INFLUENCE OF VARIOUS GRAZING INTENSITIES ON SOIL STABILITY AND SOIL WATER BALANCE IN INNER MONGOLIA, P.R. CHINA

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ABSTRACT

Increasing grazing intensities (sheep, goats) in Inner Mongolia, P.R. China, have lead to a broad degradation of the grassland, accompanied by increased soil erosion and desertification. The research group MAGIM (Matter Fluxes in Grasslands of Inner Mongolia as influenced by stocking rate), consisting of 9 subprojects belonging to different environmental sciences, investigates the effects of various landuse systems on water- and matter fluxes and on soil erosion. The subproject presented here analyzes the influence of various grazing intensities on soil stability and soil water balance. Soil mechanical properties and soil hydraulic functions have found to be influenced by grazing which is reflected by increasing values of precompression stress, decreasing shear resistance and hydraulic conductivity with increasing grazing/trampling intensity. Furthermore, the anisotropy of saturated hydraulic conductivity is affected by trampling. Dynamic compressive and shearing loads generated by sheep trampling result in soil structure degradation with negative consequences for plant available water and soil erosion.

KEYWORDS: *grassland, anisotropy of hydraulic conductivity, precompression stress*

INTRODUCTION

The experimental area is situated about 500 km north of Beijing in the Xilin river catchment. The investigated soils are Chernozems under *Leymus chinensis*- and *Stipa grandis* steppe and the annual precipitation is about 300 mm.

Increasing grazing intensities (sheep, goats) in Inner Mongolia, P.R. China, are reported to lead to an increasing degradation of the grassland followed by increasing soil erosion and desertification (OJIMA et al., 1993; WHITE et al., 2000; SCHLESINGER et al., 1990). This can be explained by a soil structure change due to sheep trampling and may result in a reduced infiltration of water and strength of the soil. Therefore the danger of surface run-off, accompanied by an enhanced erosion of the soil, is increased.

To estimate the influence of grazing on soil physical properties, we investigated four plots with different grazing intensities. In order to quantify soil stability, the precompression stress value and the shear resistance of the bulk soil were determined. Furthermore, the saturated hydraulic conductivity was measured in vertical and horizontal direction to estimate the influence of trampling on soil functions.

MATERIAL AND METHODS

The experimental area is situated in Inner Mongolia, P.R. China, ca. 500 km north of Beijing close to the city of Xilinhot. The investigated soils are Chernozems under *Leymus chinensis*- and *Stipa grandis*- steppe, respectively. The mean annual precipitation is about 300mm with mainly sporadic intense rainfalls.

We investigated four plots with different grazing intensities (Ungrazed since 1979=UG 79, Ungrazed since 1999=UG 99, Winter Grazing with 1.3 sheep units=WG and Overgrazed=OG), where undisturbed soil samples in four different depths (4-8 cm; 18-22 cm; 30-34 cm; 40-44 cm) were taken.

Precompression stresses were determined under confined compression behaviour (Multistep-oedometer, drained, 5 replicates) and the shear parameters have been measured in a frame shear test under consolidated and drained conditions for the first depth (5 replicates). Before testing, the samples have been equilibrated to a standard matric suction of -30 kPa using a suction plate assembly. Saturated hydraulic conductivities were determined with the falling head method for all 4 depths for vertically orientated samples (7 replicates). Additionally the saturated hydraulic conductivity was measured also in the horizontal direction in the first two depths (7 replicates) to be able to characterize the anisotropy of the saturated hydraulic conductivity.

RESULTS AND DISCUSSION

PRECOMPRESSION STRESS

The values of precompression stress of the first depth are significantly lower on the ungrazed sites than on the grazed sites, while the site that is protected from grazing the longest time (UG79) is lowest (Figure.1). Higher values on the grazed sites reflect the higher mechanical stability the soil gains through grazing (GREENWOOD et al., 1997) and sheep trampling, respectively, which affects mostly the topsoil layer up to a depth of 10-15 cm (DONKOR et al., 2001, GREENWOOD & McKenzie, 2001; HIERNAUX et al., 1999 ZHANG & HORN, 1996). The measured values of precompression stress reflect the static ground contact pressure of an average sheep (~80 kPa).

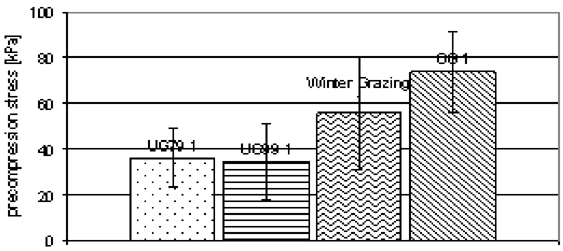

Figure 1:Precompression value [kPa] for Ungrazed since 1979 (UG79), Ungrazed since 1999 (UG99), Winter Grazing and Overgrazed (OG) sites. (1) denotes the first depth (4-8cm). The error bars show the standard deviation

Shear resistance

The comparison of the failure line of one grazed (figure 2a) and one ungrazed (figure 2b) site shows that grazing leads to an increased cohesion (c) (UG79: c=14.2 kPa, WG: c=38.8 kPa), which can be attributed to an increased number of contact points between soil particles. However, due to grazing the angle of internal friction is decreased from 40,4° to 24,9° which points at a structural degradation of the soil.

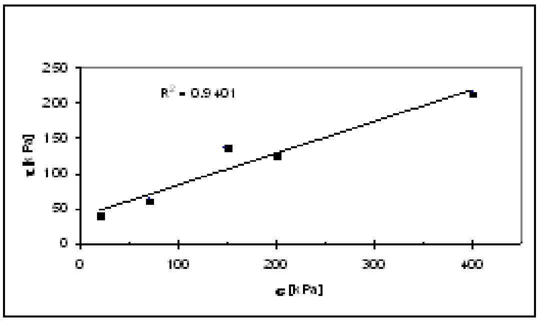

Figure 2a

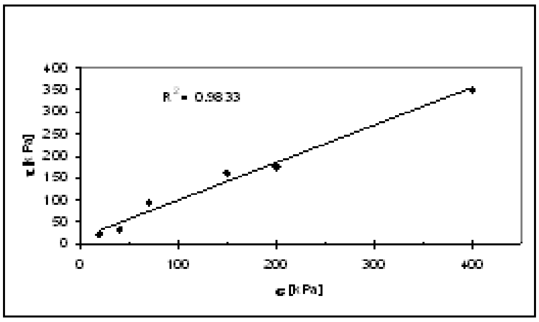

Figure 2b

Figure. 2: Mohr-Coulomb failure line for the topsoil of the winter grazed site (WG) (2a) and the ungrazed site (UG79) (2b). Cohesion=38,8 kPa, angle of internal friction=24,9° for WG (a) and 14,2 kPa and 40,4° for UG79 (b), respectively.

Saturated hydraulic conductivity

The values of saturated hydraulic conductivity (K) are highest on the site that is ungrazed since 1979, displaying decreasing values with increasing depth. (Figure 3). The site that is ungrazed since 1999 shows a similar trend with values about half as high as on the UG79. The WG site shows this trend in the last three depths, but in the first depth the value is decreased due to sheep trampling, which mostly affects the first 10-15 cm (ZHANG & HORN, 1996). Mainly wider coarse pores (> 50 mm), which are the dominant fraction of pores conducting water near saturation, are reduced due to sheep trampling (GREENWOOD et al., 1997; WILLAT &PULLAR, 1983). The higher standard deviation on the ungrazed sites can be explained by structure reformation. The relatively low standard deviation on the OG site and the first depth of the WG site, in contrast, can be explained by soil homogenization caused by repeated sheep trampling. The relatively high level of saturated hydraulic conductivity on the OG site in all depths compared to the other sites is suggested to be related to a more sandy soil texture.

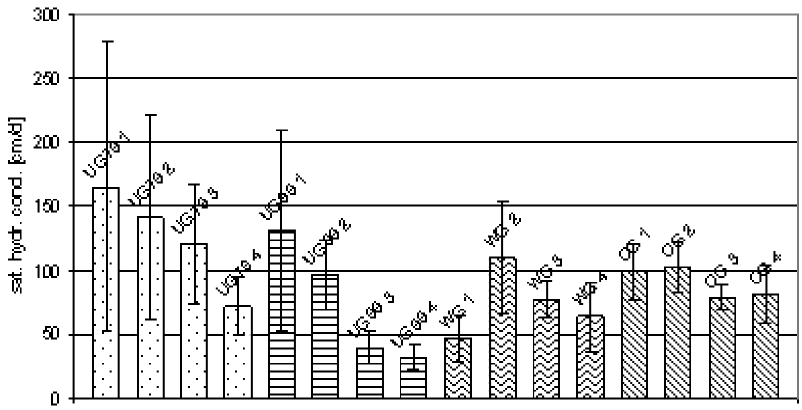

Figure 3:Influence of grazing on saturated hydraulic conductivity [cm/d]. 1; 2; 3; 4 denote the four different depths (1,2,3,4). The error bars show the standard deviation.

Anisotropy of saturated hydraulic conductivity (K)

On the WG site in the first depth anisotropy of K with higher values in the horizontal direction was found (Figure 4a). This points at a platy soil structure that developed under repeated mechanical loading of the soil due to sheep trampling (Zhang, 1996), mainly in the upper 10-20 cm (MARTINEZ & ZINCK, 2004).

If a platy-structured soil is protected from mechanical loads, the first new cracks will form vertically (BABEL et al., 1995); this may lead to an inversion of the anisotropy of K with higher values in the vertical direction as to be seen in figure 4b. A high biologic activity in the soil may enhance this anisotropy.

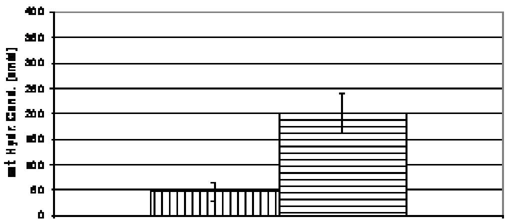

Figure 4a

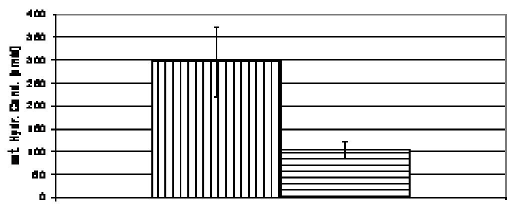

Figure 4b

Figure. 4: Saturated hydraulic conductivity [cm/d] for the winter grazed site (WG) (4a) and the ungrazed site (UG79) (4b) as a function of sampling direction. Vertical stripes = vertical saturated hydraulic conductivity, horizontal stripes = horizontal saturated hydraulic conductivity. The error bars show the standard deviation.

CONCLUSION

The values of precompression stress have been increased by sheep trampling during grazing in the topsoil layer, which points at a structural change of the soil accompanied by an increase in soil stability. This, on the one hand, results in a higher soil resistance to deformation caused by further trampling. On the other hand it proves that animal trampling leads to a soil structural change, which has consequences for soil functioning such as hydraulic conductivity. Furthermore, precompression stresses at the overgrazed site emphasize the effect of repeated loading on soil deformation. To investigate effects of soil deformation due to repeated loading cyclic loading oedometer tests will be conducted in further studies. The values of cohesion and the angle of internal friction also reflect the structural change of the soil during grazing and protection from grazing, respectively. The cohesion is increased by grazing through the increasing number of contact points between soil particles, while the angle of internal friction is reduced by weakening the soil structure.

In this study it could be shown that grazing decreases the saturated hydraulic conductivity, which is most obvious for the topsoil layer. However, this will reduce the infiltration capacity of the soil and may, especially during heavy rainstorms, which are not seldom encountered in Inner Mongolia, lead to increased surface runoff and hence initiate soil erosion. The risk for horizontal water flow and hence solute and particle bound nutrient transport is also indicated by the anisotropy of the saturated hydraulic conductivity at the winter grazing site which is the result of the development of a platy soil structure. This can even more be expected in cases where the soil texture contains a higher fraction of clay particles. Under such circumstances both the low saturated hydraulic conductivity in the subsoil as well as the possible development of a platy soil structure under heavy trampling may increase the risk of soil degradation. Under the prevailing climatic conditions in Inner Mongolia soil water is one of the most limiting factors for plant growth, and therefore especially the change in hydraulic conductivity resulting from soil deformation is of major importance for future pasture productivity. Our results show that heavy grazing adversely affects soil hydraulic functions and therefore is assumed to be one of the reasons for less productive pastures.

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