The Development and Use of Spatially Explicit Erodible Soil Indices for Nebraska

Rainwater Basin Joint Venture Report
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Andy Bishop[1], Neil Dominy[2], Roger Grosse[1], Christopher Jorgensen[1], Kelly Klenke[2], and Daniel Shurtliff[2]
[1]Rainwater Basin Joint Venture, Grand Island, NE
[2]U.S. Department of Agriculture's Natural Resources Conservation Service, Lincoln, NE

Introduction

Anthropogenically accelerated soil erosion has significantly increased over the past 60 years and is widely attributed to land degradation throughout the world. Unlike the slow geologic erosion process, which is caused by displacement of soil over time by a variety of mechanisms (e.g., flooding, runoff, wind, gravity, etc.) and can be beneficial for soil fertility renewal, human-induced accelerated soil loss can be extremely destructive (i.e., United States 1930s Dust Bowl). Wind and water erosion can remove fine organic particles from the substrate, leaving behind a coarse, nutrient-depleted soil. Severely nutrient-depleted soils can stunt plant growth and reduce crop yields up to 30% compared to un-eroded soils. Even more alarming, continuous soil loss can lead to arable land becoming unproductive. As land is rendered infertile, grassland and forests are continually being cut, plowed, and converted to fulfill agricultural demands. Additional costs to society, including sedimentation and pollution of waterways, property damage, and impairment to fisheries are some of the many additive effects of culturally accelerated soil erosion and are externalized to local communities, states, and regions.

In the United States, anthropogenically accelerated soil erosion has consistently been an issue in regions that use traditional cropping practices. Consequently, in the last century various federal and state programs have been established to offer landowners incentives to reduce soil erosion by shifting lands with highly erodible soils out of production and into various soil conservation practices. Although we are more aware of the negative effects and mitigation of soil erosion in today's agricultural practices, soil erosion continues to be an issue.

In order to help pinpoint areas with potentially elevated wind and water erosion, various erodibility models have been developed (e.g., Universal Soil Loss Equation [USLE], Revised Universal Soil Loss Equation [RUSLE], Wind Erosion Equation [WEQ], etc.). Although the USLE was originally intended to assist soil conservationists in planning farming practices, today soil erosion indices are useful to professionals in a broad set of disciplines, including agricultural economists, wildlife biologists, and foresters. Ecologists and conservationists use soil erosion indices to strategically target land parcels for conservation or farming practices that reduce soil loss and increase wildlife habitat (e.g., establish prairie for grassland birds), while still meeting the requirements of the land manager or farmer. Moreover, since their inception, various soil indices have been implemented to estimate the regional and national impacts of anthropogenically accelerated soil erosion, and in developing public policy.

To help pinpoint specific regions that contain highly erodible soils and are well suited for establishing conservation practices to reduce soil loss in Nebraska, U.S.A., the Rainwater Basin Joint Venture worked in cooperation with the U.S. Department of Agriculture's Natural Resources Conservation Service to construct a Wind and Water Erodibility Index using the Soil Survey Geographic (SSURGO) database. Our objectives were to produce statewide spatially explicit Geographic Information System (GIS) layers indicating highly erodible soils to aid in conservation planning and design.

Methods

Data Procurement and Processing

We obtained statewide spatially explicit gridded soil survey data for Nebraska from the Soil Survey Geographic (SSURGO) database. The 'chorizon,' 'chtexture,' 'chtexturegrp,' 'mapunit,' and 'mutext' tables in the Gridded SSURGO database were joined together using the "mukey" attribute field in a geographic information system (GIS). The representative values for slope (rvslope) and slope length (rvslopelenusle), the susceptibility of the soil to water erosion (Kw), and the soil loss tolerance (t_fact) values were obtained from the set of joined tables and were included in the Water Erosion Index calculation. We acquired county-specific rainfall and runoff factor values (R) from the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS). Fields used in calculating the Wind Erosion Index calculation, such as the susceptibility of soils to wind erosion (wei), and the county specific climate characterization of wind speed and surface soil moisture values (C), were obtained from the joined SSURGO tables or from the NRCS, respectively.

Calculating and Developing Erosion Indices

We used a modified version of the Universal Soil Loss Equation (USLE) to create the Water Erosion Index for Nebraska. In order to calculate the combined effects of Slope Length and Steepness (LS) on water erosion, we first adjusted any null representative slope length values (rvslopelenusle) using a predefined criterion. Furthermore, we adjusted the LS equation to more accurately compute soil loss on irregular slopes (i.e., appreciably convex, concave, or complex) such as those found in cropland, ranging from 3 to 18 percent steepness. We added an exponent (*m*) to the LS equation, where *m* is 0.5 if the percent slope is *5* or more, 0.4 on slopes of 3.5 to 4.5 percent, 0.3 on slopes of 1 to 3 percent, and 0.2 on uniform gradients of less than 1 percent. Based on the LS equation for irregular slopes, we calculated out LS using:

$$((0.065 + (0.0456 * \mathrm{rvslope}) + (0.006541 * (\mathrm{rvslope}^\wedge 2))) * ((\mathrm{rvslopelenusle} / 22.1) ^\wedge m))$$

We combined the remaining factors used in the USLE with the LS values, and the final index for sheet and rill erosion was calculated using the formula:

$$\frac{R*Kw*LS}{t\_fact}$$

In order to estimate the potential erodibility caused by wind, we used a modified version of the Wind Erosion Equation (WEQ). We reduced the climate characterization of wind speed and surface soil moisture values (C) by a factor of 10. We then multiplied the values representing the susceptibility of soils to wind erosion (wei) with the reduced C values and divided the product by the potential maximum annual rate of soil erosion that can take place without reducing long-term productivity (t_fact). The potential Wind Erodibility Index calculation is represented by the formula:

$$\frac{(C*0.1)*wei}{t\_fact}$$

To identify areas in Nebraska containing highly erodible soils, we modified the wind erosion and water erosion indices by reclassifying raster values greater than 8 to a value of 1, and everything else to a value of 0, using a GIS. The two reclassified erosion indices were combined into a single GIS raster dataset. Soils in the resulting raster dataset are considered highly erodible if either of the wind erosion or water erosion indices have an erosion index value greater than 8. The final Highly Erodible Soils Index raster dataset has a resolution of 10 x 10 m.

Results and Discussion

Water Erosion Index values ranged from 0 – 314, where higher values represent greater erosion potential. The resulting Water Erosion Index for Nebraska showed a number of regions throughout the state as having an elevated potential for severe rill and sheet erosion. Parts of the Missouri River Valley, Panhandle (i.e., Pine Ridge), the southwest (i.e., Loess Canyons), and central (i.e., Loess Hills) regions of the state are all indicated as having high water erosion potential. Even more alarming, many of these regions are considered Biologically Unique Landscapes in the Nebraska's State Wildlife Action Plan and represent biodiversity hotspots in the state. These regions are prime examples of places where soil conservation practices may help reduce soil loss due to water erosion and provide additional benefits to wildlife by improving or even increasing habitat.

The Wind Erosion Index values ranged from 0 – 66, where higher values indicate more erosion potential. The resulting model showed regions containing loose, sandy soils as being susceptible to erosion. Not surprisingly, a large portion of the Sandhills region in central Nebraska was indicated as being at risk for wind erosion. Additional regions, including parts of the Panhandle and the southwestern corner of the state, are also indicated as having high potential for wind erosion.

Based on the soil properties and the wind and water erosion calculations, the resulting Highly Erodible Soils Index for Nebraska shows a large portion of the state as having high soil erodibility potential (Figure 1). Given the low erodibility threshold value of eight, which was the cut-off value used to reclassify the wind and water erosion indices to 'highly erodible' and 'not highly erodible,' we suspect the model is a conservative estimate of what is truly at risk for soil erosion. However, given the significant amounts of land in the state that contain loess or sandy soils, it is not surprising that much of the soil in Nebraska is considered highly erodible. Farmers, land operators, and managers may want to take special precautions when planning farming or other land-use practices in these at-risk regions of the state.

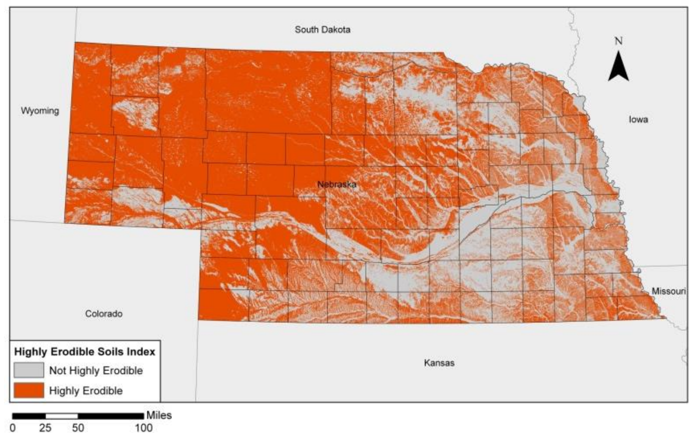

Figure 1. The Highly Erodible Soil Index was constructed by reclassifying Water Erodibility and Wind Erodibility Indices for Nebraska, where any water or wind erosion values over 8 were reclassified as being highly erodible.

The resulting wind, water, and highly erodible soil indices may be an effective means to pinpoint regions in need of special conservation attention, and certainly have been used in similar fashion in the past. Furthermore, these GIS layers can be used in conjunction with other spatially explicit datasets for Nebraska, such as Groundwater Management Areas (established by Nebraska's Natural Resource Districts) or species distribution models, to better inform decision makers as to which conservation practices are most appropriate to meet multiple objectives, and where to implement conservation programs in the landscape to gain the most benefit from each conservation dollar. Decision support systems of this nature allow policy makers and managers a means to compromise and meet multiple objectives established by stakeholders from a variety of conservation disciplines.

For additional information regarding the analysis, results and discussion consult the full document.