Community Traits Examination of an Altered Precipitation, Nutrient Addition Ecosystem

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Abstract

Current climate and human-induced changes are projected to alter many regimes of ecosystem functioning. It is projected that invasive species, nonnative species that can be of great detriment to an ecosystem, will benefit under these conditions. The Prairie Invasion and Climate Experiment (PRICLE) studies the effects of two global change factors – N addition and altered precipitation – on invasive species success and the traits that are selected for in a mixed-grass prairie ecosystem. PRICLE is a two by two factorial design over three replications in a restored mixed-grass prairie ecosystem. The major findings from the community traits examination of PRICLE are that the plants with a low %N and low LMA were selected for under N fertilization and more variable precipitation. It is expected that these results can aid in understanding the impacts of human-induced global change. Understanding other plant functional traits and their significance for invasive species success is hoped to be studied in the future.

Introduction

Much effort has been devoted to understanding the effects of climate change on ecosystems. It has been well documented that global temperature and carbon dioxide concentrations have been increasing worldwide in the last 200 years (IPCC 2007, NCDC 2010). Climate change has also affected precipitation regimes. Precipitation regimes are expected to show an increase in extreme rainfall events and an increase in the time interval between rainfall events (prolonged drought; Easterling et al. 2000). As a result, water availability may be drastically altered under future, warmer climates, consequently reducing the ability of native plant communities to resist invasive plant species (Diez et al. 2012).

The effects of altered precipitation on ecosystems have been studied before (Jentsch and Beierkuhnlein 2008, Fay et al. 2003). Jentsch and Beierkuhnlein summarized recent findings and found that communities' resistance to against invasion can be significantly altered by variable precipitation, with drought decreasing and heavy rain increasing invasion rates. Fay studied the productivity responses to altered rainfall patterns in a C4-dominated grassland and found reduced growth, biomass and flowering of subdominant C4 grasses while the dominant C4 grass was unresponsive. However, the interactive effects of more variable precipitation and N deposition from agricultural fields on natural systems has received less attention (Siemann et al. 2007). Increased nitrogen deposition can be linked to increased fertilizer usage in agricultural settings (Galloway et al. 2004). Fertilizer can runoff into nearby natural systems which allows greater success of invasive species (Dukes 1999).

Thus, the Prairie Invasion and Climate Experiment (PRICLE) was created to examine the effects of variable precipitation and increased nitrogen availability on the invasive species invasion success and the plant traits that are selected for. It was hypothesized that under nitrogen addition, species with a low nitrogen composition (%N) would be favored because nitrogen would no longer be a limiting resource giving legumes and other high nitrogen composition species a competitive advantage. Under the variable precipitation, it was hypothesized that species with a lower LMA would be favored because the species with a high LMA and a presumed drought tolerance would no longer be a competitive advantage.

Methods

The Prairie Invasion and Climate Experiment (PRICLE) is aimed toward understanding the success of non-native species and the traits that are selected for in a grass prairie ecosystem under increased nitrogen availability and more variable precipitation regimes.

There are twelve plots at PRICLE, which was established in May 2012, with two by two factorial design replicated three times. The four treatment combinations include (i) ambient rainfall and no N addition (ii) variable precipitation and N addition (iii) ambient rainfall and N addition and (iv) variable precipitation and no N addition.

Figure 1: The PRICLE plots

Each plot of PRICLE (see Fig. 1) in the restored mixed-grass prairie measures 4 by 5.5 meters. A 1-meter tolerance around the perimeter of the plot was established for each plot and was ignored for any data collection. The N deposition treatment proceeded by the random addition of slow-release polymer coated urea at a rate of $5gm^{-2}yr^{-1}$. PRICLE defined variable precipitation as reduced rainfall events by 50% for a month with that amount restored to the plots in a once every 30 days event (see Fig. 2). Thus the total rainfall applied to the treatment plot was the same amount as the ambient plots.

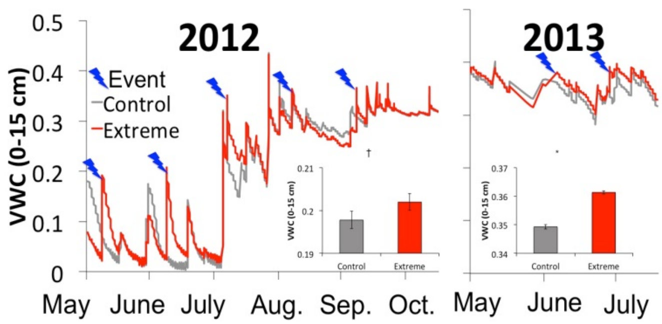

Figure 2: The soil moisture content of the variable precipitation plots vs. the control plots with the applied rainfall events

Eighteen Polycarbonate rain guards were applied as evenly spaced, roof-like structures that covered the variable precipitation plots to reduce rainfall by 50%. This water filtered into side gutters that emptied outside of the plots. Once a month, non-potable water was reapplied through rainfall simulation by pumping water from a tank.

To account for the sun protection the variable precipitation-treated plots would receive from the water guards, black netting was applied on the top of the ambient precipitation plots that, too, would reduce sunlight by 5%.

For this experiment, ten propagules of the three most common forbs (*Solidago canadensis, Symphyotrichum pilosum, Euthamia graminifolia*), grasses (*Schizachyrium scoparium, Elymus virginicus, Sorghastrum nutans*), and nitrogen-fixers (*Lotus corniculatus, Desmodium illinoesnse, Trifolium pratense*) were harvested from outside of the plots. These species and according functional groups were selected to allow for greater generalization of study results.

Because *S. canadensis* (Canada Golden Rod) and *S. scoparium* (Little Blue Stem) were the two most common species and were present for each treatment, three samples of each were harvested from each plot. With the assumption that the individual plants' compositions remains unchanged inside the plot, the measured characteristics of the plants can help understand what traits and conditions will survive best under each treatment.

In order to conduct the experiment, the area of the leaves of each of the forbs and legumes and the area of the individual blades of Little Blue Stem were found using Winfolia. The samples were then dried at 65°C for 48 hours and weighed for a dry leaf mass per are (LMA) calculation. The samples were then ground, subsampled, pulverized and subsampled again for analysis with the Costech ECS 4100 to determine the N concentration of each tissue.

Once a month, a percent cover measurement was taken for each of the plots by visual estimation using a 2 x 2m quadrat as a guide.

Results

The community traits examination of PRICLE included a LMA and %N analysis. The analysis was inconclusive for LMA expectations under the two global change factor treatments – variable precipitation and N addition – while the results showed a lower %N of the plant tissue is favored.

After sampling biomass from nine species of three functional groups outside of the plots, the analysis showed that the grasses had the highest LMA followed by forbs and legumes (see Fig. 3). Species with high LMA have a thicker leaf blade or denser tissue, or both (Wright 2004). An increased LMA is a known response to drought (Weih et al. 2011). During the 2013 growing season, the monthly precipitation to date has not been notably different than the 100 year average, and plants experience little drought stress.

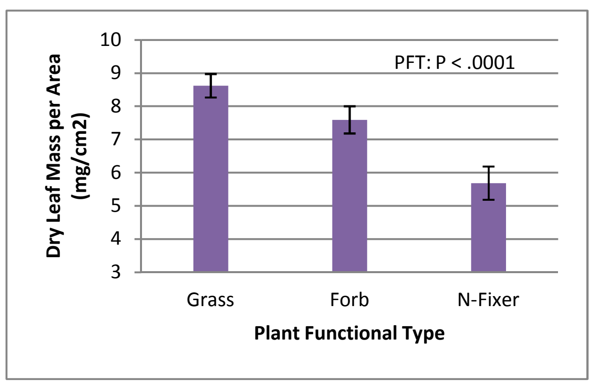

Figure 3: The LMA of sampled functional groups outside of the plots. The Legumes had the lowest LMA

Both increased variability and N addition exhibited a trend of lowering LMA (see Fig. 4). Lower LMA was likely favored under increased precipitation variability due to increased water availability, which would diminish the benefits of higher LMA. Instead plants with lower LMA likely outcompeted higher LMA plants by increased photosynthetic capacity (REF). Additionally, the species that could use its resources to grow would thus outcompete those species that used their resources to support nitrogen fixation.

Because LMA was lowered under each treatment, it was expected that the legumes would increase in percent cover while the grasses would decrease. However, the legumes actually decreased in percent cover while grasses had an insignificant change and forbs (the functional group with the intermediate LMA) increased (see Fig. 5).

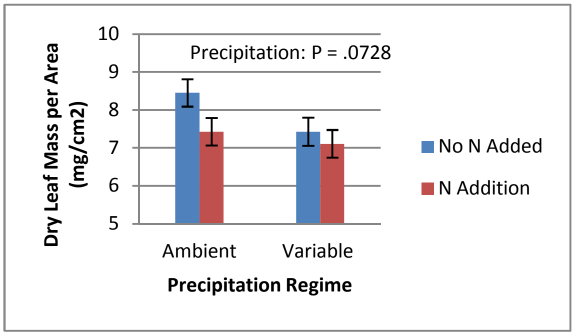

Figure 4: The effects of variable precipitation and N addition on LMA. Both treatments caused for a decrease in LMA of the plant tissue

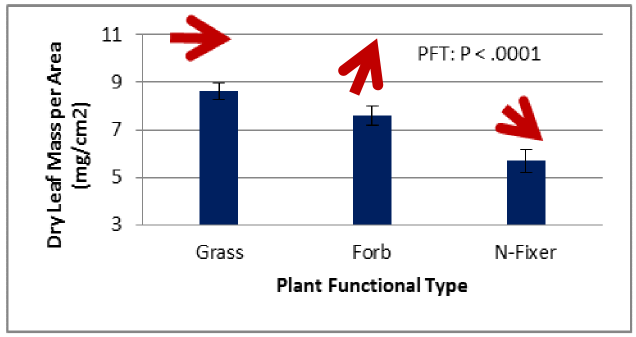

Figure 5: The percent cover data showed no trend based off LMA. It was predicted that a higher LMA would be selected for under the treatments

The results of the nitrogen concentration analysis showed that a lower %N in the plant tissue under the two global change factors resulted in an increased percent cover (see Fig. 6). The results support the hypothesis that under N deposition, plants that are able to fix their own nitrogen will no longer be at a competitive advantage, as nitrogen is no longer a limiting resource. As expected, the increased nitrogen availability resulted in increased %N in the plant tissue regardless of precipitation treatment (see Fig. 7). This was expected because an increased N availability for plants would allow for more N uptake to the leaves for increased photosynthesis rates. It is worth noting that the N addition had a greater impact of plant tissue %N concentration under the variable precipitation regime than it did under ambient rainfall. An explanation for this is unknown.

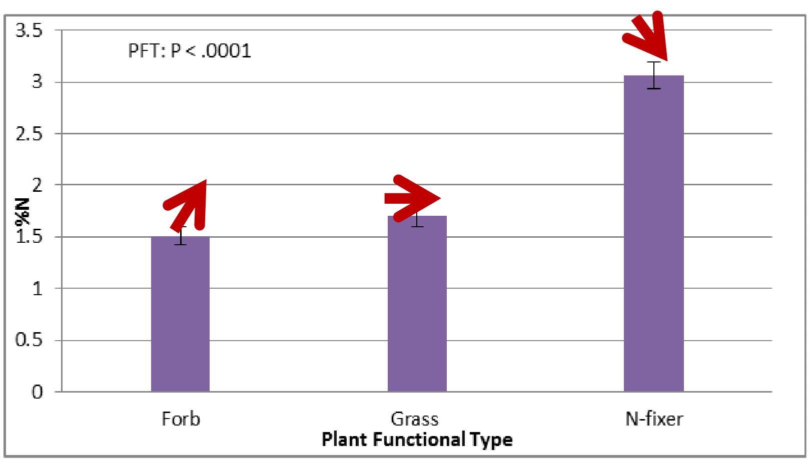

Figure 6: Under N addition, the species that increased in percent cover were species with the lowest N concentration in their plant tissue

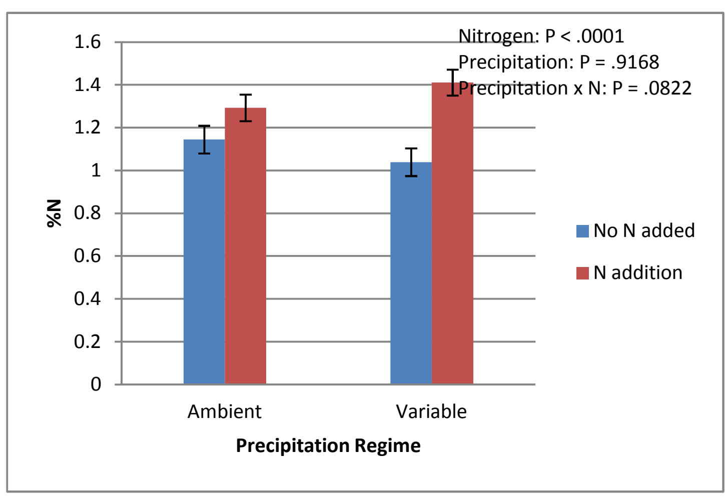

Figure 7: The nitrogen concentration in plant tissue increased under N addition

Conclusions

Climate change and human-induced changes are projected to alter many regimes of ecosystem functioning. PRICLE studied the effects of two global change factors – N addition and increased precipitation variability – on invasive species success and the traits that are selected for in a mixed-grass prairie ecosystem over two growing seasons. PRICLE showed that under projected climate change, species with a low %N tissue concentration and presumably lower LMA may have competitive success in the future. The results of the community traits examination should only be applied to similar ecosystems.

Recommendation for Future Work

There is still much to be learned with regards to the community traits examination of PRICLE. Although LMA and %N are good indicators of plant growth strategies, they are not inclusive or conclusive of the entire experiment. It is hoped that the study will continue using other plant functional traits and understanding the relative significance of each trait under the conditions. In this project it was assumed each species composition remained constant outside the plots and inside the plots under treatment. It would be interesting to test to see if and how different species adjusted under the treatments. This could be of great importance because it could project future evolutionary patterns of such species.

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