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## **Erosion Potential in Travis County**

### **INTRODUCTION**

Erosion has played a vital role in the morphology of the Earth as its processes have been used to transport sediments throughout the lands. In this regard, understanding erosion is important in order to understand the effects of the natural transport of sediments. One area of study that emphasizes the importance of streams naturally transporting sediments downstream are dams. The creation of large dams and structures disrupt the naturally occurring processes of sediment transport. The sediment accumulates behind the dam or structure, which causes a problem for the dams as well as the downstream ecology. One example of its impact on the downstream ecology is in rivers discharging into the ocean. The natural transport of sediment caused by erosion allows sediment to accumulate at the delta of the river and acts as a barrier against the ocean currents. Therefore, it is important to recognize the importance of erosion and the positive impact it has on the environment.

On the other hand, in the past half century there has been a lot of research into understanding the negative impacts that erosion has on the environment. Erosion is one of the leading sources of nonpoint source pollution. Erosion typically increases the amount of sediment, typically fine silt and sands from nearby lands, in streams and rivers. This increase in the amount of sediment degrades the water quality by decreasing the depth of streams, increasing the turbidity, increasing nutrient pollution and in turn degrading the waters such that aquatic life may suffer as a result. As a result, the research being conducted on erosion looks into these negative impacts on the ecology of streams, but there has also been a lot of research analyzing methods that can reduce the amount of erosion on lands.

These methods to reduce the amount of erosion are of particular interest to me because my research is focused on the use of polyacrylamides to reduce turbidity from construction site runoff. The aim of this work is to use ArcGIS to model the erosion potential of Travis County in order to determine what areas of the county are particularly vulnerable to erosion. This information would be helpful in order to understand what areas should look into the use of best management practices in order to reduce erosion (nonpoint source pollution).

## **RUSLE MODEL**

The Revised Universal Soil Loss Equation (RUSLE) is a modified version of the Universal Soil Loss Equation, which has been widely used to understand and predict soil erosion. The equation is a multiplicative relationship amongst variables as shown below:

$$A = R \times K \times L \times S \times C \times P \quad (\text{Equation 1})$$

where A is the annual average soil loss per unit area, R is the rainfall/runoff factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover and management factor and P is the supporting conservation practice factor. Each factor plays a vital part in predicting soil erosion as will be discussed in the project methods section of this report.

The RUSLE model has been used in many GIS application all over the globe to help simplify the task of calculating the average annual soil loss and also has the ability to provide a visual depiction of soil erosion for specific locations. Khosrowpanah et al. (2007) utilized the RUSLE model in GIS to model potential soil erosion in the Ugum watershed in Guam. The approach they take to incorporate the RUSLE model in Guam is the same approach that I took with my project. Figure 1 shows the process of creating rasters for each variable in order to ultimately combine these rasters together to calculate the annual average soil loss.

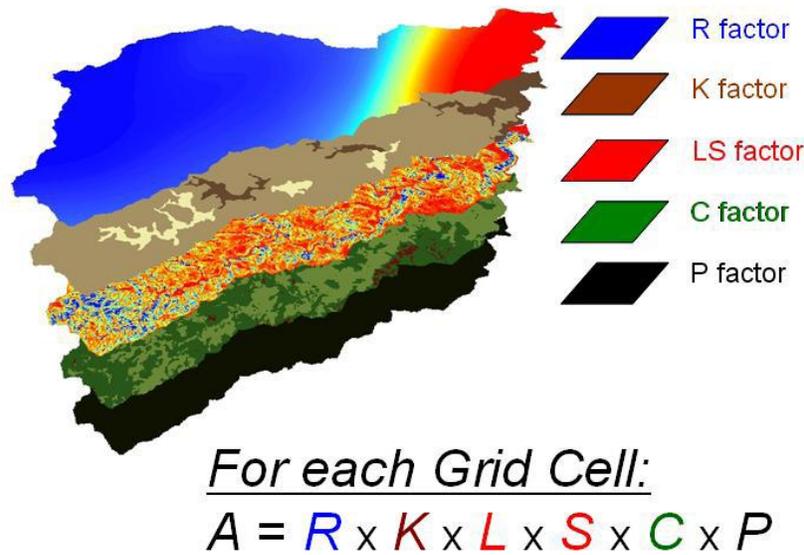


Figure 1. GIS process to model potential soil erosion (Khosrowpanah et al., 2007)

## PROJECT METHODS

The approach used to model the potential soil erosion in Travis County followed the same approach shown in Figure 1. Each variable had its own source of data and particular process in ArcMap 10, which is discussed in detail below. It is important to note that the methods used in this project only relied on the use of data that is available to the public and on ArcGIS. Therefore, the methods outlined in this analysis may differ considerably from others who have utilized ArcGIS in combination with other programs to determine the variables. As a result, for each variable the methods used in the project will be described in detail such that anyone with access to the internet and ArcGIS could utilize this methodology to model potential erosion in their specific region of interest.

### R- Rainfall/Runoff Factor

The rainfall/runoff factor accounts for the energy and runoff that accompanies rainfall averaged over a specific period of time or for specific intensities. There are a variety of

equations that have been developed to determine the relationship between rainfall intensity and energy (Haan et al., 1994). These relationships combine the intensity of storms and empirical relationships relating the intensity to energy and then combining the energy and intensity to produce an R value. For the simplicity of this project, a map (Figure 2) depicting isolines of annual R factors across the United States was developed and used in Haan et al. (1994) and therefore this was utilized to select the appropriate R value.



Figure 2. Adapted from Haan et al. (1994), Isolines of annual R factor for the Eastern United States (ft•tonsf•in/acre•hr•year)

Figure 2 is broken down into county level regions, therefore Travis County was easy to identify on the map. The county fell between isolines 250 and 300 and therefore through visual interpretation an R value of 270 ft•tonsf•in/acre•hr•year was selected to be incorporated into the RUSLE model.

## K- Soil Erodibility Factor

The soil erodibility factor is the rate of soil loss primarily based on soil texture and similar physical properties of the soil. There are many equations, figures, nomographs, and tables (Haan et al., 1994) that can be utilized in order to calculate the K factor. However, the simplest way to determine values of K is to use those that are publicly available through the National Resource Conservation Services (NRCS) from SSURGO data. NRCS has incredibly detailed data on soils throughout the country and one of the properties they have of soil is the erodibility factor (K).

Acquiring the data from NRCS is quite simple and is given in a .zip file, which comes with a file to be used in Microsoft Access that contains all of the data on the soil. Since there is so much data stored in this file, it is not provided in a format that can be directly opened in ArcMap. However, there are methods and programs that allow you to take the data from Microsoft Access and incorporate it into rasters in ArcMap. Using the Microsoft Access file, a query is created for the K value. This query is then saved and exported as a dbase file, so that it is in the proper format to be used in ArcMap. In order to access this soil data in ArcMap, the Soil Data Viewer program must be installed. This program is free to download from the NRCS website, but is currently not available for ArcMap 10. The soil data viewer will allow you to import a soil map layer that comes with the .zip file from NRCS. This map will have a variable MUKEY, which will be used with exported query in order to join the K value to this map. After the join is finished, the K values over the county are ready to be incorporated in the RUSLE model.

The computer used in this project was upgraded from ArcGIS 9.3 to ArcGIS 10 midway through and therefore this data was unable to be completed to be used in this analysis. Once this

program is available for ArcGIS 10 it can be incorporated into the model. However, since the K values were not able to be accessed, a typical K value of 0.25 tons•acre•hr/hundreds•acres•ft•tonsf•in was selected from a table in Haan et al. (1994) to be used in the model.

### L-Slope Length Factor

The slope length factor is the ratio of soil loss from a slope length relative to the standard erosion plot length of 72.6ft. The actual slope length is the horizontal distance (excludes slopes) of the plot being modeled. Therefore, for Travis County, this distance was the horizontal distance from any point in the county to the closest stream. The slope length is then converted to the slope length factor by the following equation:

$$L = \left( \frac{\lambda}{72.6} \right)^m \quad (\text{Equation 2})$$

where  $\lambda$  is the actual slope length and m is the slope length exponent that is the ratio of rill to interrill erosion. For this analysis a mid-range m value of 0.25 was used.

ArcMap 10 was used to calculate the slope length from a digital elevation model (DEM) of Travis County. DEMs are publicly available all across the country from the United States Geological Survey (USGS), which can be found on the seamless server. For Travis County, there were a variety of different spatial resolutions offered by the seamless server (1", 1/3", and 1/9"). Initially, 1" resolution was selected to be used, but was changed to 1/3" resolution due to the enhanced resolution (30m to 10m), which was anticipated to yield more accurate slope lengths due to its finer resolution. The 1/3" seamless data for Travis County had to be downloaded in 4 different separate .zip files due to the amount of data contained in the DEMs.

After these files were unzipped and imported into ArcMap 10 they needed to be combined so the county could be treated as a single entity. The mosaic function in ArcMap 10

was used to combine this data, but this mosaic incorporated data outside of the county as well to ensure that data for the entire county was acquired. Therefore, the mosaic function was followed by the Extract by Mask (spatial analysis) function utilizing a feature of the shape of the county, which essentially trimmed off the excess data in the raster. Once these functions were completed, the DEM of Travis County was completed. The project then needed to be projected into a new coordinate system in order to be able to measure distance for slope length in meters instead of degrees. The Texas Lambert State System was selected in order to preserve length and therefore the DEM of Travis County was projected into this new coordinate system using the project raster function.

In order to determine the slope length in ArcMap 10, the Near function was selected to be used. This function calculates the nearest distance between two features, which for this project was each point on the land to the nearest stream. One of the problems encountered in using this function was that it can only calculate the distance between feature classes, while the DEM created was a raster. Therefore, the DEM needed to be converted into a feature class. The data for the streams was obtained from NHDPlus Flowlines, which are publicly available from the National Hydrography Dataset (NHD) and come in the form of a polyline feature class. The streams for the state of Texas were imported into ArcMap 10 and then a clip function was used so that only the streams in Travis County were displayed.

The process of converting the DEM was to use the Raster to Polygon function, which would create a point feature class for the raster DEM. For Travis County this function took approximately an hour creating a point for the center of every raster grid cell, since the DEM was 1/3" resolution. The Near function was then used to find the distances between the DEM and the stream, but after 20 minutes the function had not made any progress (showed 0%). Therefore,

for this project the decision was made to resample the raster in order to reduce the number of points in the feature class. The DEM was resampled multiple times and it was found that 100m was the resolution at which the ensuing functions could be run in a reasonable time frame. The problem with this resampling was that the high resolution was lost, but for the project that was truly focusing on the process of this analysis it was alright to use.

The resampled DEM was then converted into a point feature class using the Raster to Polygon function. This function was followed by the Near function with the input being the new point feature class and the other features being the streams. The output had a variety of components, but the crucial component for this project was the Near\_Dist, which is the horizontal distance between the two features from every point (Figure 3). Figure 3 shows that the points close to the streams (lighter in color) are a short distance away and the points far away from any streams (darker in color) are a larger distance away, which is intuitive.

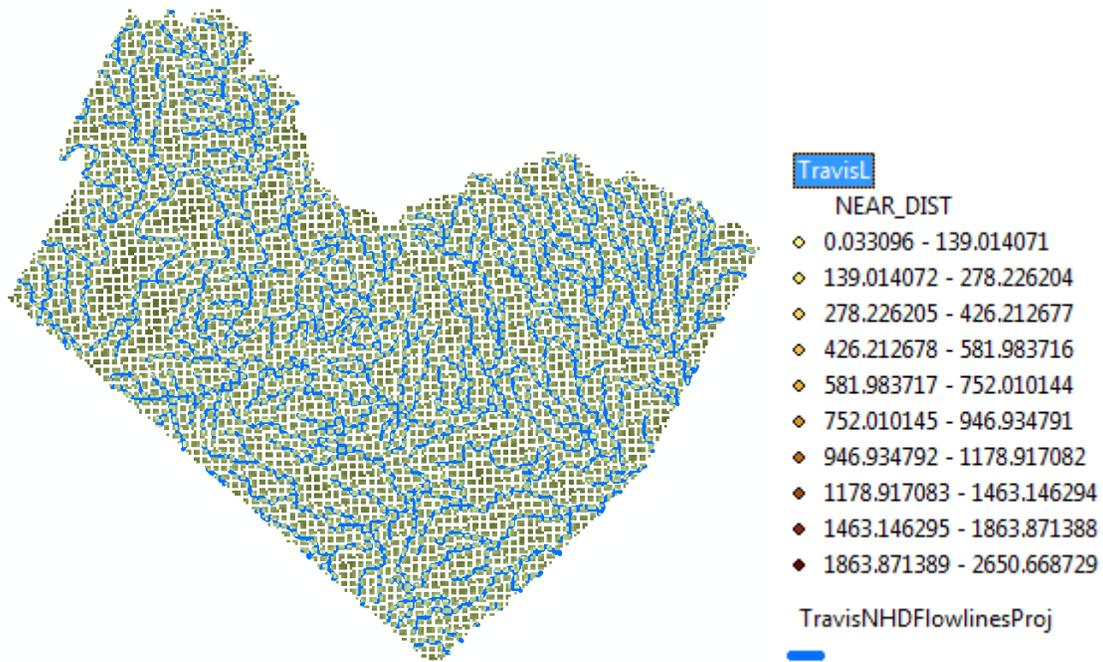


Figure 3. Near distance output: distance between each point in Travis County and closest stream

In order to incorporate this information into the RUSLE model the slope length (near distance) had to be converted into a raster and also had to be converted into the slope length factor. The feature to raster function using the Near\_Dist as the variable of interest was utilized to convert the point feature class back into a raster. The raster calculator function was then used to calculate the slope length factor (S) for each point using equation 2. It is important to note that the units of length are meters and 72.6 refers to the standard erosion plot in feet; therefore, a conversion from meters to feet was incorporated into the raster calculator function. The values of S that resulted from this calculation are shown below in Figure 4.

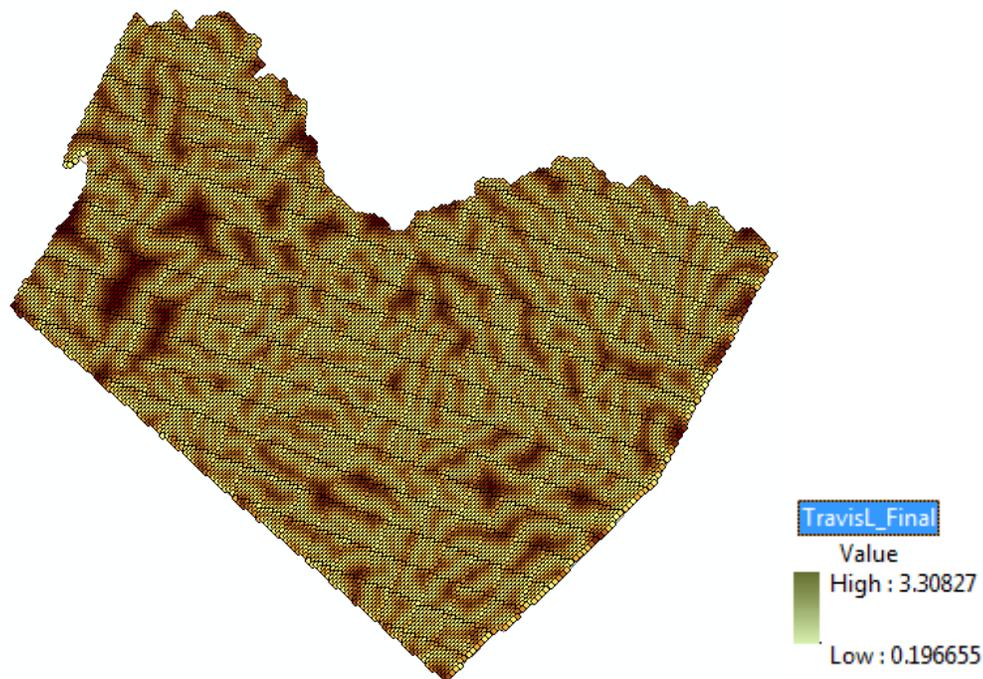


Figure 4. L values for Travis County

S-Slope Steepness Factor

The slope steepness factor is the ratio of soil loss relative to a 9% slope, which is the standard slope that experiment plots use. The slope steepness factor is calculated as a function of slope as shown below:

$$S = 10.8 \sin(\theta) + 0.03, \quad \text{where } \sin(\theta) < 0.09 \quad (\text{Equation 3})$$

$$S = 16.8 \sin(\theta) - 0.50, \quad \text{where } \sin(\theta) \geq 0.09 \quad (\text{Equation 4})$$

The DEM of Travis County was already created and therefore this raster was used to calculate the slopes each grid cell. The surface slope was calculated using the slope function (Spatial Analyst) with the output being degrees (Figure 5).

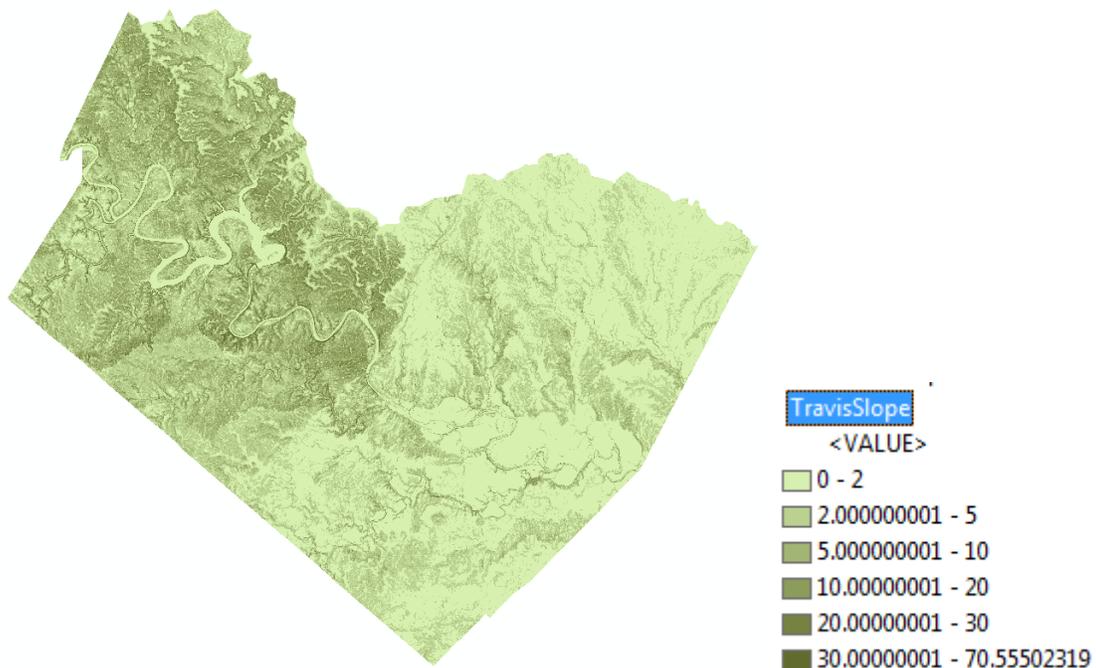


Figure 5. Slopes for Travis County

The slope then had to be converted to the slope steepness factors using Equations 3 and 4. If Equations 3 and 4 are combined into one expression they could be an if-then function. Supposedly, ArcMap 10 has the ability to perform if-then expressions in raster calculator; however, this was unable to be figured out. Therefore, this if-then function was manually created in a feature class by adding a field and using the field calculator.

In order to do this the raster had to be converted into a feature class yet again. However, only integers can be converted into feature classes. As a result, the initial step was to use the raster calculator's integer function to convert all the floating values to integers. The raster was then transformed to a polygon feature class using the raster to feature function. Yet again, in order to obtain results in a timely manner, the raster had to be resampled at 100m resolution. In the feature class a field was added to the table named Value, which represented the S value. The table was then ordered by slope (degrees). For the all values less than 5.16 degrees ( $\sin^{-1}(0.09)$ ), the field calculator was used with Equation 3 to calculate the slope steepness factor. The same was done for the values greater than 5.16 degrees using Equation 4. This was the manual method to calculate the values of S. The feature class was then transformed into a raster using the feature to raster function and the output raster (Figure 6) was ready to be incorporated into the RUSLE Model.

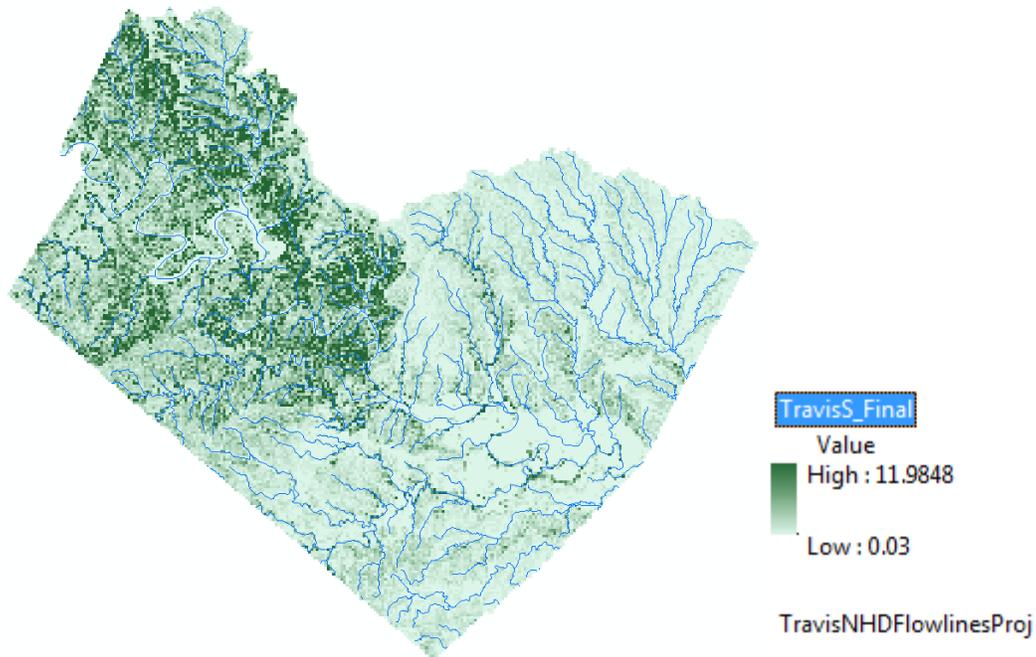


Figure 6. S values for Travis County

### C- Cover and Management Factor

The cover and management factor is the ratio of soil loss from an area of specific land cover to the same area covered in a continuous fallow. There are a variety of sources of land cover data across the nation that are publicly available, but the source selected for this project was the USGS seamless server. From the seamless server land cover from 2001 in raster format was able to be downloaded and imported into ArcMap 10. The imported data was compiled together and trimmed down to Travis County by using the mosaic and clip functions in ArcMap 10.

The important data in this imported feature is a set of values that relate to particular classification of land cover. The values follow a standard land cover classification used by the USGS, EPA and other organizations. Therefore, a field was added to the table in order to

understand what each value represented. Figure 7 shows the classifications of land cover throughout Travis County.

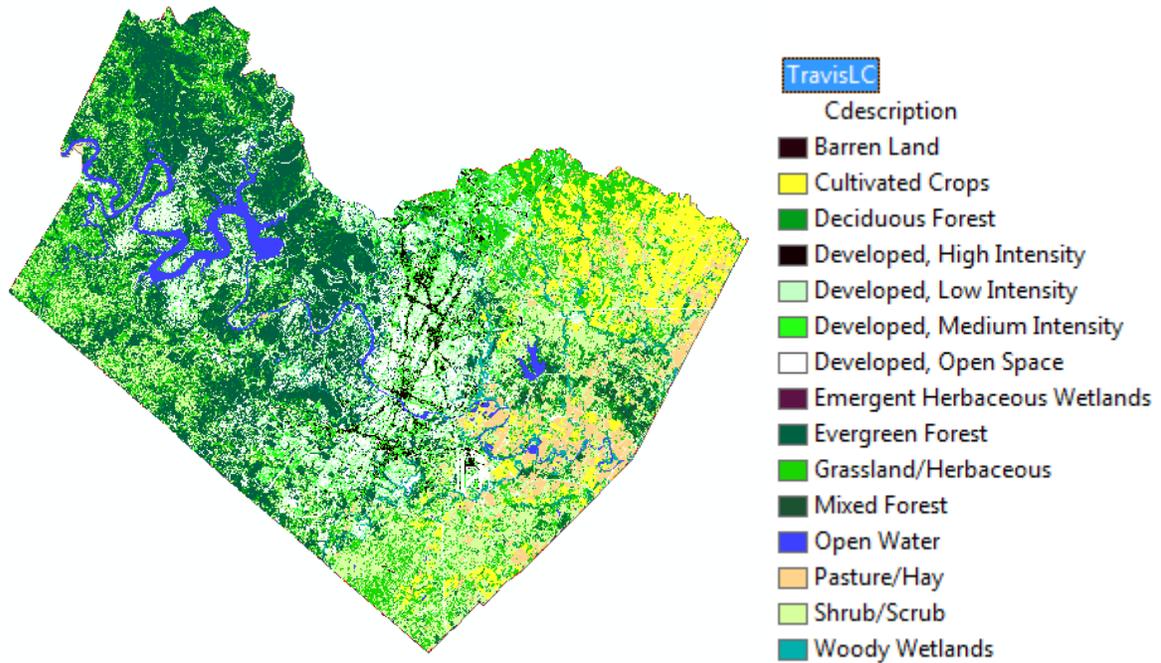


Figure 7. Land Cover throughout Travis County

These land cover classifications were then used to develop values of C. Haan et al. (1994) provides a table of C values for a variety of land conditions. This table was used in coordination with the land cover classifications to determine the values of C for each land classification (Table 1).

Table 1. C Values for each Land Cover Classification in Travis County

Value	C	Cdescription
11	0	Open Water
21	0.003	Developed, Open Space
22	0.013	Developed, Low Intensity
23	0.2	Developed, Medium Intensity
24	0.45	Developed, High Intensity
31	1	Barren Land
41	0.003	Deciduous Forest
42	0.003	Evergreen Forest
43	0.003	Mixed Forest
52	0.009	Shrub/Scrub
71	0.013	Grassland/Herbaceous
81	0.003	Pasture/Hay
82	0.003	Cultivated Crops
90	0.001	Woody Wetlands
95	0.003	Emergent Herbaceous Wetlands

In order to incorporate these values into ArcMap 10 a new field was created in the land classification layer and the values of C were manually entered. The feature was then converted into a raster using the feature to raster function based on the C value and the output was C values throughout the course of Travis County (Figure 8), which were ready to use in the RUSLE model.

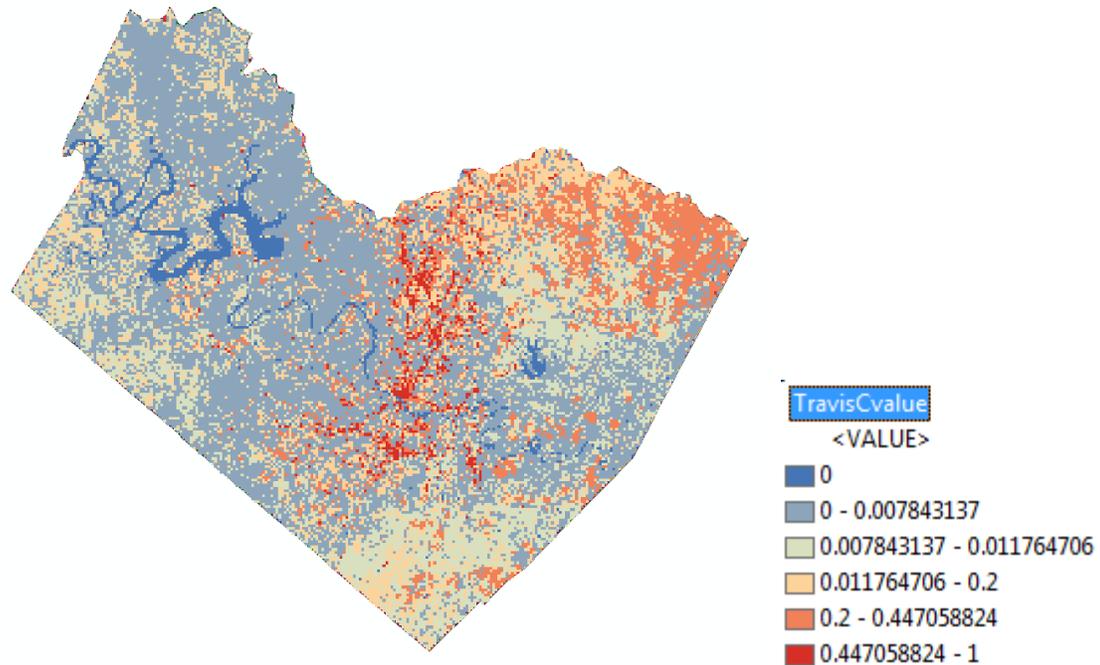


Figure 8. C values for Travis County

#### P- Supporting Conservation Practice Factor

The supporting conservation practice factor adjusts the average annual soil loss accordingly if measures are taken to prevent erosion. In this project a factor of 1.0 was assumed, which is typical unless other information on the area is known.

#### **RESULTS**

The average annual soil loss (A) was calculated using the raster calculator and inputting the rasters of values for each variable as described above. The results are shown in Figure 9.

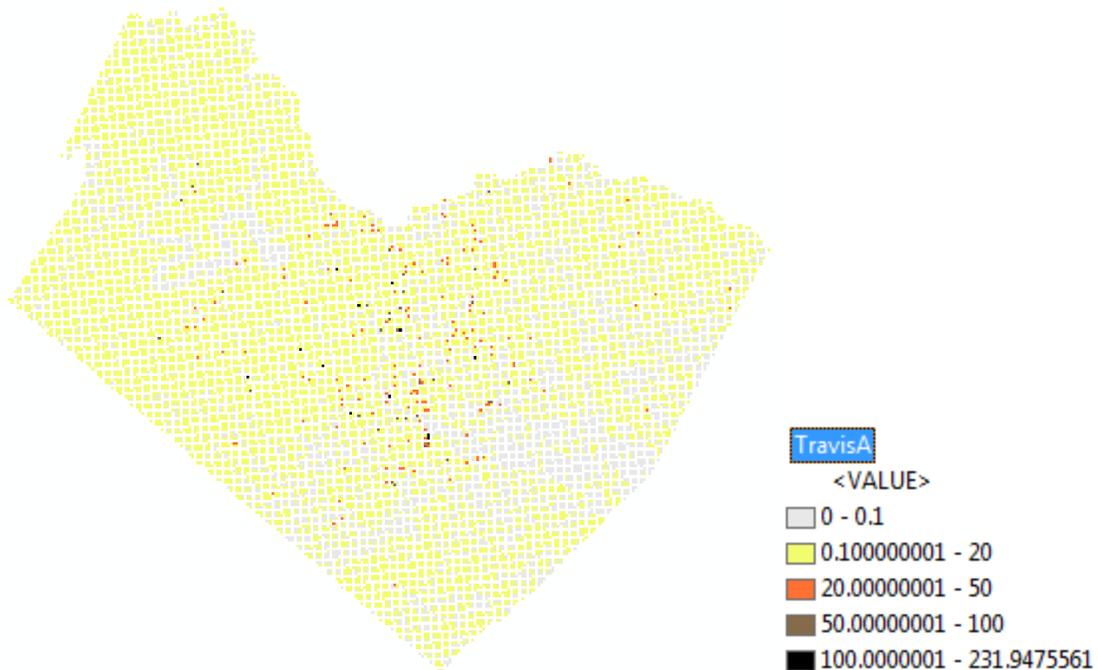


Figure 9. Average annual soil loss for Travis County

The units for average annual soil loss are tons/acre•yr. Figure 9 shows that the darker areas are the soils are very vulnerable to erosion. In these areas, erosion prevention methods such as best management practices or others would need to be consider to reduce the soil erosion. On the other hand, it is clear that there are a lot of areas that are not susceptible to erosion. However, based on the assumptions made in the project methods to create each variable for the RUSLE model, caution should be used when interpreting these results.

## DISCUSSION

The methods outlined in this paper are valuable to individuals that may want to utilize the RUSLE model and ArcGIS to model erosion in their particular area of interest. However, the results obtained by these particular methods need to be interpreted with great caution. There are

a variety of areas where these methods can be approved upon in order to yield better models of erosion potential.

The rainfall/runoff factor (R) dealt with the amount of energy caused by the duration, intensity and frequency of precipitation and its impact on erosion. The methods described in this paper utilized one value for the entire county that was based on annual averages. Therefore, depending on the size of future studies or the time period of future studies this factor could be adjusted. For example, if this model was extended for the entire state of Texas, then one average value would not be detailed enough. Furthermore, if the time period of interest was a particular storm event, or hurricane, that has a high amount of energy, this could be considered by utilizing the equations referenced in the rainfall/runoff factor section in order to obtain more accurate results for these particular events.

Other areas where the model could be improved have been mentioned in previous sections, but it is important to reiterate them. The development of the soil data viewer for ArcMap 10 would greatly enhance the models described in this paper. The methods for utilizing the soil data viewer were described in detail such that if the user has ArcGIS 9.3, the soil erodibility factor could be included in the model. Furthermore, the methods described in this paper utilized transformations from Raster to Polygon and vice versa, which forced some resolution of the data to be sacrificed in order to complete the model in a timely manner. Therefore, in order to improve future models the initial 1" or 1/3" data could be utilized instead of resampling.

Lastly, the soil SSURGO data obtained through the National Resource Conservation Services that was used to find the soil erodibility factor, also has detailed information on the tolerable soil loss (T) of each soil. The tolerable soil loss is the amount of erosion that is

acceptable for each specific area. This data would be an excellent way to improve the interpretation of the results. Instead of just understanding the regions that are vulnerable to erosion, comparison of the tolerable soil loss and the average annual soil loss would allow the user to identify all the areas that exceed the tolerable amounts of erosion. The use of best management practices would be vital in these regions.

## **CONCLUSION**

The methods used in this project made a lot of assumptions, which in turn induced a great deal of error within the results. Therefore, even though these results should be interpreted with caution, the methods described in this paper demonstrate that ArcGIS can be a valuable tool in modeling erosion potential. The combination of using these methods with the improvements discussed in this paper could lead to ArcGIS being an effective tool in understanding erosion potential throughout Travis County or any other specific region of interest. Furthermore, the methods taken in this paper took a general approach such that they can be used in many applications.

One interesting application would be the use of this model on small scales such as construction sites. The model could then be used to understand the potential for erosion of a construction project and its impact on a nearby stream. Through this type of analysis, the model could show how much erosion is tolerable and how much erosion needs to be prevented by the use of best management practices. These best management practices could also be incorporated into the model by utilizing different types of Supporting Conservation Practice Factors (P). If research is done to understand how effective silt fences, polyacrylamides, sedimentation ponds, etc, a table of P-values could be developed and incorporated into the model. On the other hand,

these methods could be used for large scale models to understand what regions of the state are particularly vulnerable to erosion and therefore need to take appropriate measures in reducing erosion. If this data was combined with water quality data of streams, it could yield very interesting results.

The possibilities of utilizing ArcGIS as a tool to model erosion potential are endless. Therefore, the true value of this paper is in the methods and understanding that it can be an effective tool. There are a lot of improvements and future work that can be done with this type of modeling, but the methods described in this paper are a great base to begin with.

## References

Haan, C.T., Barfield, B.J. and Hayes J.C. (1994). *Design Hydrology and Sedimentology for Small Catchments*. Academic Press, Inc, California.

Khosrowpanah, S., Heitz, L., Wen, Y., and Park, M. (2007). "Developing a GIS-based Soil Erosion Potential Model of the Ugum Watershed." Technical Report No. 117. Water Environmental Research Institute of the Western Pacific, University of Guam.

USDA-NRCS, [www.soils.usda.gov/survey/geography/ssurgo](http://www.soils.usda.gov/survey/geography/ssurgo)

USGS, <http://seamless.usgs.gov/>