DOCTORAL THESIS

Grassland Ecosystems Functioning and Stability in Response to Climatic Variability and Climate Extremes

HOSSAIN, Md Lokman

Date of Award:
2022

Abstract

Grasslands have been considered the most imperiled ecosystems in the world because, over the past three decades, grasslands have been subjected to major natural and anthropogenic disturbances (e.g., land-use change and global climate change). Despite there is increasing evidence that grassland ecosystems are under threat of global climate change, our understanding of the functioning (e.g., above-ground biomass (AGB) and below-ground biomass (BGB)) and stability (e.g., resistance and resilience) of these ecosystems in response to climatic variability and climate extremes is limited.

In this thesis, grassland biomass observations in 5 ecoregions (cold steppe, humid temperate, humid savanna, savanna and temperate dry steppe) and Bayreuth Biodiversity Experiment were studied to examine the effects of climatic variability and climate extremes on ecosystem functioning and assess the role of biodiversity on ecosystem functioning and stability. Growing-season climatic variables were defined based on respective harvests (hereafter single-harvest), which include growing-season temperature (GST), precipitation (GSP), mean temperature (GST_{mean}), maximum temperature (GST_{max}), minimum temperature (GST_{min}) and cumulative precipitation (GSP_{cum}). Annual climatic variables include mean annual temperature (MAT), maximum temperature (MAT_{max}), minimum temperature (MAT_{min}), annual precipitation (AP) and frequency (AP_{freq}). Standardized Precipitation Evapotranspiration Index was used to identify growing-season and annual climatic conditions (extreme dry, moderate dry, normal, moderate wet and extreme wet) based on drought index classification. Annual harvest frequencies were classified into extensive, low-intensive, mid-intensive, and intensive. Biomass (i.e., AGB, BGB and BGB:AGB ratio) data were analyzed using multiple tests (i.e. *Pearson* correlation, one-way ANOVA, post-hoc test, generalized linear models and linear mixed-effects models.

Results showed that irrespective of study sites, ecoregions and plant types, growing-season climatic variables were the strong determinants in controlling single-harvest biomass rather than the annual climatic variables in explaining annual biomass. For example, single-harvest AGB in cold steppe, humid temperate and humid savanna ecoregions increased with increasing GSP and GST. For total BGB in C_3- and C_4-dominated grasslands across ecoregions, GST, GST_{max} and GST_{min} had significantly positive effects on the single-harvest BGB of C_3 plants in humid temperate and cold steppe, and C_4 plants in temperate dry steppe and savanna ecoregions. When BGB:AGB ratio was examined, I found that the single-harvest BGB:AGB ratio of C_4-dominated grasslands increased, and C_3-dominated grassland decreased with GST and GST_{max}.

The differential effects of climate extremes on biomass were not only caused by the differences in sites, ecoregions and plant types, but also ascribed by the direction and timescale of climate extremes. Compared to normal climatic conditions, the single-harvest BGB:AGB ratio of C_3-dominated grasslands in cold steppe and C_4-dominated grasslands in savanna and humid savanna ecoregions was higher (lower) in growing-season dry (wet) climatic conditions. Higher single-harvest BGB:AGB ratio of C_4-dominated grasslands in savanna and humid savanna in growing-season extreme dry climatic conditions caused by a decrease (increase) of AGB (BGB) in

these grasslands. The C_3-dominated grasslands in cold steppe ecoregion are at great threat of drought, as it was observed that growing-season extreme dry climates reduced both the single-harvest AGB and BGB.

The relationships between species richness and AGB were (i) concave-up in June harvest and unimodal in September harvests for dry conditions, and (ii) negative linear in June harvests and positive linear in September harvests for the wet conditions. Species richness increased ecosystem resistance against climate extremes of different intensities and directions but decreased resilience towards climate extremes of all dry events.

This research concludes that growing-season climatic variables rather than annual climatic variables are the strong determinant in predicting grassland biomass productivity. The observed significant effects of climate extremes on biomass in most sites and ecoregions suggest that the functioning and stability of grasslands in these ecoregions are potentially under threat of increasing intensity and frequency of climate extremes. However, in order to buffer the negative effects of climate extremes on ecosystem functioning, the presence of higher species richness and functional groups is of great importance.

This research helps improve the understanding of the differences in the responses of grassland functioning to climatic variability and climate extremes across ecoregions and provides new insights into biodiversity-functioning and biodiversity-stability relationships under climate extremes, which is of importance to achieving sustainable grassland management in different geographical regions.