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Sub-theme 5.1. Climate change and grassland management

Gross biomass and root/shoot ratio mediated drought sensitivities of ecosystem carbon exchange in a meadow steppe

Yunbo Wang, Wei Sun*, Deli Wang
Institute of Grassland Science, Northeast Normal University, Changchun, China
*Corresponding author e-mail: sunwei@nenu.edu.cn

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Introduction

According to IPCC's Report (2007), global precipitation regimes will change largely in the future, with more annual precipitation at the mid-latitude regions. Simultaneously, due to the accelerating industrialization and use of nitrogen (N) fertilizer, significant increase in nitrogen deposition has been widely documented (Liu *et al*., 2013).

Water and nitrogen are the two most important limiting factors for the ecological processes of arid and semi-arid grassland ecosystems; therefore, altered precipitation regimes and enhanced nitrogen deposition are likely to change vegetation composition, ecosystem productivity, and aboveground vs belowground biomass distribution.

In addition to these long-term changes, short-term climate extremes, such as drought, are projected to increase in frequency and intensity in the future, and thus there is a clear need to understand how they will impact ecosystem carbon exchange, especially after the vegetation structure has been modified by altered precipitation regimes and nitrogen deposition (Reichstein *et al*., 2013).

However, not much information is available in the literature about the sensitivity of ecosystem carbon exchange to extreme drought, particularly when the ecosystem productivity and biomass distribution were altered by nitrogen deposition and changed precipitation regimes.

It has been reported that water and nitrogen addition could change the gross biomass (GB) and photosynthate distribution of steppe community (Swemmer *et al*., 2007; Hasibeder *et al*., 2015) In general, both water and nitrogen addition will decrease root/shoot ratio because of higher soil resource availability. These changes are likely to enhance the sensitivity of ecosystem carbon exchange to extreme drought; however, this hypothesis has not been tested yet.

We conducted a 45 days artificial extreme drought experiment in a long-term water and N addition experimental field in Northeast China. the objectives were: 1) to assess net effects of water and N amendments on the drought sensitivities of ecosystem carbon exchange; 2) to evaluate the mechanisms underlying these patterns of the drought sensitivities of ecosystem carbon exchange.

Materials and Methods

The experimental site is located at the Grassland Ecosystem Experimental Station (44°30′–44°45′N, 123°31′–123°56′E) of the Northeast Normal University in Jilin Province, China. The studied area has a typical meso-thermal monsoon climate with a mean annual temperature of 6.4°C. Mean annual rainfall is 471 mm. Vegetation is dominated by *Leymuschinensis*, a C_3 perennial grass.

The 24 m x 10 m plots were arranged into a complete randomized block design with water and nitrogen addition treatments, including no water or nitrogen addition (C), water addition (W), nitrogen addition (N) and water addition plus nitrogen addition (WN). In each water addition plot, 15 mm of water was applied every two weeks from later May to middle September. In nitrogen addition plots, 5 g N m^{-2}, N in form of urea, was applied twice a year in early May and July (10 g N m^{-2} yr^{-1}). Water and nitrogen addition treatments were started in 2012.

In 2014, 45 days (Jun-16 to Jul-29) drought treatment was applied in each long-term nitrogen and water addition experiment plots. In each plot, we employed a 3 m × 3 m rainout shelter. Net ecosystem CO_2 exchange (NEE) was measured 6 times (Jun-16, Jun-25, Jul-2, Jul-13, Jul-22 and Jul-29) by a Li-6400 CO_2 analyzer. Aboveground biomass (AGB) and 0-10cm belowground biomass (BGB) were measured twice at Jun-15 and Aug-1 by the harvesting method. The slopes of linear regression analysis between NEE and soil moisture were used as an indicator of drought sensitivities of ecosystem carbon exchange (S_{NEE}).

Results and Discussion

After 2 years treatment, nitrogen addition significantly increased AGB and BGB, which has been lead to a greater positive impact on GB; whereas, water addition showed negative effects on BGB and tiny impact on AGB. However, root/shoot ratios decreased in both nitrogen and water plots. For the studied meadow steppe, drought sensitivities of ecosystem carbon exchange (S_{NEE}) increased significantly in both water and nitrogen addition plots (Fig. 1). However, the magnitude of enhancement was more significant in N addition plots than in water addition plots. Additionally, we detected strong correlations between S_{NEE} and GB or root/shoot ratio (Fig. 2); however trends of responses differed between high and low GB (Fig. 2).

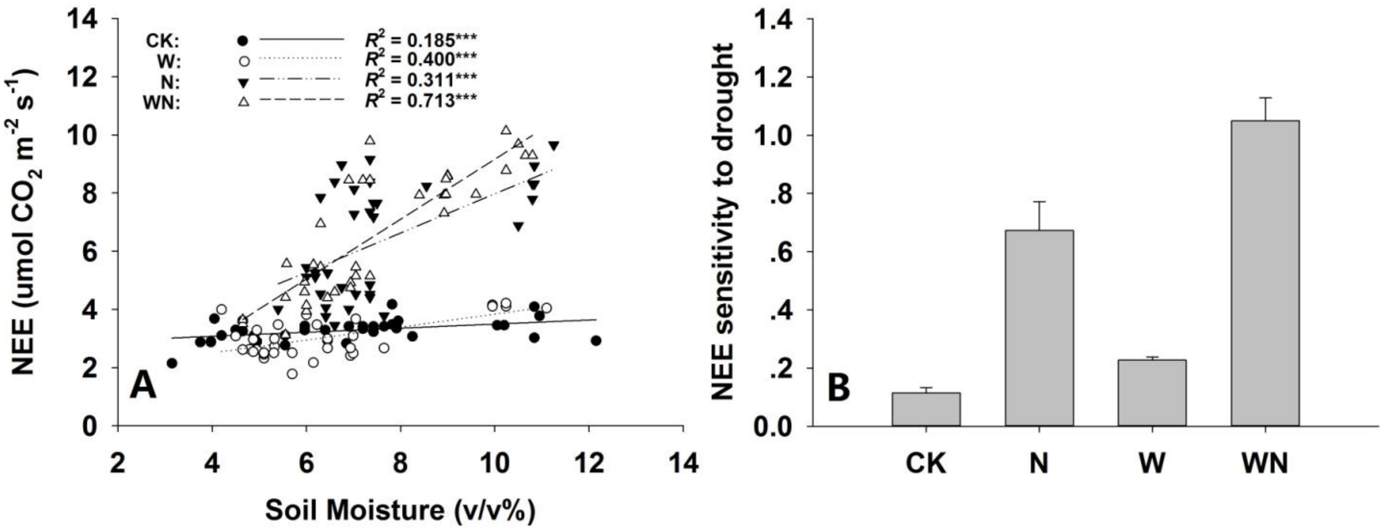

Fig. 1: Dependence of net ecosystem CO_2 exchange (NEE, µmol m^{-2} s^{-1}) on soil moisture (V/V %) during the drought period (A). *** represents a significant relationship at the P < 0.001 level. Mean of the sensitivities of ecosystem carbon exchange to drought (S_{NEE}) among treatments (Duncan's test). CK: control; W: water addition; N: nitrogen addition; WN: water and nitrogen added in combination (B). Data are reported as mean ± 1 SD (n = 6). Different letters above bars denote significant differences among treatments (P < 0.05).

The observed nitrogen addition induced decrease in root/shoot ratio was largely due to imbalanced effects of nitrogen addition on AGB and BGB with enhancement in AGB was greater than in BGB. However, decreased root/shoot ratio in the water addition plots was due to a significant reduction in BGB. The dependence of S_{NEE} on GB and root/shoot ratio can be described by a multiple linear regression equation (*P*<0.001). The results of our study suggested that water and nitrogen addition effects on S_{NEE} in the studied meadow steppe are highly regulated by the gross biomass and biomass distribution (root/shoot ratio).

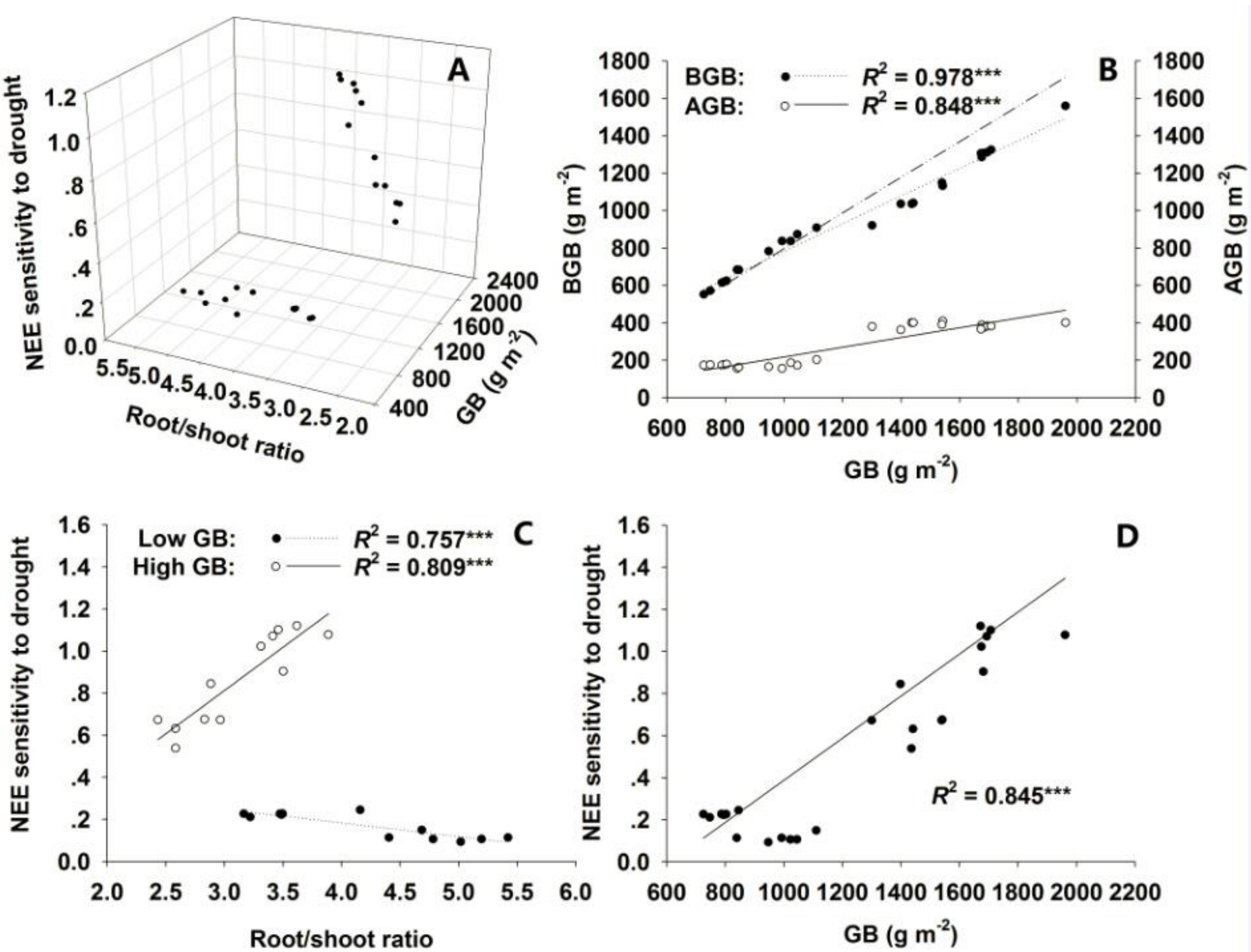

Fig. 2: Responses of the drought sensitivities of ecosystem carbon exchange (S_{NEE}) to (A) root/shoot ratio and gross biomass (GB, g m^{-2}) in combination, (C) root/shoot ratio and (D) gross biomass (GB, g m^{-2}). Dependence of aboveground biomass (AGB, g m^{-2}) and belowground biomass (BGB, g m^{-2}) on gross biomass (GB, g m^{-2}) during the drought period (B). *** represents a significant correlation at the P < 0.001 level.

Conclusion

For the studied meadow steppe, more nitrogen deposition and annual precipitation will significantly increase the drought sensitivities of ecosystem carbon exchange. Nitrogen deposition and increased rainfall amount alter the drought sensitivities of ecosystem carbon exchange through gross biomass and root/shoot ratio. Enhanced drought sensitivities in ecosystem carbon exchange may have profound impacts on the stabilities of ecosystem processes and need to be thoroughly studied in the future.

References

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