stewart and Hull, 1949; Talbot et al., 1939; Enloe et al., 2004). These conversions have resulted in significant changes to the community structure and phenology of these grasslands, which in turn have impacted temporal and spatial trends in water uptake (Enloe et al., 2004; Borman et al., 1992; Holmes and Rice, 1996). A key emerging

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question is, how will changes to the precipitation regime brought about by climate change influence subsurface moisture dynamics and plant growth in what are currently grassland ecosystems in California?

Studies conducted in California grasslands have shown that increases in annual precipitation have neutral to positive effects on productivity (Dukes et al., 2005; Harpole et al., 2007; Suttle et al., 2007). The range of possible outcomes draws attention to the need for a fundamental understanding of soil–water dynamics in these ecosystems, to better evaluate the impact of elevated CO_2, atmospheric warming or cooling, and altered precipitation regimes on California grasslands. To develop meaningful predictive climate and ecological models, we must therefore understand both the availability of water and its use by plants. However, because it is uncertain whether annual precipitation totals will increase or decrease in California with global climate change (IPCC, 2007), it is necessary to assess scenarios associated with both wetter and drier rainfall patterns.

The objective of this study was to characterize the impact of precipitation (variability and amount) and vegetation associated with these grasslands on near-surface soil-moisture dynamics. We assessed the hydrologic response of three types of grassland vegetation (that vary in structure and composition characteristics) subject to three rainfall treatments. Of particular interest were the temporal trends in soil moisture associated with precipitation treatments, and the role of vegetation structure in controlling soil moisture.

2. Methods

2.1. Experimental design

The experiment was designed to isolate the impact of precipitation and vegetation on soil-moisture conditions, and was conducted in a climate-controlled greenhouse in Richmond, California. Environmental conditions were set based on conditions

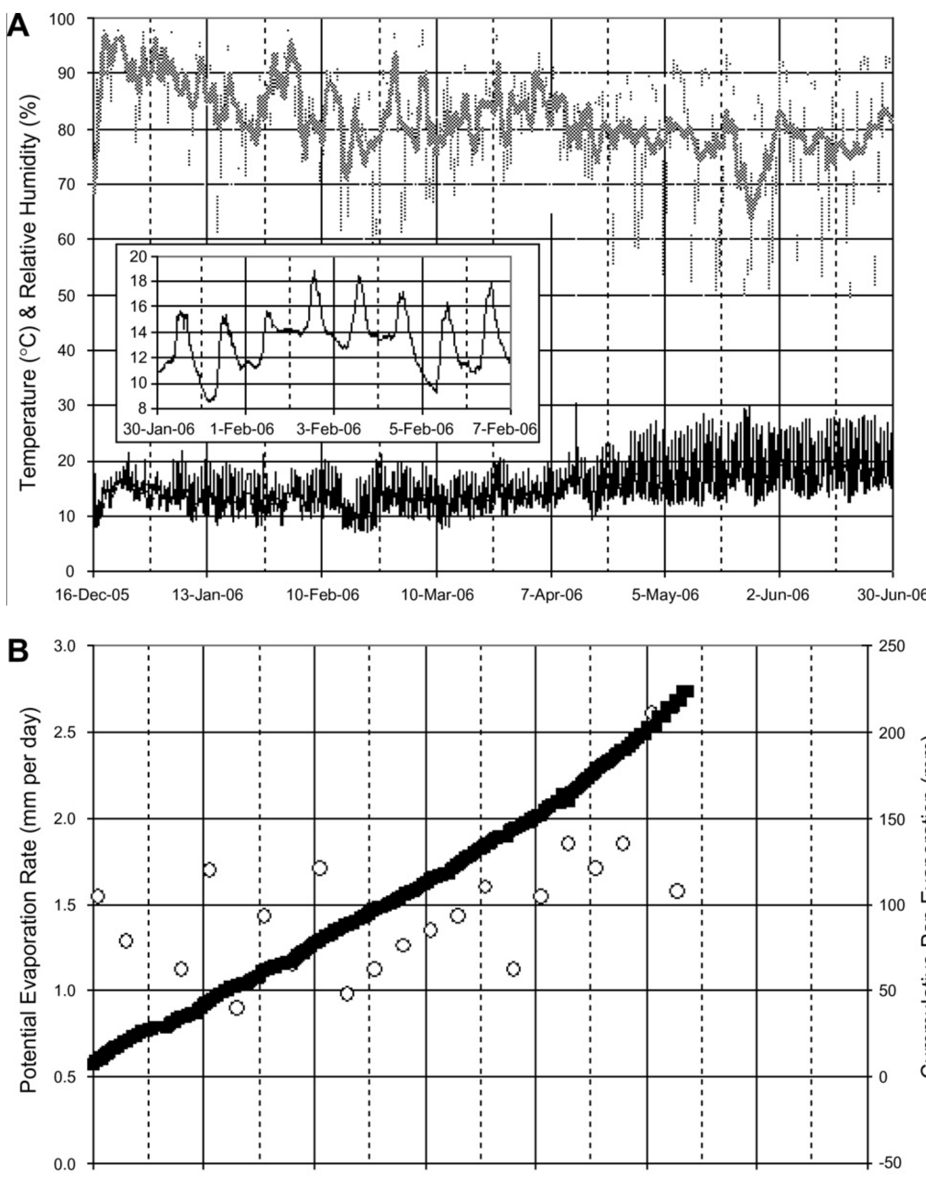

Fig. 1. (A) Temperature (solid lines) and Relative Humidity (dotted lines) measured in the greenhouse at 15 min intervals during the course of the experiment. Also included are moving averages (over period of 24 h). Inset: Diurnal fluctuations for 7 day period in early February 2006. (B) Potential evapotranspiration rate and cumulative evaporation measured inside the greenhouse.