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Grazing effects on surface energy fluxes in a desert steppe on the Mongolian Plateau

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Abstract. Quantifying the surface energy fluxes of grazed and ungrazed steppes is essential to understand the roles of grasslands in local and global climate and in land use change. We used paired eddy-covariance towers to investigate the effects of grazing on energy balance (EB) components: net radiation (R_n), latent heat (LE), sensible heat (H), and soil heat (G) fluxes on adjacent grazed and ungrazed areas in a desert steppe of the Mongolian Plateau for a two-year period (2010–2012). Near 95% of R_n was partitioned as LE and H, whereas the contributions of G and other components of the EB were 5% at an annual scale. H dominated the energy partitioning and shared ~50% of R_n. When comparing the grazed and the ungrazed desert steppe, there was remarkably lower R_n and a lower H, but higher G at the grazed site than at the ungrazed site. Both reduced available energy ($R_n - G$) and H indicated a "cooling effect" feedback onto the local climate through grazing. Grazing reduced the dry year LE but enhanced the wet year LE. Energy partitioning of LE/R_n was positively correlated with the canopy conductivity, leaf area index, and soil moisture. H/R_n was positively correlated with the vapor pressure deficit but negatively correlated with the soil moisture. Boosted regression tree results showed that LE/R_n was dominated by soil moisture in both years and at both sites, while grazing shifted the H/R_n domination from temperature to soil moisture in the wet year. Grazing not only caused an LE shift between the dry and the wet year, but also triggered a decrease in the H/R_n because of changes in vegetation and soil properties, indicating that the ungrazed area had a greater resistance while the grazed area had a greater sensitivity of EB components to the changing climate.

Key words: available energy; cooling effect; ecosystem function; ecosystem stability; eddy-covariance; energy balance; energy partitioning; land use change; latent heat; net radiation; sensible heat; soil heat.

Introduction

The energy exchange between the land surface and the atmosphere is influenced by vegetation and may strongly affect the local, regional and global carbon and water cycles and climate change (Aires et al. 2008, Rotenberg and Yakir 2011, Abraha et al. 2016). Grazing is the most ubiquitous land use practice in grasslands, causing substantial changes in the vegetation cover, species composition and their functional type (Klein et al. 2005, Wang et al. 2012). Consequently, the magnitude and dynamics of carbon, water, and energy are altered (Owensby et al. 2006, Polley et al. 2008, Shao et al. 2013), accompanied with changes in aerodynamic characteristics, microclimate, surface resistance to evaporation, and soil water holding capacity (Wan et al. 2002, Hernandez-Ramirez et al. 2010, Paustian et al. 2016).

The European-Asian mid-latitude desert steppe is a transitional type that connects the desert and the typical steppe (Han et al. 2009). It is very sensitive to global climate change, especially on the Mongolian Plateau where climate change is occurring at a pronounced pace (Qi et al. 2012, Liu et al. 2013, IPCC 2014, Chen et al. 2015*b*), with an increases of 0.35°C per 10 years in mean air temperature since 1955 (Lu et al. 2009, John et al. 2016), and a decreasing trend of precipitation frequency and 7% (i.e., 22 mm) in precipitation in central Mongolia (Li et al. 2006, Chen et al. 2013). In this region, grazing coupled with these climate changes have shown already substantial effects on the ecological (e.g., biogeochemical cycling and community dynamics) and hydrological processes (Polley et al. 2008, Groisman et al. 2009, Han et al. 2014, Liu et al. 2014). Quantifying the energy fluxes of grazed and ungrazed desert steppes is therefore an essential step for understanding the role of semiarid temperate grasslands in local-to-global climate and land use changes (Chen et al. 2015*a*).

Changes in community composition and structure will result in changes of the regime of energy balance (EB) components, including latent heat flux (LE, a measure of evapotranspiration), sensible heat flux (H), net radiation (R_n), and soil heat flux (G) and their partitioning. Grazing

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