Integrating the USLE into ArcGIS 9.2:

Predicting Annual Soil Loss from the Plant Sciences Research Farm

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Introduction

The Universal Soil Loss Equation (USLE) is an empirical soil loss model for predicting average annual soil erosion from agriculture fields (Wischmeier and Smith 1976). It was derived from over 11,000 plots years of data from 47 locations in 24 states. The USLE best predicts sheet erosion on uniform slopes, making the model most applicable to modern agriculture soil erosion.

Integration of the USLE into a GIS software package such as ArcGIS allows for the prediction of soil loss over expanded areas with multiple land uses and vegetation cover, while at the same time posing new problems for the determination of the model's empirically-derived inputs.

The University of Georgia Plant Sciences Research Farm near Watkinsville, GA was used to show the benefits and difficulties of implementing the USLE into ArcGIS 9.2.

The USLE

The USLE is the product of five soil erosion factors:

$$A = R \times K \times LS \times C \times P$$

Avg. Annual Soil Loss (tons ac^{-1} yr^{-1})

Rainfall Erosivity

Soil Erodibility

Length-Slope Factor

Crop Cover

Conservation Practices

Rainfall Erosivity

The R factor is based on the kinetic energy of rain drops and the maximum intensity of rainfall in a 30 minute timeframe.

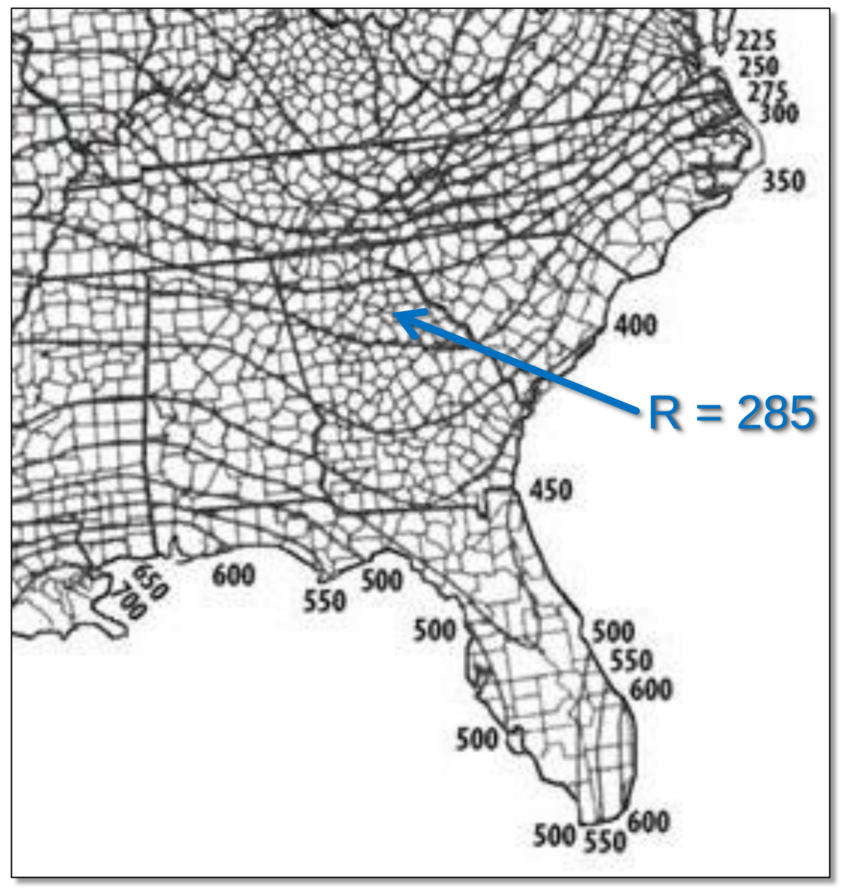

Figure 1. Isoerodent map of R factors for Southeastern US

Soil Erodibility

The K factor is determined by the soil texture, % organic matter, aggregate structure, and water permeability.

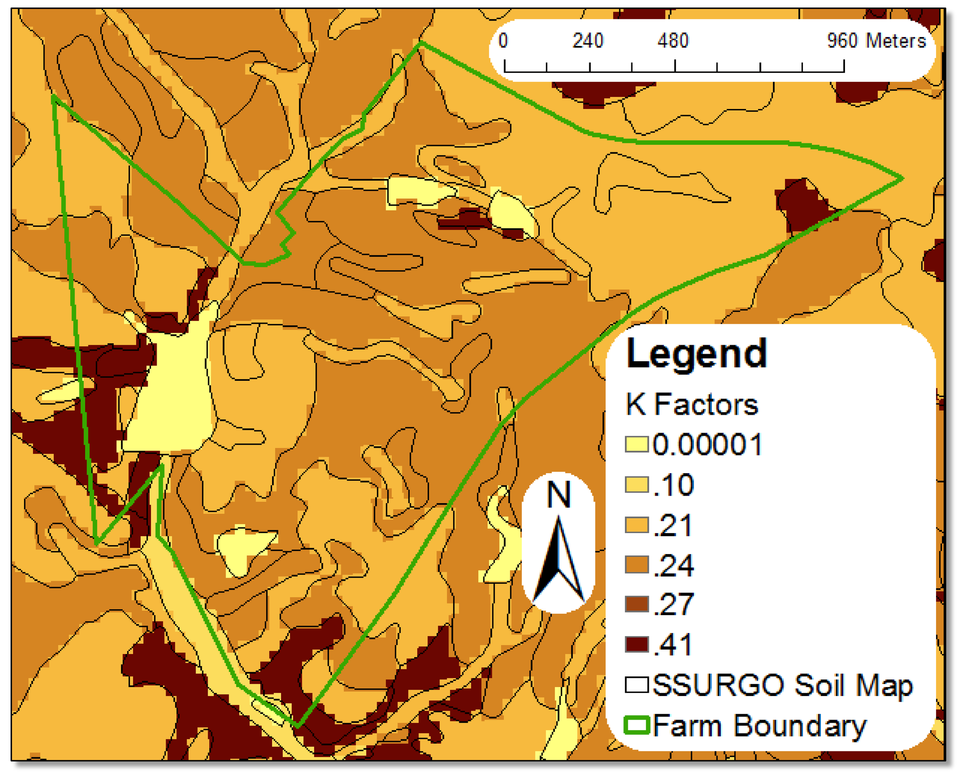

Figure 2. Digitized K factor values in raster format

Length-Slope

The LS factor originally applied to a 2-D uniform hillslope, where L = length of slope and S = % slope. When considering a 3-D landscape as in GIS the length of slope is difficult to quantify because of landscape irregularities. Desmet and Govers (1995) proposed a method of automatically calculating the LS factor using *flow accumulation* derived from Digital Elevation Models (DEM):

$$LS = (FA * \text{cell size} / 22.13)^{0.4} * (\sin S / 0.0896)^{1.3}$$

where **FA** is flow accumulation, as calculated by ArcHydro Tools 9 from a DEM, **cell size** is the length (m) of the DEM cell side, and **S** is the slope expressed as radians.

The LS factor calculated with this formula results in values of zero for areas with minimal to no slope, resulting in A = 0. Therefore, the lowest allowed LS value was set to 0.06, which represents a LS value for a 25 ft slope at 0.2%.

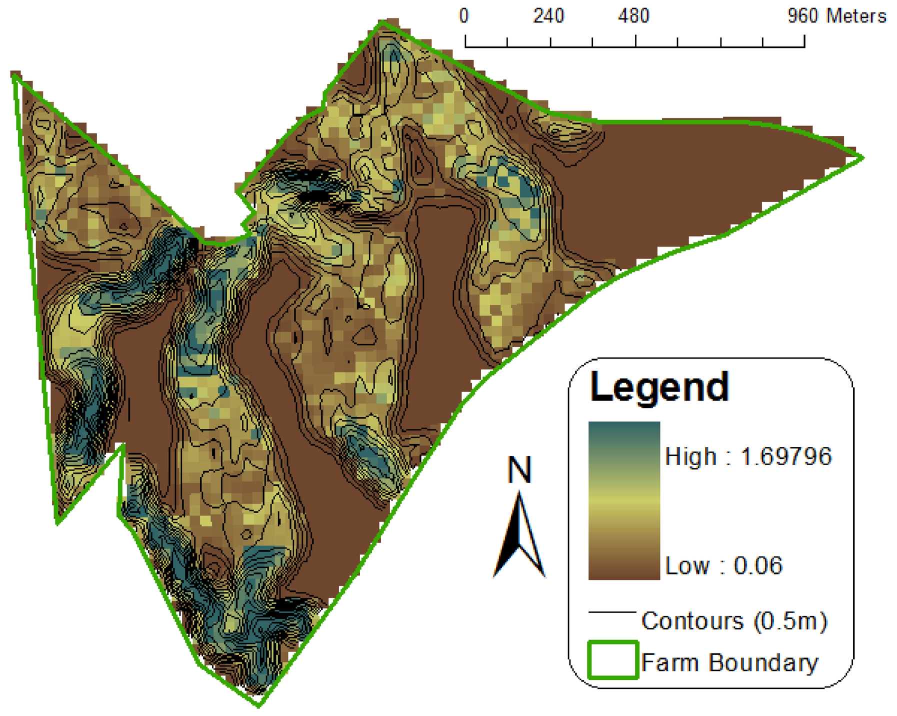

Figure 3. LS values derived from DEM and flow accumulation

Crop Cover

The C factor is determined from DOQQs and digitizing "field boundaries" by land cover/use, assigning each a specific value.

Conservation Practices

The most common conservation practice is plowing along the contours, which was assumed to be practiced on the farm. The values differ between minimal (1-2%) and moderate (2-8%) slope.

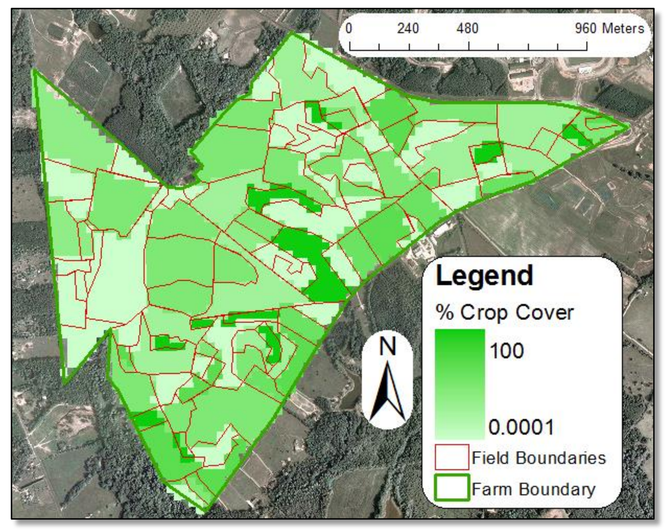

Figure 4. C factor values

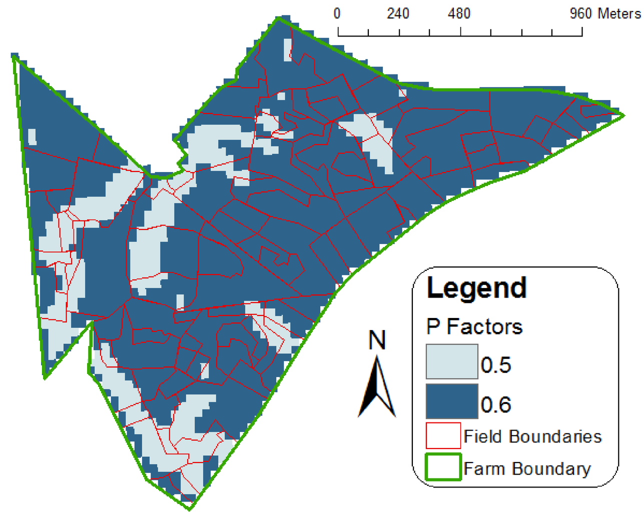

Figure 5. P factor values

Average Annual Soil Loss

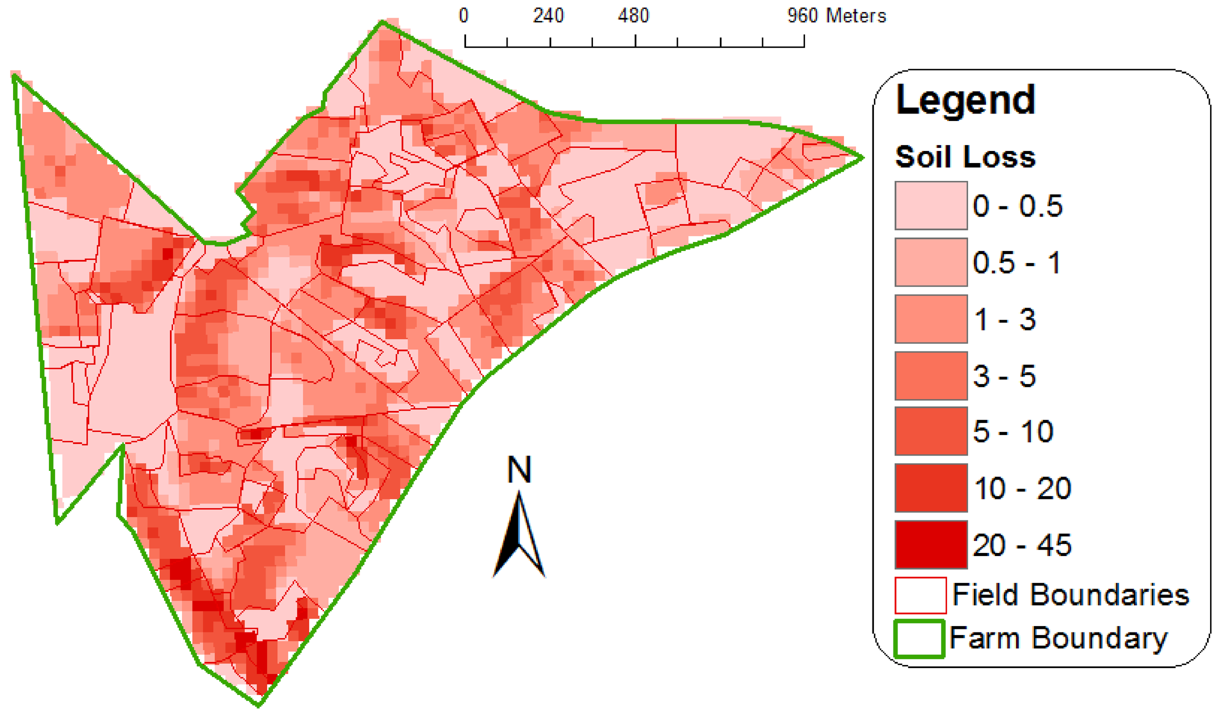

Figure 6. Average annual soil loss in tons acre^{-1} year^{-1}

Discussion

Errors associated with implementing the USLE into GIS are consideration of depositional areas, data resolution/quality, and replacing empirically derived input factors with 3-D spatial data.

Net erosion does not occur in depositional areas, but the LS values are generally the greatest where the most flow accumulation is, e.g. the farm ponds. This error is made null by the near zero K values (1x10^{-5}) given to inundated soils.

DEM resolution (30m) can be a problem when considering small areas as it is used to calculate flow accumulation.

Benefits are a visual reference for where to focus erosion control practices while being able to quantify a practice's effectiveness.

References

Wischmeier and Smith. 1976. Predicting rainfall erosion losses – a guide to conservation planning. U.S. Department of Agriculture, Agriculture Handbook No 537.

Desmet and Govers. 1995. GIS-based simulation of erosion and deposition patterns in an agricultural landscape: a comparison of model results with soil map information. Catena (25:389-401).