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Aggregate stability and potential erodibility of dry steppe soils

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Erosion caused by extreme climate conditions and intense agricultural use is a severe threat to the soil quality of dry steppe ecosystems. The susceptibility of soil to erosion depends mainly on the stability of its structure against mechanical stress, which is directly related to the stability of aggregates. However, there is no generally accepted method to determine soil aggregate stability and most tests cannot be adequately linked to disruptive forces soils experience under field conditions. Thus, our main objective was to explore the aggregate stability of steppe soils against disruptive stresses by wind and water to assess their potential erodibility. We examined 132 topsoil samples from northern Kazakhstan under two land-use types (grassland and cropland), covering a large range of physico-chemical soil properties (texture, organic carbon, inorganic carbon, pH, and electrical conductivity). We combined several methods that capture the soil`s susceptibility against mechanical stresses common in the dry continental climate: An adjusted drop-shatter technique (energy input of 60 Joule) was used to estimate the stability of dry soil against weak mechanical forces, such as wind stroking over bare soil after tillage and before crop emergence. In addition, three wet-aggregate stability tests (fast wetting, slow wetting, and wet mechanical breakdown) were used to estimate the stability of soil aggregates under various stresses caused by precipitation. Results indicate that aggregate stability was generally higher for grassland than cropland soils. Aggregate stability under both land-use types decreased along with increasing sand and decreasing organic carbon contents. The drop-shatter method suggested that only 5% of cropland soils were at high risk of wind erosion (i.e., erodible fraction <60%). In contrast, the fast wetting test revealed that 98% of the samples are unstable after a heavy rain event or snowmelt. Even after a light rain event or the raindrop impact, 54-58% of the samples were unstable and prone to erosion.

We conclude that cropland in the dry steppe of Kazakhstan is much more vulnerable to the disruptive forces caused by water than by wind. Especially the severe breakdown of aggregates during heavy rain events or snowmelts goes well in line with the increasing erosion risk under current and future climate scenarios.