GIS-Based Comparisons of Digital Elevation Models – A Temporal Perspective

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GEOG 4550 Group 5 Class Project Report

For

Dr. Minhe Ji

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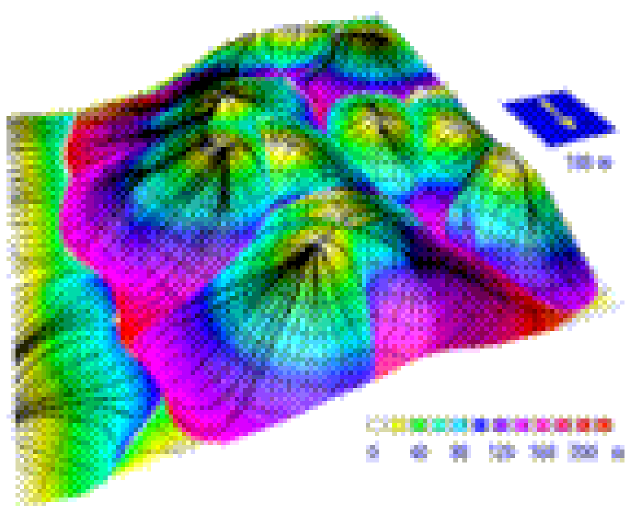

I. EXECUTIVE SUMMARY

A comparison of two Digital Elevation Models was conducted and resulted in slight differences in erosion potential. The slight differences in the location of potential highly erodible areas may indicate either head cutting or model errors due to grid transformations. Site verification would be necessary to confirm the observed results. Based on the possible sources of errors and the limitations of the RUSLE computations, the comparison of DEMs over time with varying projections and over larger geographic areas is not unattainable; however, care must be taken to eliminate all sources of errors in order to use this indicating tool effectively. Overall, RUSLE values for the AOI appear to be reasonably located

II. BACKGROUND INFORMATION

A. DATA SOURCES

1. United States Geological Service

a) Digital Orthophotograph Quarter Quadrangle

The data required for this project was downloaded from the Texas Natural Resource Information System (TNRIS) website and consists of tiled digital orthophotograph quarter quadrangles (DOQQs) collected between January and February 1995. Specifically, the DOQQs identified as Sanger NE and Sanger NW were downloaded from (http://www.tnris.state.tx.us/DigitalData/DOQ_2.5m/s.htm) and have a ground resolution of 2.5-meters/pixel. The DOQQs were collected for the United States Geological Service (USGS) by VARGIS as part of the National Mapping Program. The complete and detailed metadata listing for the DOQQs downloaded from the TNRIS website is included in Appendix A.

b) Digital Elevation Model

Additional USGS data required for this project consisted of a Digital Elevation Model (DEM). The specific DEM for Sanger, TX was downloaded from the TNRIS website with the following web address: (http://www.tnris.state.tx.us/DigitalData/DEMs/dem-s.htm) and is in standard USGS DEM format. The DEM is based on a 30-meter grid pattern utilizing the DOQQ as a base. A complete and detailed metadata report for the Sanger, TX DEM is included in Appendix B.

2. CoServ Data

Alan Plummer Associates, Inc. (APAI) originally obtained this data for utilization with an in-house project. Authorization for use during this class project has been obtained from APAI principal, Mr. Richard Smith, and also from Mr. John Long (GIS Manager) with CoServ under the strict stipulation that the data may not be utilized in any fashion outside the purpose of this class project. CoServ has removed the portion of the Denton County orthophotograph within the City of Denton corporate limits prior to distribution to APAI.

a) Digital Orthophotographs

CoServ's data consists of multi-band (Red, Green & Blue) digital orthophotographs in MrSID format with a ground resolution of 2-feet/pixel for the northern half of Denton County, Texas. The MrSID format digital orthophotos are seamless and as such there is only a single image comprising the entire coverage area.

b) Digital Elevation Model

A second data set from CoServ contains the DEM for Denton County minus that portion contained within the City of Denton, TX. This data set was provided in AutoCad (*.dwg) format and contains polygon, polyline, point and annotation layers.

The DEM is based on a 500-foot grid pattern utilizing the digital orthophotograph as a base. A combined metadata report for the MrSID format orthophotograph and the AutoCad format DEM is included in Appendix C.

3. STATSGO Soil Database

The soils information utilized within this project were downloaded from the USDA-NRCS Soil Survey Division National STATSGO Database Data Access website (http://www.ftw.nrcs.usda.gov/stat_data.html). A complete and detailed metadata report for the State of Texas mapping series is included in Appendix D. Additional soils information was obtained from the Soil Survey of Denton County Manual published by the Department of Agriculture, NRCS, January 1980.

4. Texas Streams Network Coverage

The background coverage of streams for the AOI was downloaded from the TNRIS website via a hypertext link to the Texas General Land Office website at the following address (ftp://204.64.181.202/pub/glo/hydrotxdota.e00.gz). A complete and detailed metadata report for the Texas stream coverage is included in Appendix E.

5. Texas Roadway Coverage

The background coverage of roadways for the AOI was downloaded from the TNRIS website at the following address (http://www.tnris.state.tx.us/DigitalData/TxDOT/txdot_d.htm). A complete and detailed metadata report for the Texas stream coverage is included in Appendix F.

6. RUSLE Grid Variables

The values used for several of the factors necessary to complete the calculations required by the RUSLE/GIS model were provided via personnel communications to the authors from Mr. Glenn Lubke, Conservation Agronomist, National Resource Conservation Service (NRCS), Forney, TX. Field Office. In particular, Mr. Lubke provided the values of 275, 90 and 5 for the R-factor, C-factor and P-factor grids, respectively. Mr. Lubke also provided a K-factor value of 0.32; however, this factor was not used, as site-specific information was available.

B. RUSLE EQUATION

The Revised Universal Soil Loss Equation (RUSLE) is an erosion model designed to predict the longtime average annual soil loss (E) carried by runoff from specific field slopes in specified cropping and management systems as well as from rangeland (Renard, K.G. et. al., 1997). Widespread use has substantiated the usefulness and validity of RUSLE for this purpose. RUSLE is an empirical equation derived from theory of erosion processes and more than 10,000 plot-years of data from natural runoff plots and an estimated 2,000 plot-years of rainfall simulator data (Shea, G. and Hankley, C., 1997). RUSLE users need to be aware that (E) is the average loss over a field slope and that the losses at various points on the slope may differ greatly from one another.

Erosion and sedimentation by water involve the processes of detachment, transport, and deposition of soil particles. The major forces are from the impact of raindrops and from water flowing over the land surface. Erosion may be unnoticed on exposed soil surfaces even though raindrops are eroding large quantities of sediment; however, erosion can be dramatic where concentrated flows create extensive rill and gully systems (Toy, T. J. and Foster, G.R., 1998). Factors affecting the average annual erosion expected on field slopes can be expressed in an equation of the form:

$$E = R * K * L * S * C * P$$

Where:

E = computed spatial average soil loss and temporal average soil loss per unit of area, expressed typically in ton/(acre.year);

R = rainfall-runoff erosivity factor – the rainfall erosion index plus a factor for any significant runoff from snowmelt, typically in hundreds of ft.tonsf.in/acre.hr.year;

K = soil erodibility factor – the soil-loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as a 72.6-foot length of uniform 9% slope in continuous clean-tilled fallow, typically in tons per acre per unit R;

L = slope length factor – the ratio of soil loss from the field slope length to soil loss from a 72.6-foot length under identical conditions (dimensionless);

S = slope steepness factor – the ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions (dimensionless);

C = cover-management factor – the ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow (dimensionless);

P = support practice factor – the ratio of soil loss with a support practice like contouring, strip cropping, or terracing to soil loss with straight-row farming up and down the slope (dimensionless) (Mitasova, 1999).

C. SITE INFORMATION

1. Location and Description

The study area for this project begins at the junction of United States Interstate 35 (I-35) and Clear Creek and includes the western portion of the drainage basin for Clear Creek that is located between I-35 and F. M. 2450. Figures 1 and 2 illustrate the project's Area of Interest (AOI) identified on the 1995 USGS DOQQ and the 2000 CoServ digital orthophotograph, respectively. The area consists of mostly open grassland with scattered agricultural plots. Clear Creek flows from the northwest to the southeast across the AOI.

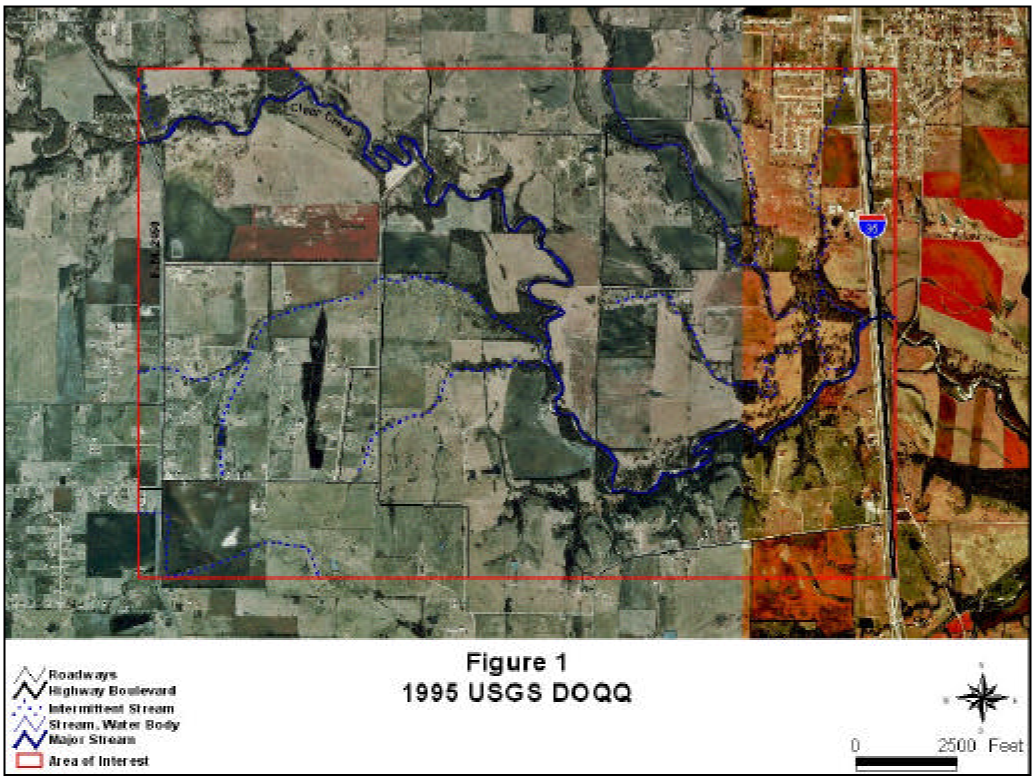

Figure 1
1995 USGS DOQQ

2. Soils

The soils in the general vicinity consist of mainly Sanger-Somerville in the upland areas (well drained, gently sloping to moderately steep, clayey and loamy soils that havemoderate and very slow permeability) and Frio-Ovan in the valleys (well drained and moderately well drained, nearly level, clayey soils that have moderately slow and very slow permeability) as described within the Soil Survey of Denton County, Texas. Specific soils groups located within the AOI, as described within the State Soil Geographic (STATSGO) database, are illustrated on Figure 3.

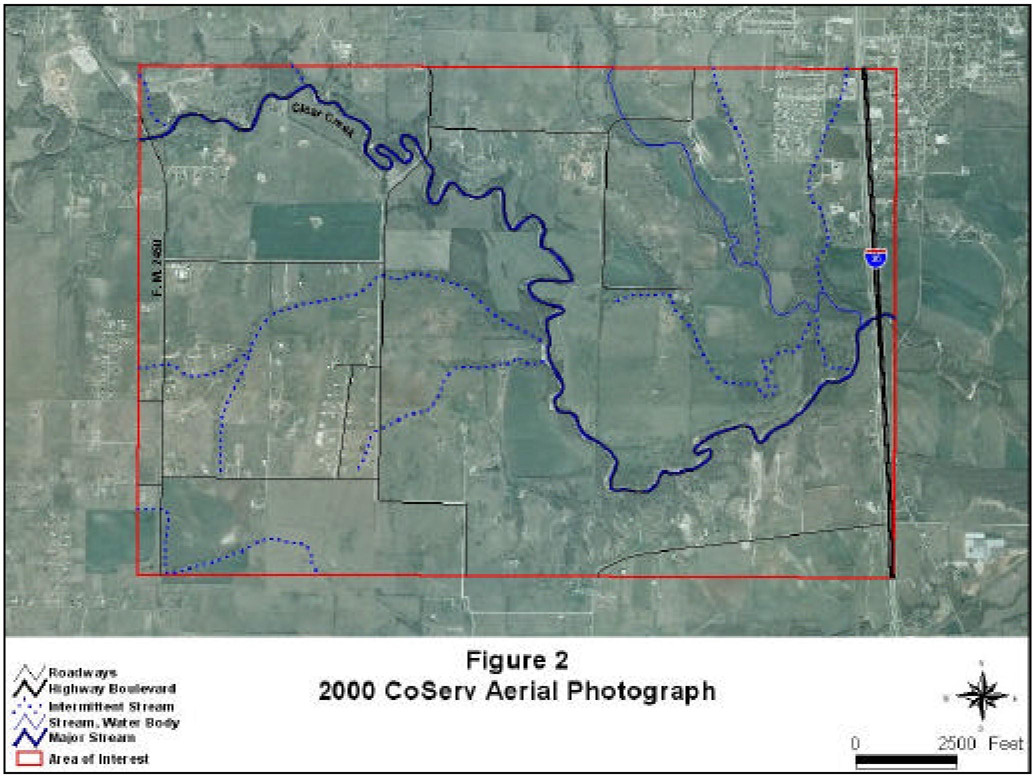

Figure 2
2000 CoServ Aerial Photograph

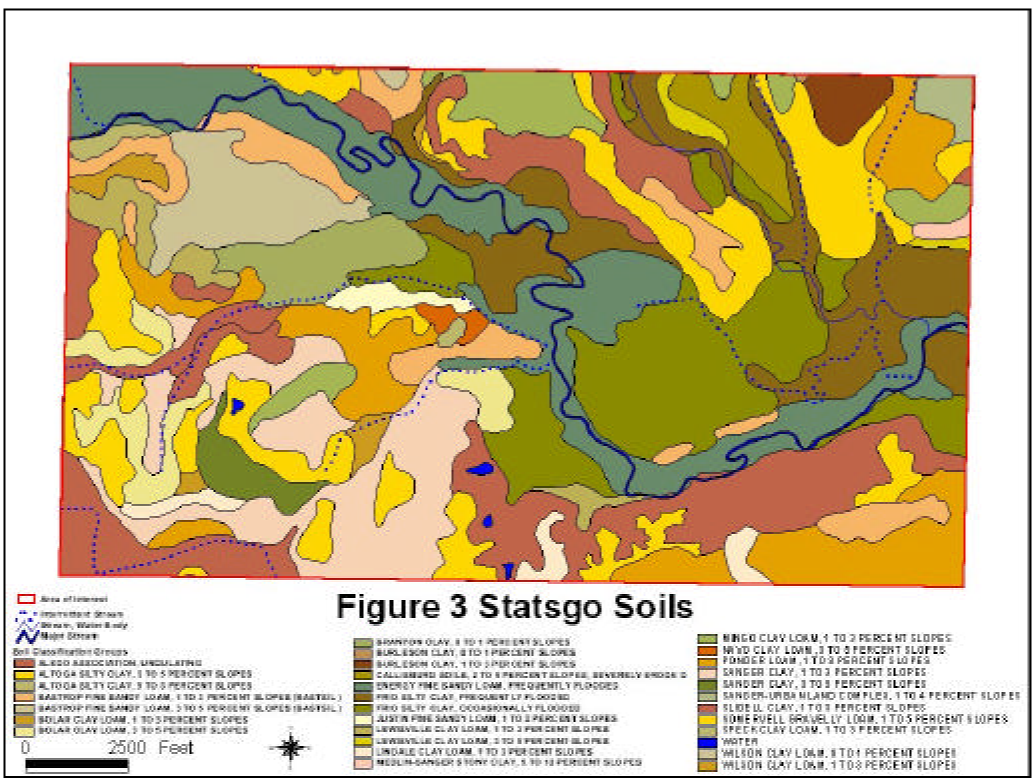

Figure 3 Statsgo Soils

III. METHODOLOGY

A. DATA SET PREPARATIONS

1. USGS Data Sets

Subsequent to downloading the Sanger NE and Sanger NW DOQQs from the TNRIS website, the DOQQs were added into a new view in ArcVeiw GIS where the site AOI was determined and added as a polygon theme. Additional themes were added, such as roadways and streams. All themes within this view were projected in UTM NAD83 Zone 14 with the horizontal units of measure being meters. The additional themes were then geoprocessed (clipped) utilizing the AOI theme as the clipping boundary.

After downloading the Sanger DEM from the TNRIS website, the DEM was first imported into a new view using ArcView Spatial Analyst and then the AOI theme was added. Since the native format of the USGS DEM is a grid, the DEM needed to be converted into an ArcView Shapefile so that the AOI could be clipped out of the original DEM. Once the AOI was clipped from the original DEM, the clipped USGS DEM was then converted back into a grid (Figure 4). The grid parameters were selected to match the coarser cell size of the CoServ DEM. The CoServ AOI grid consisted of 500-foot cell size with 25 rows and 37 columns.

In addition to the grid containing elevations, additional grids are necessary to complete the RUSLE calculation. The easiest grids to produce were the R-factor, C-factor and P-factor grids. Generic values were obtained for these grids via personnel communications with a NRCS Conservation Agronomist, Mr. Glenn Lubke. Mr. Lubke suggested values of 275, 90 and 5 for the R-factor, C-factor and P-factor grids, respectively. His comments suggested that these numbers would be general numbers; however, they should still be reliable enough for the purposes of this project. These values were added as attributes while the data was still in Shapefile format, and then used as the cell value range when the Shapefile was converted back into grids.

Adding K attribute values to the Shapefile based on unique soils groups and then converting the soils Shapefile into a grid using the K-factor attribute as the cell value range is how the K-factor grid was created. These K-factor values were obtained from Table 15, page 149 in the Soil Survey of Denton County, Texas. Each soil group within the AOI was assigned a value, with water being assigned “0”. Figure 5 illustrates the K-factor grid used with both the USGS and CoServ data sets. Note the single white cell in the south central p[portion of the AOI – this is a water body that measured in excess of 500’ in length and thus was interpolated within the grid as a “0” value.

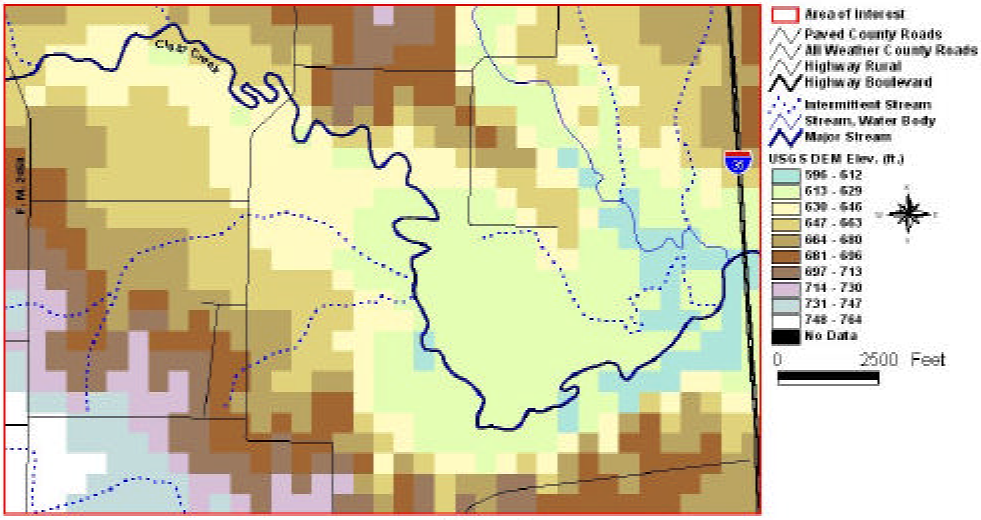

Figure 4
USGS - Processed DEM

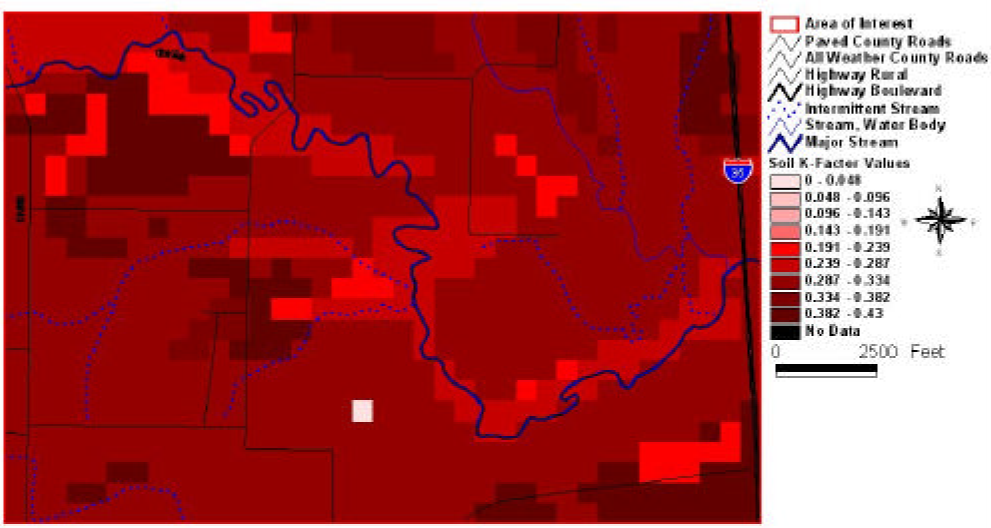

Figure 5
K-Factor Distribution

The final grid to be created is the combined grid for the L-factor and S-factors. This grid was constructed based on instructions documented by Ms. Helena Mitasova, 1999. A copy of the documentation regarding these calculations is included in Appendix G. The first step to calculating the LS-factor grid is to first derive a slope grid (Figure 6). Once the slope has been calculated, a flow accumulation grid can be generated (Figure 7).

Substituting our AOI R-factor of 275 for her value of 120 and accepting her value of 10 for resolution, the LS-factor grid was created (Figure 8). At the time of writing, the authors were unable to reach Ms. Mitasova to request clarification on the resolution and its function.

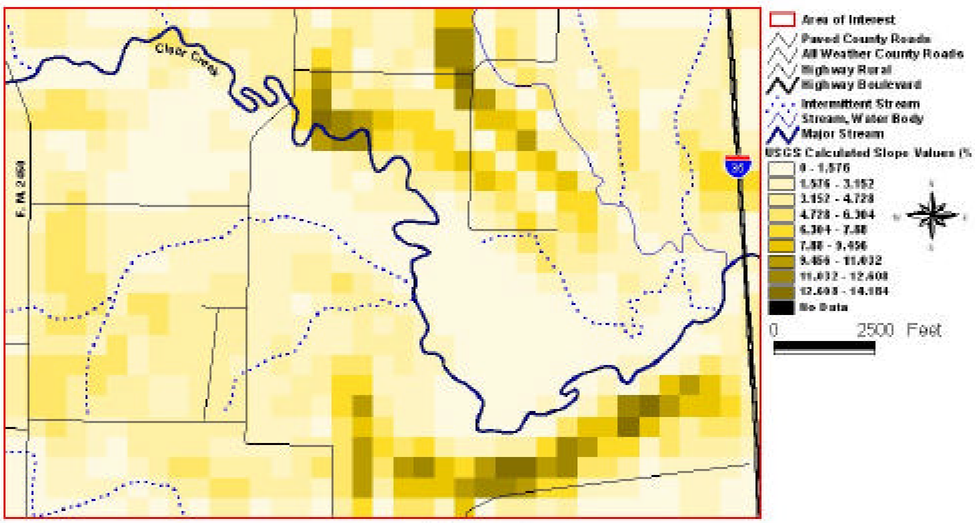

Figure 6
Calculated USGS Slope Grid

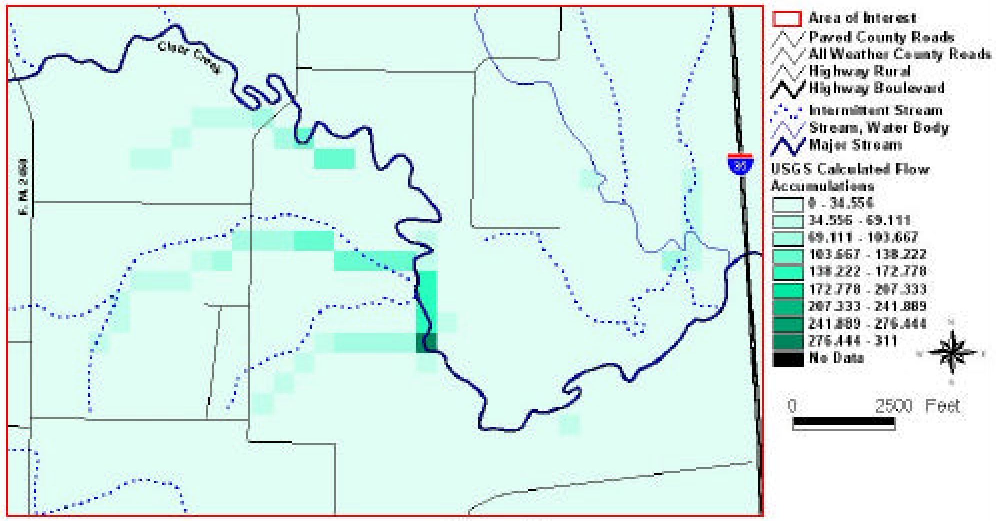

Figure 7
USGS Calculated Flow Accumulations

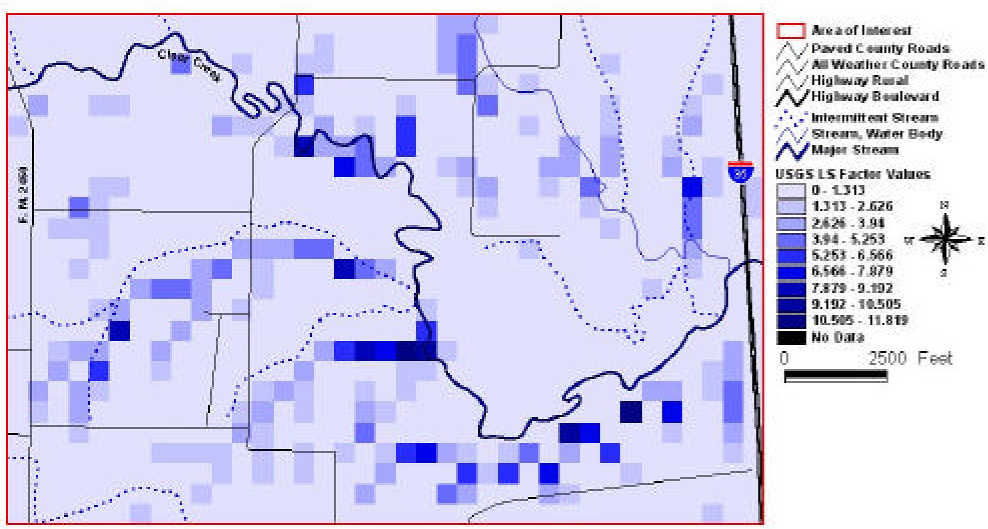

Figure 8
USGS Calculated Slope Length Factor Grid

The final calculation completes the RUSLE evaluation by multiplying the K, C, P, lsfac and R (As a Grid) grids together (Figure 9). Finally, a “Brightness Theme” was applied to assist in interpretation.

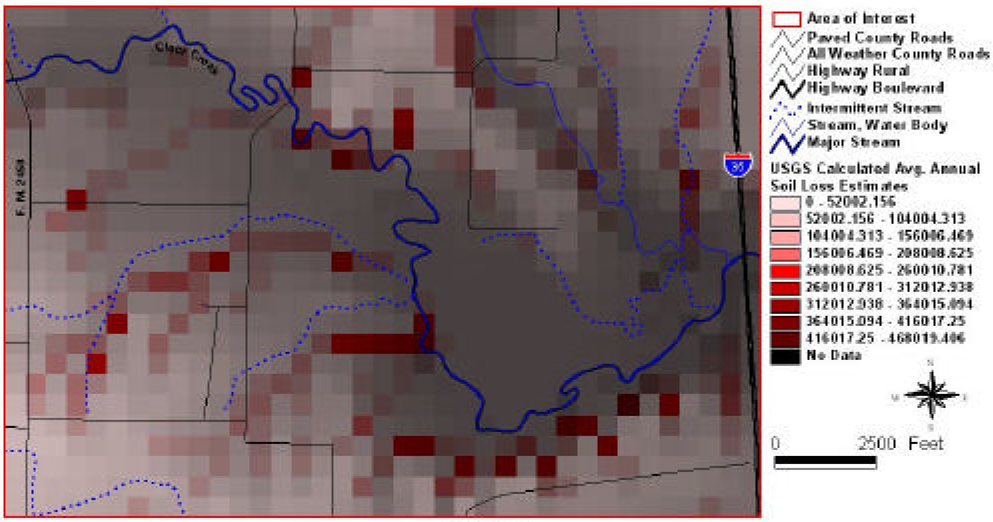

Figure 9
USGS Calculated Avg. Annual Soil Loss

2. CoServ Data Sets

The data manipulation procedures described above was identical to that necessary for the CoServ Data sets, with the following exceptions: the CoServ data sets are projected as State Plain NAD83 Texas North Central Zone with horizontal units of measure being feet. The grid size was not altered, as this DEM had the coarser grid cell size. Figures 10 through 14 illustrate the CoServ DEM, CoServ slope, CoServ flow accumulation, CoServ Slope Length Factor and CoServ Soil Loss figures, respectively.

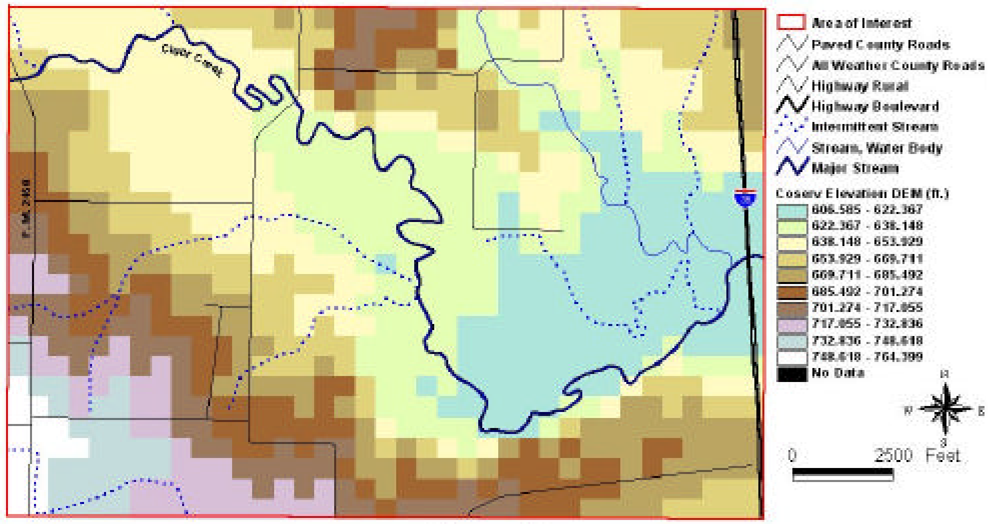

Figure 10
CoServ DEM (ft.)

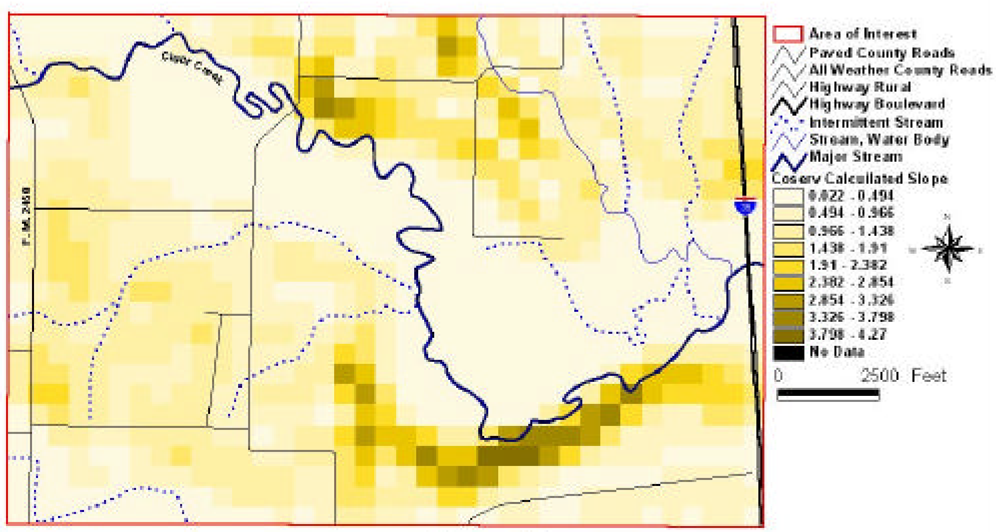

Figure 11
CoServ Calculated Slope

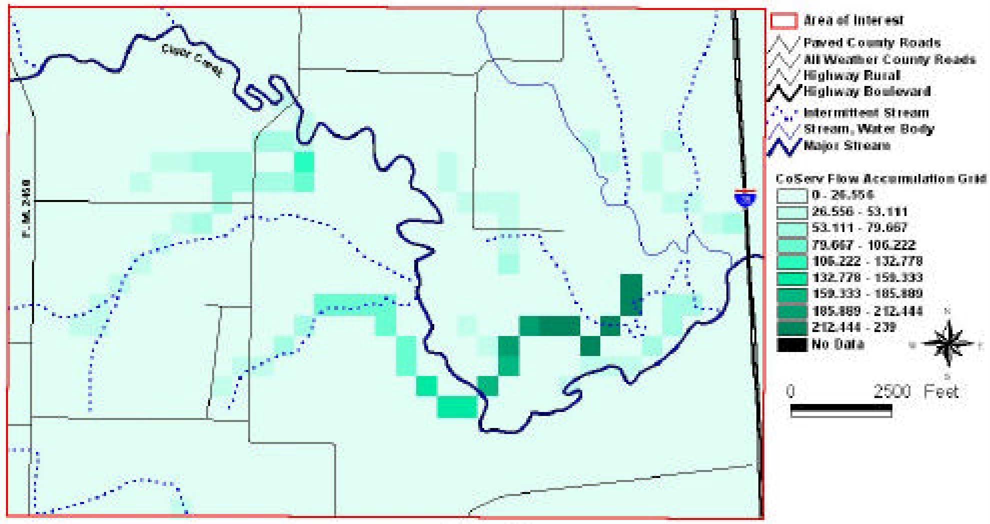

Figure 12
CoServ Calculated Flow Accumulation Grid

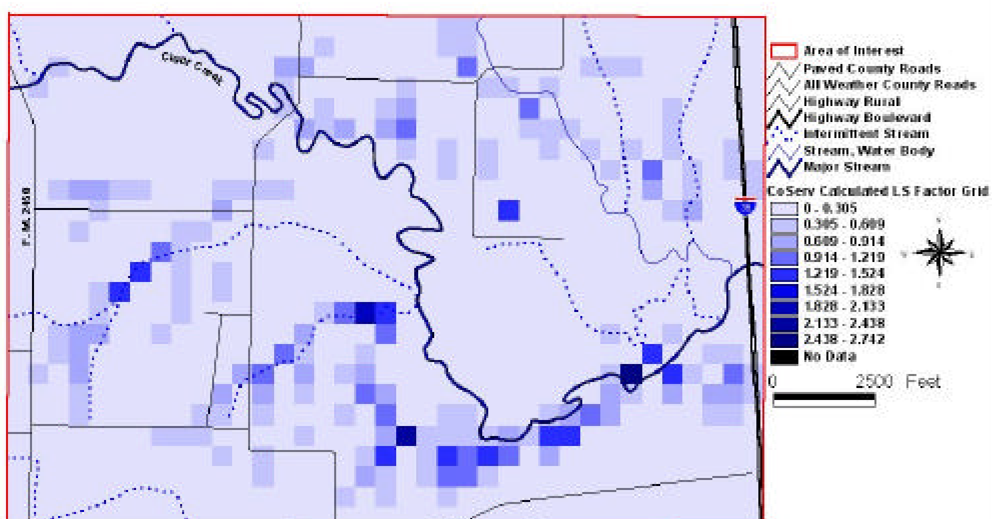

Figure 13
CoServ Calculated LS Factor Grid

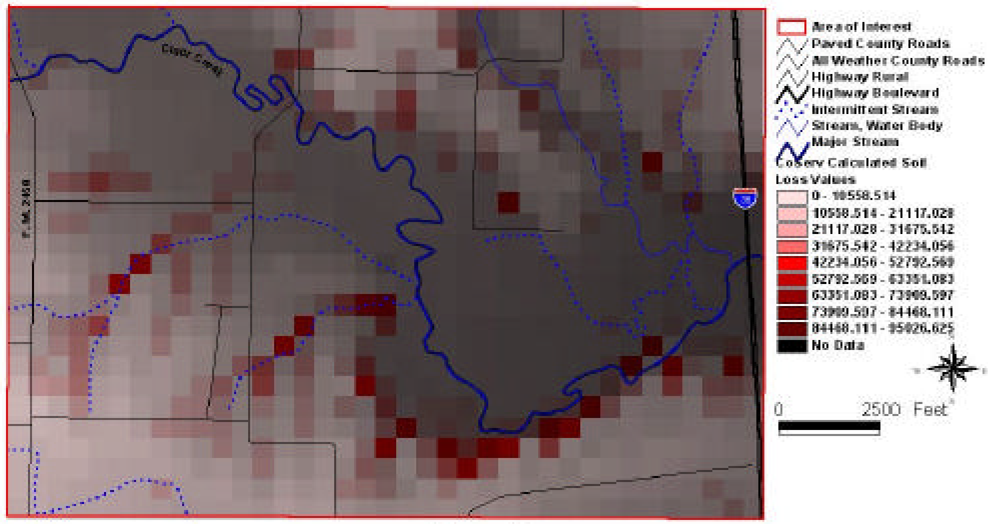

Figure 14
CoServ Calculated Soil Loss Grid

B. DEM COMPARISONS

In order to determine if any difference existed between the two DEMs, the CoServ DEM grid was re-projected to match the USGS DEM grid projection. Inspecting the two DEMs, it became readily apparent that they did not have identical minimum values. Since a straight comparison would not yield readily apparent changes in slope, both DEMs were adjusted to have a matching minimum value of 600 feet above mean sea level. The USGS DEM was adjusted up by 4.0 feet, while the CoServ DEM was adjusted down by 6.585 feet. Once both DEMs had identical minimum values simple map algebra was used to determine what differences existed between these two DEMs (Figure 15).

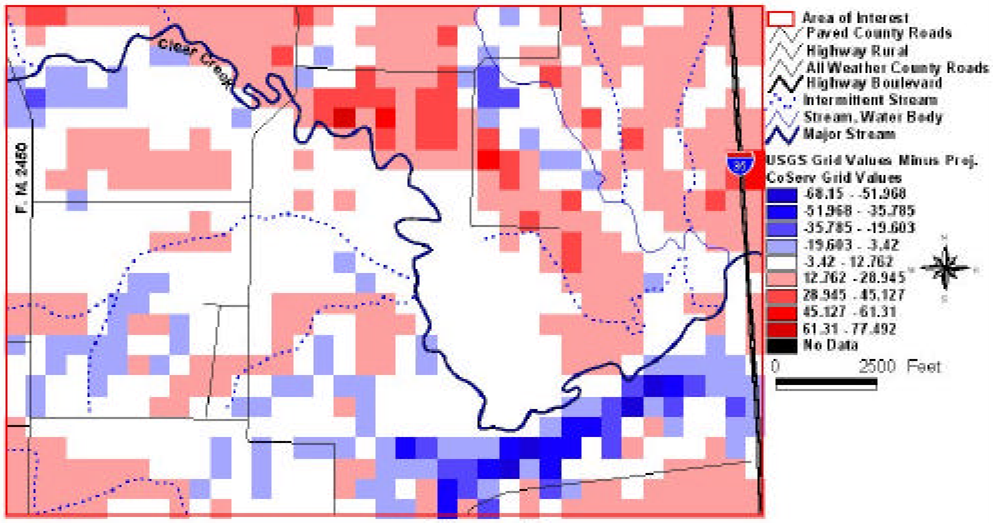

Figure 15
USGS Grid Minus Projected CoServ Grid

IV. RESULTS

Based on the calculated grid results, both DEMs are predicting the highest levels of erosion to be located within the curve located in the southeastern corner of the AOI and also within the two tributaries that feed into Clear Creek from the south. Although there are a few sensitive areas located along the northern portion of the valley, the vast majority of the calculated erosion is anticipated to be from the southern curve and the two southern tributaries.

Further, based on the map algebra, the differences between the two DEMs, indicates conflicting results. Some of the CoServ DEM grid cells are higher than the corresponding grid cells in the USGS DEM.

V. DISCUSSION

A. Sources of Error

At the beginning of this project, an examination of the two DEMs revealed several areas of concern that could present problems for the analysis of difference between these two DEMS. These areas of concern are as follows:

?? The two DEMS were collected approximately 5 years apart.

- Since different individuals, with differing photogrammetric equipment collected these DEMs, the potential for error increases with the difference in equipment, personnel training levels and overall data handling techniques.
- Since the main objective of the collection activities are different, i.e. the USGS data was collected as part of a national program while the CoServ data was collected for a group of investors within the utility and public facility management realms, therefore, cost concerns would be a major concern in the smaller CoServ project.
- The two DEMs are in different projections and as such have different horizontal units of measure.
- The most obvious difference, next to the difference in projections, would be the different grid cell size. The USGS DEM has a 30-meter cell size while the CoServ DEM has a 500-foot grid cell size. The handling of the CoServ data will not be discussed in great detail here, as the major item of discussion is the conversion of the USGS grid to match the coarser CoServ grid parameters. The decision to match the USGS to the CoServ grid parameters was performed to conform to standard industry practices, where comparisons can only be made in the coarser data set's parameters. This conversion; however, lost a tremendous amount of detail and precision in the USGS DEM as the cell size increased from 30-meters to 152-meters. Compare the original USGS AOI prior to grid conversion (Figure 16) with the grid in Figure 4.

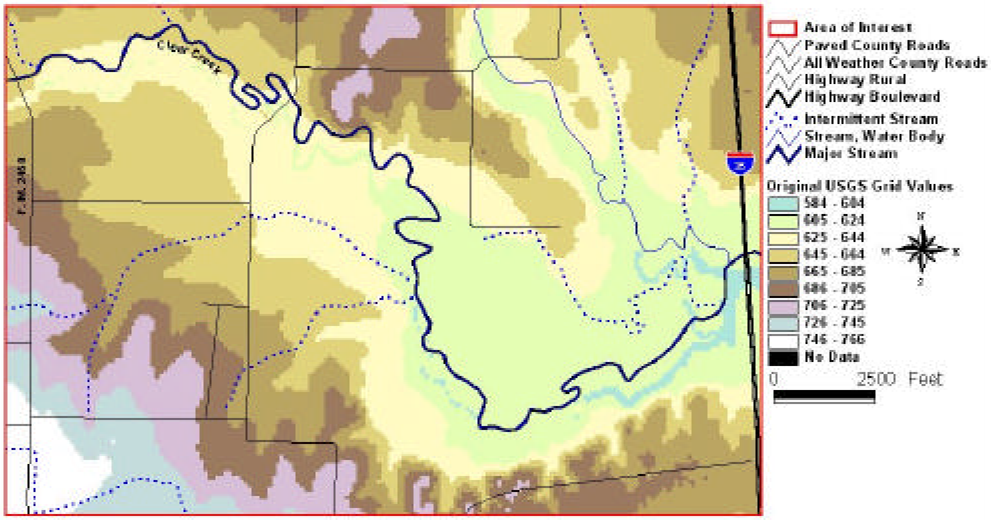

Figure 16
Original USGS Grid

?? The ability to identify errors within the converted USGS and CoServ DEM data is for all practical purposes not feasible as there is so little definition to start with.

?? As powerful a tool GIS is becoming, it is still at the mercy of those operating it. The RUSLE equations and assumptions were not developed for use in smaller-scale (i.e. large geographic extent) examinations. Initially developed for use on smaller specific land parcels with finite parameters, RUSLE is a very powerful indicator of plot specific erosion. Many advances and adjustments have occurred within the last 50 years that have modified the original USLE equations into those we know today as RUSLE. For the amateur agronomist, calculating the RUSLE can be extremely difficult, as each component requires tremendous amounts of complex mathematical computations in conjunction with the associated assumptions. Even though custom software is available from the NRCS, the RUSLE determinations still require vast amounts of site-specific information to achieve the most accurate model results.

?? And finally, as mentioned earlier, the use of general factor values in lieu of site-specific data will always reduce the level of confidence in the calculated outcomes, regardless of the problem.

B. Evaluation of Results

Examining the intermediate grids for both USGS and CoServ data sets, each grid depicted what would have been expected. The slope grids indicate the steepest slope along the ridge located within the southeastern portion and also along the ridge located in the north central portion of the AOI.

The flow accumulation grids both indicate that there is an accumulation located at or just downstream of the junction of Clear Creek and the western most tributary located on the south side of Clear Creek. However, the CoServ flow grid also indicates substantial accumulation north of Clear Creek within the valley floor. Examining this northern accumulation may indicate that there are slight discrepancies in the georegistration of the various themes utilized. Assuming this to be true, then a very substantial accumulation may exist within the CoServ DEM along Clear Creek.

The slope length factor grids appear to agree very well with the slope grids and suggest higher slope length values in the southern curve and along the two tributaries on the south side of Clear Creek.

The final answer grids also agree with the slope and slope length grids – the areas of highest potential are along the southern curve, the southern two tributaries and some potential exists along the northern valley boundary in the north central portion of the AOI.

VI. CONCLUSION

The RUSLE equations and assumptions were originally developed for use on single small plots with specific site parameters. Today, many different disciplines are in need of data that fit larger areas of their local area, typically watersheds. The application of the RUSLE equations on larger regions has been well documented and can be used with confidence if the operator incorporates as much site-specific details as is possible. The more accurate the input variables and the greater the ability to break down the larger region into smaller regions, greatly increases this tools ability to predict how much and where the landscape will erode the most.

With respect to this project, the RUSLE values calculated require in-situ verification to validate that the areas indicated are in fact areas of high erosion. The RUSLE predictions of high erodibility locations appear to be sound, even with the use of several generic parameter values.

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