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Carbon sequestration in degraded semi-arid grasslands of Northern China

Martin Wiesmeier, Markus Steffens, Angelika Kölbl, and Ingrid Kögel-Knabner
TU München, Lehrstuhl für Bodenkunde, Freising, Germany (wiesmeier@wzw.tum.de)

Soils in semi-arid grasslands are discussed to store significant amounts of soil organic carbon (SOC) and to be of global importance for carbon sequestration. However, land use changes, in particular overgrazing, caused a large release of SOC in the last decades. The aim of this study was to investigate the carbon sequestration potential of degraded grasslands after grazing cessation and to reveal the stabilization processes of soil organic matter (SOM). Intensively grazed as well as ungrazed experimental sites were sampled in Inner Mongolia, Northern China, to study the amount, spatial distribution and stabilization of SOM. In order to determine short-term effects of grazing cessation, a controlled grazing experiment was established in 2005. Topsoil samples were taken in 2005 and again in 2008 from ungrazed (UG05), moderately grazed (MG) and heavily grazed plots (HG) and analyzed for chemical and physical soil properties. The effects of long-term grazing exclusion were investigated in detail at ungrazed sites that were fenced in 1979 (UG79) and compared to adjacent continuously grazed sites (CG). To elucidate the spatial structure of selected topsoil parameters at the field scale, 100 grid points with spacings of 5 m and 15 m were sampled. For detection of small-scale variability at the plant scale, 40 randomly selected points were sampled inside areas of 2 m $\times$ 2 m at each plot. Semivariances were calculated for the determined soil properties. To quantify the contribution of single SOC fractions to carbon sequestration, a combined density and particle size fractionation was applied. Carbon mineralization was determined in an incubation experiment for a period of one month for UG79 and CG sites.
Grazing exclusion led to a significant increase of SOC in the topsoil already three years after grazing exclusion and resulted in 35% higher amounts after 30 years. This increase is based on higher input of particulate organic matter (POM) and on increased amount of labile SOM physically protected within soil aggregates. This was evident as carbon mineralization of grazed sites with lower amounts of aggregate occluded POM was considerably higher compared to ungrazed sites. The ongoing carbon sequestration at long-term ungrazed grasslands indicates a high potential of degraded semi-arid steppes for mitigation of climate change after cessation of grazing. Analysis of the spatial distribution of SOM showed a heterogeneous pattern for ungrazed sites and a homogeneous distribution for grazed sites. Apparently, the recovery after grazing cessation starts with the formation of “islands of fertility”, where a higher input of water and organic matter promotes the development of vegetation and associated SOM patches. We conclude that grazing exclusion in degraded semi-arid grasslands has a high potential to immediately sequester atmospheric carbon and mitigate climate change.