Using GIS to Estimate Soil Loss Rates in Denton County, Texas

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Research Problem

Soil loss is a fundamental local, national, and global issue. Related effects include: long-term loss of soil fertility; non-point source water pollution (sediment); filling of reservoirs; and aquatic habitat degradation (Brady and Weil 2000, pp. 473-476).

Objective

The research objective is to investigate local soil loss rates through geographic information system (GIS) analysis.

Study area

The study area is Denton County, Texas, located at the northern apex of the Dallas-Fort Worth metropolitan area. The landscape is dominated by cross-timbers and bottomland forest, grand prairie, cropland, reservoirs, and urban/suburban growth. Denton County population has grown from 75,633 in 1970 to 143,126 in 1980 and 276,083 in 1990. Most of the industrial, commercial, and population growth has occurred in southern Denton County. The northern part of the county is a center for horse ranches and cropland producing wheat, cotton, beef and dairy cattle (Denton County Department of Information Services 2001).

Literature Review

Atkinson *et al.* (1988) completed a report for City of Dallas, using GIS and remote sensing. They found non-point source pollution to be an increasing problem in the City of Dallas' western watersheds. The report states that the Universal Soil Loss Equation (USLE) model is most accurate for medium-textured soils, slope lengths of less than 400 feet, gradients of 3 to 18%, and consistent cropping and management systems that have been represented in erosion plot studies.

Construction site factors have been formulated enabling the model to be more applicable to multi-use, urban watersheds. Applying the equation for factors that cannot be accurately determined is a misuse. Complex watersheds should be divided into areas for which representative values of the six factors can be defined.

Bruce Hunter (1990) completed a master's thesis comparing use of GIS, remote sensing, and the USLE model with field calculation of USLE factors. His methodology incorporated several assumed constant values, such as R, P, and slope length. The thesis found that the USLE model was capable of identifying the same areas of high erosion potential as those identified by a Soil Conservation Service survey, plus additional areas of concern

Burroughs and McDonnell (1998), a GIS textbook, indicates that empirical models of soil erosion can be useful because data is relatively easy to find and analyze (p. 174-175). Specialized models for specific locations often require data that is not found in generally accessible databases. Models are often limited in ability to analyze sediment transport over large areas. The authors recommend setting up a local drain direction (LDD) network to allow inclusion of a transport component to the model (pp. 207-208).

Hudak *et al.* (2000), an article in *Geospatial Solutions* resulting from a previous class in Advanced GIS, identified areas of highest concern for erosion risk in Denton County. The authors used a modified USLE model with only three components – the output was not in USLE units of soils loss (tons per acre per year). Their model was:

H (hazard) = K (soil structure, grain size, permeability) *
C (vegetative cover) * S (slope percent)

The County was broken down into low risk (57%), medium risk (30%), and high risk (3%). Areas of highest risk correspond to three layers – a northeast trending belt of erosive sandstone, agricultural fields with low cover, and steep slopes along streams and reservoir boundaries.

Slope had the strongest influence on ratings - results were skewed by the different parameter for slope percent (0-12, versus 0-1 for K and C). The USLE model incorporates slope indirectly through a model factor LS related to slope length (L) and slope percent (S) (Table 3, p. 53, Hunter 1990)

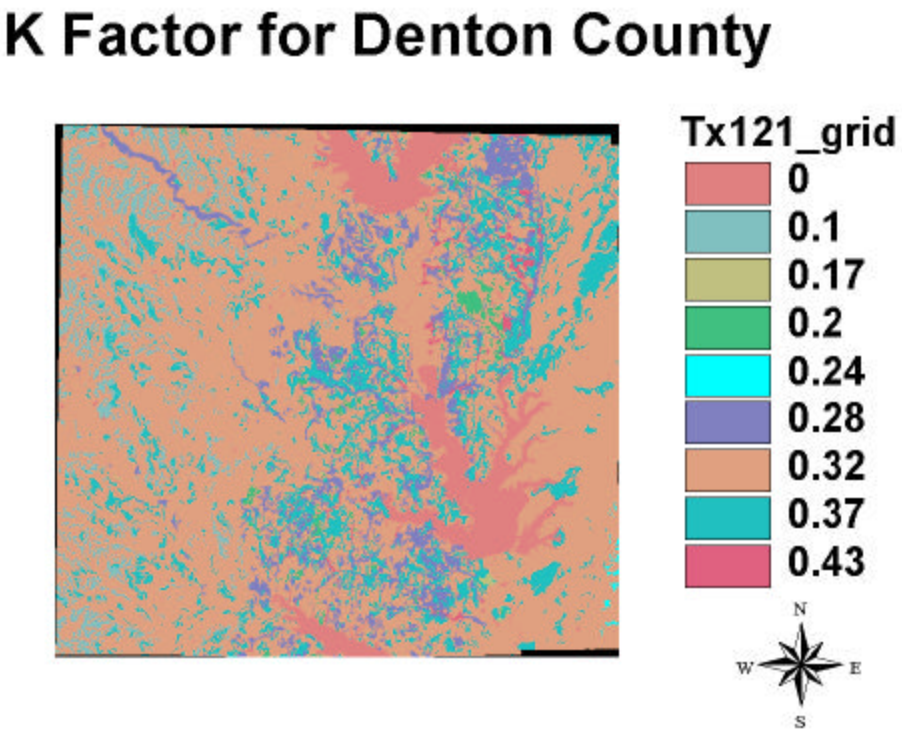
Methodology

The Universal Soil Loss Equation (USLE) will be used to predict soil loss in Denton County. The model was developed by Wischmeier and Smith in 1978. It is the basis for newer models such as EPIC. Its output is given in predicted soil loss (tons/acre/year). It is written as:

$$A=R*K*LS*C*P$$

Arcview map calculator were used to create a composite of R, K, LS, C, P factors. Constant R (280) and P (1) factors were combined with K, LS, C layers.
R is a factor incorporating rainfall erosivity (0.11 annual precipitation (cm), maximum day precipitation over two years, maximum preciptation of a storm over two years, plus 66). NOAA precipitation data only covered two of the three. R values for 1979 incorporated ranges of extreme local rainfall events such as 1957 (McGregor 2001). A value of 280 used, acquired from Figure 3, Hunter (1990, p 44), derived directly from Greiner (1979).

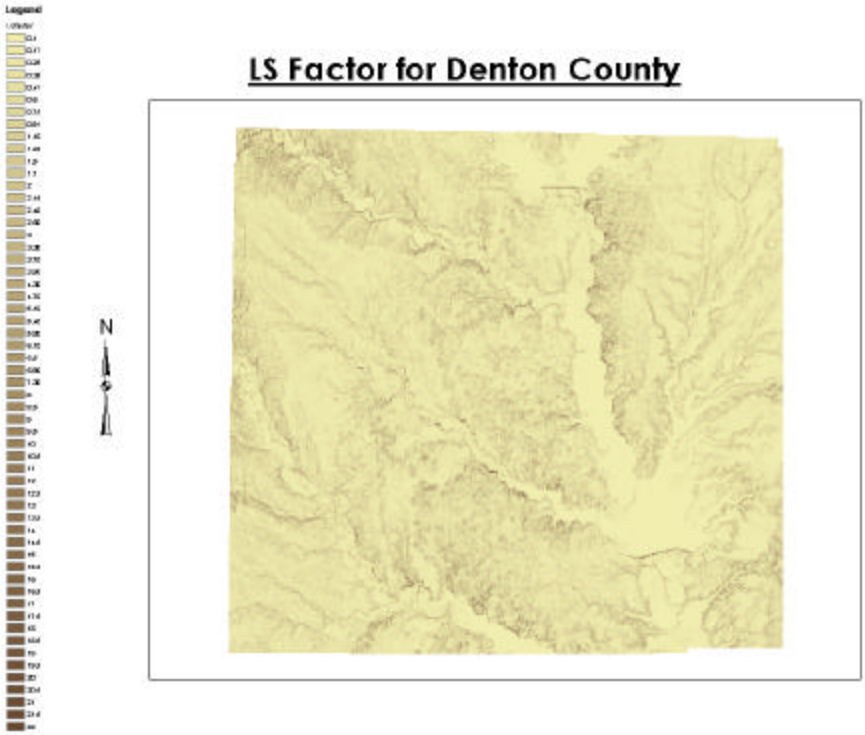
K is a factor incorporating soil erodibility (soil structure, grain size, permeability) by soil type. It ranges from 0 to 1, 1 being highest erosivity. Ratings were calculated by matching electronic USDA Natural Resource Conservation Service (NRCS) SSURGO data with hard copy 1980 K factors (USDA NRCS 1980).

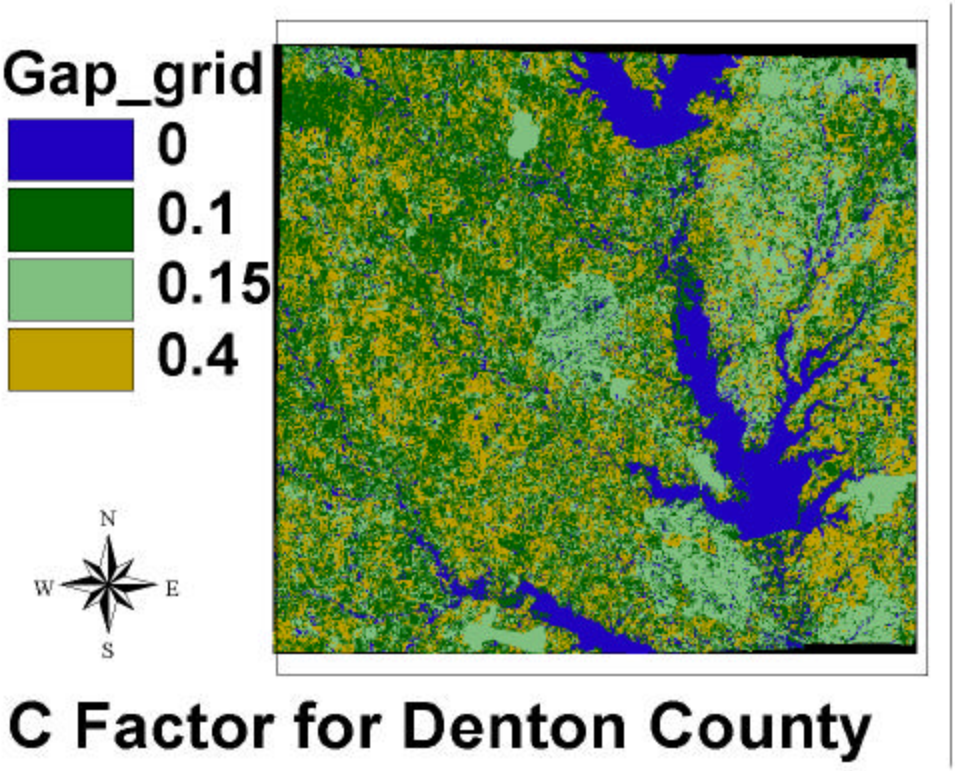


LS is a factor combining slope length and percent. A 100-foot slope length constant was recommended by Hunter (1990, 2001). USGS digital elevation model (DEM) data was acquired for Denton County and matched with Table 3 in Hunter (1990, p. 53).
Local values range from 0.08 (0.2% slope) to 22 (57 % slope).

C is a factor incorporating vegetative cover by type. Data was acquired from Texas Geographic Approach to Planning for Biodiversity (GAP) files. Sample C values from a soils textbook (Brady and Weil 2000) and information used by a local NRCS agent (Brown 2001) were assigned to similar vegetation types in GAP data, which was lumped into broad categories. Values assigned were: 0.0 (water); 0.1 (70% tree cover, 40% litter cover); 0.15 (urban – includes construction; and grasslands/rangelands); and 0.4 (frequent bare soil from conventional tillage, fall plowing).

P is a factor incorporating agricultural soil protection measures. This value generally ranges from 1.0 for up and downhill cropping to 0.37 for contour strip cropping. Conservation measures have recently been disrupted locally by needs of large equipment (Brown 2001). A constant protection parameter of 1.0 was used, based on Hunter (1990, 2001) and Brown (2001).


LS Factor for Denton County
N


Gap_grid
0
0.1
0.15
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N
W
E
S
C Factor for Denton County

Results

Values are similar to typical field-rated values obtained by a local NRCS agent for selected sites (2-10 tons per acre per year, maximum near 40) (Brown 2001).

Table 1. Sample output values for GIS USLE model for Denton County (tons of soil loss/acre/year):

LLELA forest	2.0
Greenbelt forest	1.4
Urban within City of Denton	5.3
Cropland near Krum	6.3
Cropland near Ponder	5.8
Cropland near Justin	4.7
Cropland east of Aubrey, near Collin County line	22.0
Cropland east of Little Elm " "	38.0

Areas of highest predicted erosion are similar to Hudak *et al.* (2000): a northeast trending belt of erosive sandstone; cropland with low cover; and steep slopes along streams and reservoir boundaries. Sample values for the latter category are provided in the following table:

Table 2. Sample output values of a GIS USLE model for Steep slopes along streamsides and reservoir boundaries in Denton County (tons of soil loss/acre/year):

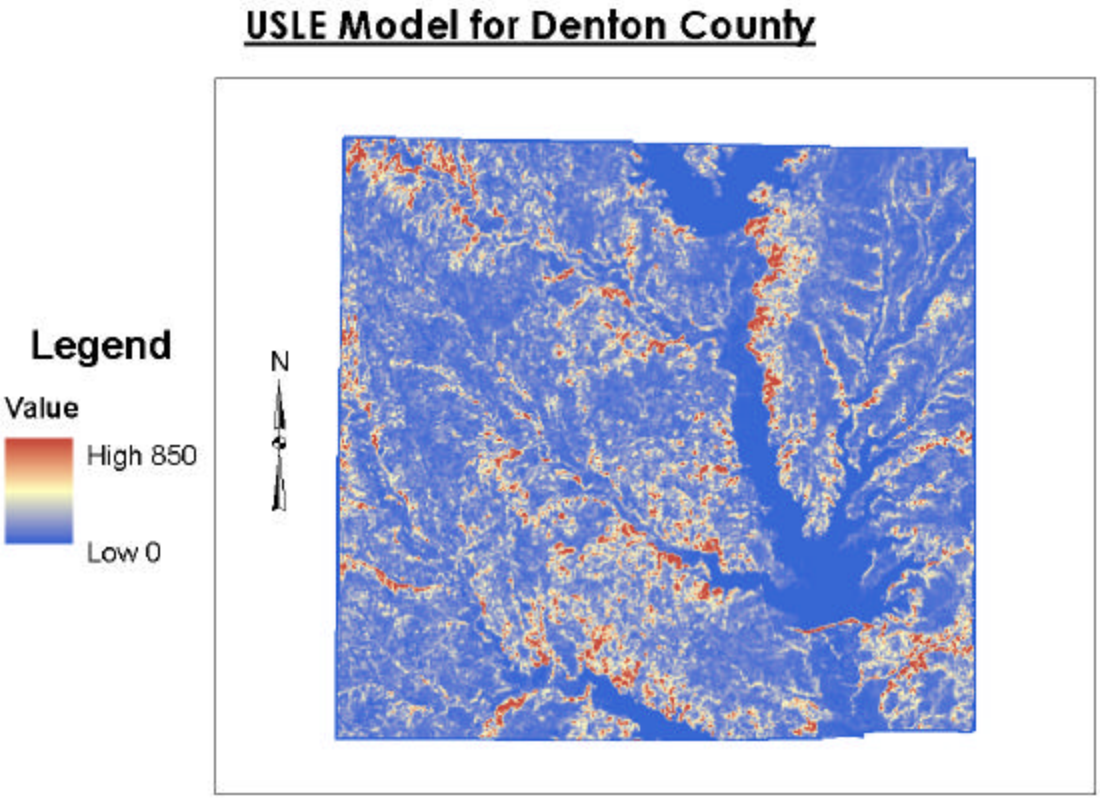
Hickory Creek/Lewisville Lake arm	38.6
Upper Clear Creek	52.1
East side of Elm Fork of Trinity River	82.2
Denton Creek/Grapevine Lake arm	122.5

Discussion

There are several positive aspects of this study. Utilization of the full USLE model yields units in tons/acre/year, which are more tangible than high, medium, low ratings. This format may also draw more attention to the problem than ratings. Results are also not as skewed by slope percent as in the Hudak *et al.* (2000) model. Comparison can also be made with other counties and field calculations.

There are also several negative aspects of the methodology. The maximum value of 850 and other high values are likely inaccurate, as the local NRCS agent rarely obtains values over 50. Internal decisions were made that may lead to less accurate results, such as: lumping specific K (SSURGO data), C (GAP data), and LS (DEM) values into categories; and using 100 foot slope length as a constant for the LS factor.

Future research might include: comparing this effort with use of other models, such as SLEMSA or EPIC; incorporating an LDD network to more accurately estimate loss between cells; refining use of the local construction factor provided (Brown 2001) to spatially illustrate and predict erosion associated with increasing urban development, especially on highly erosive soils; incorporate T values (soil-building rates) and ArcView City Green models to determine dollar values of ecosystem services provided by local habitats (Forbes *et al.* 2000).



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