Grazing effects on hydraulic, thermal and mechanical soil properties at multiple spatial scales — a case study in Inner Mongolia grassland

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Summary

Over-grazing has been regarded as a main cause for grassland degradation in Inner Mongolia. Given the vital importance for the production of live stock and the environmental changes, it is crucial to have a thorough understanding of the mechanisms that maintain or change the ecosystem in response to the changes of land management.

Intensive observations, analysis and modeling of environmental changes in Inner Mongolia grassland were carried out within the framework of project MAGIM: Matter fluxes in grasslands of Inner Mongolia as influenced by stocking rate (2004-2007). Based on this, we concentrated into investigations of soil physical, hydrological and ecological processes in general and modeling the effects of grazing management (i.e. ungrazed since 1979=UG 79, ungrazed since 1999=UG 99, winter grazed=WG, continuously grazed=CG and heavily grazed=HG) on water and heat fluxes in particular.

Geostatistical analysis showed that soil properties including soil water content (SWC), hydraulic conductivity (Ks), water drop penetration time (WDPT), shear strength (SS), soil organic carbon (SOC) concentration, bulk density (BD) and soil texture exhibited a moderate or strong spatial dependency. Multiple regression analysis showed significant correlations among SWC, Ks, WDPT, SOC and BD; as well as between SS and silt content, indicating that soil properties are interrelated with each other at the same location. Furthermore, multivariate geostatistical analysis revealed scale-dependent correlations among water-related variables. We observed that the soil and plant variables (e.g. soil texture, SOC, and biomass), which were affected by land management, are main contributors to the variations of soil moisture at different spatial scales. It suggests that current pasture management strongly modified soil moisture patterns, e.g. a more homogenous spatial distribution in HG, which should be considered in the co-regionalizing hydrological models.

In addition, a combination of in situ monitoring with process oriented modeling was used to evaluate the grazing effects on water and heat fluxes. The representativeness of the selected locations was justified using the time stability concept. We proofed that even though only one location is selected, the field mean water content was estimated with a high precision. Especially, a hydraulic model applied in time stability point (TSP) was validated to express well both the measured water contents of TSP as well as field mean water contents.

Grazing had an influence on soil hydraulic, thermal and mechanical properties. Grazing resulted in decreased SWC, SOC and WDPT but increased BD and SS. Structural changes due to grazing were also reflected by decreased values of Ks and modified water retention characteristics. Compared with the ungrazed sites, the total- and macro-pore volume decreased in the grazed sites.

Those grazing-induced changes were further used to parameterize the model HYDRUS-1D. It was verified with a reasonable agreement between simulated and measured data. The results indicated that soil heat fluxes increased with increasing grazing intensity. In comparison with the ungrazed sites, winter grazing did not show any effect on the water household components, while heavy grazing remarkably decreased soil water storage by 25-45%, interception by 50-55% and transpiration by 20-30%, and increased evaporation by 25-40%, runoff by 100-300% and drainage by 100-200%. We conclude that intense grazing deteriorates soil functions, consequently reduces plant available water and thus grassland productivity.

Furthermore, an extended freezing code in the HYDRUS-1D model is capable of predicting the changes in soil water and heat fluxes accompanied by soil freezing and thawing behavior as well as grazing effects.