Potential Soil Loss of the Upper Rio Laja Watershed using the Revised Universal Soil Loss Equation

Background

Through centuries of poor land-use practices, the services that the Upper Rio Laja watershed provides to the region's inhabitants are now severely compromised. Deforestation from extensive wood harvesting and the overgrazing of livestock have resulted in a landscape that is vulnerable to desertification. This degraded hillside and riparian status within the watershed undermines its ability to absorb the monsoon-like summer rains. The resulting higher volumes and velocities of flow within the Upper Rio Laja cause accelerated rates of sedimentation in the Ignacio Allende reservoir, a man-made catchment basin for municipal and agricultural use. In addition, much of the most fertile topsoil is being washed away from the region's agricultural land. The Laja River is part of the Lerma-Chapala basin—a basin that is considered Mexico's breadbasket.

Study Area

Located in the central Mexican plateau, the Upper Rio Laja watershed encompasses nearly 10,000 km^2; the main stem of the river is over 300 km in length. Elevations within the watershed range from 1,800 to 2,900 meters above sea level (Tofflemire, et. al., n.d.). The region's climate is variable, with most of the average annual rainfall of 70-75 cm received from June through October; the months of winter and spring are considered arid.

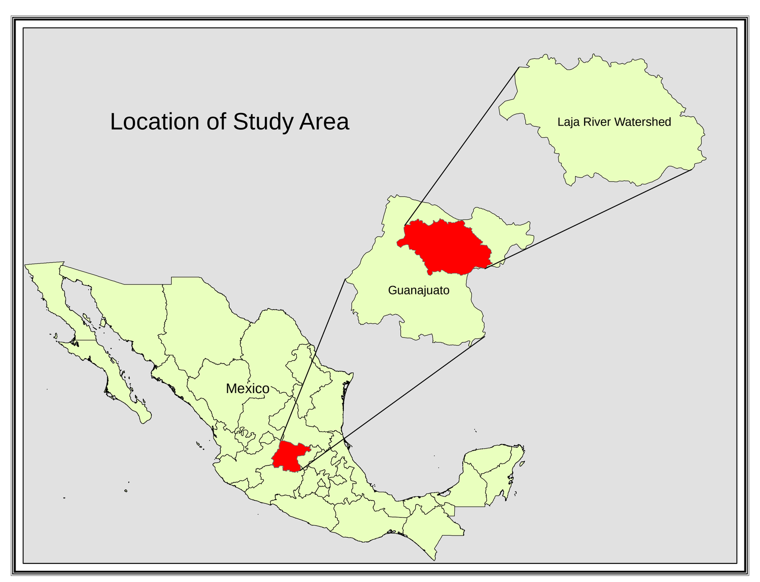

Figure 1. The location of the Upper Rio Laja watershed within the state of Guanajuato, central Mexico.

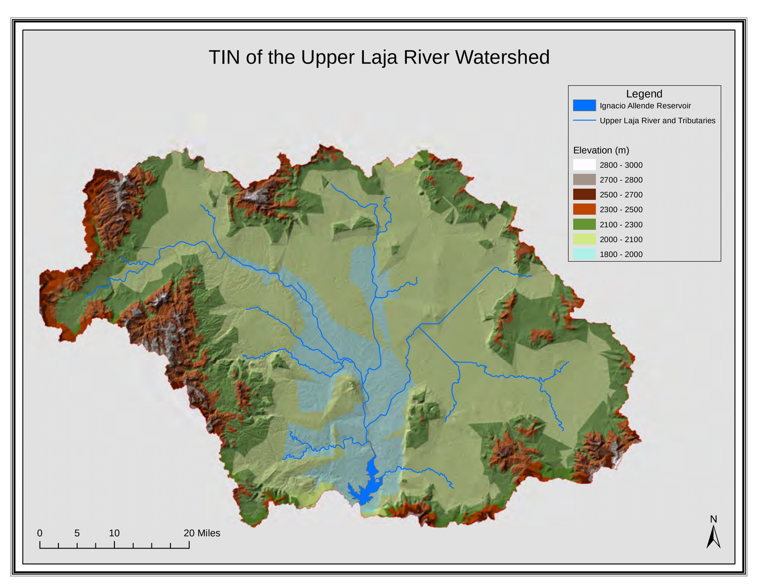

Figure 2. Triangulated Irregular Network surface of study area.

Methodology

The object of this project was to estimate the potential annual soil loss due to sheet and rill erosion within the Upper Rio Laja Watershed. This was accomplished through integrating the Revised Universal Soil Loss Equation (RUSLE) with Geographic Information System (GIS) technology. RUSLE is an updated, and more flexible version of USLE, which was the result of nearly a half-century of data collection and analysis. The Agricultural Handbook 282 and 537 were the products of this work (Wischmeier and Smith, 1965 and 1978). The equation is as follows:

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

Where:

A = mean annual soil loss potential (tons ha^{-1} yr^{-1})

R = Rainfall Runoff Erosivity Factor (MJ mm ha^{-1} hr^{-1} yr^{-1})

K = Soil Erodability Factor (t ha h ha^{-1} MJ^{-1} mm^{-1})

C = Land Cover Factor (unitless)

LS = Slope Length and Gradient Factor (unitless)

P = Support Practice Factor (unitless)

* The P factor was not used for this project because the desired output is baseline potential erosion.

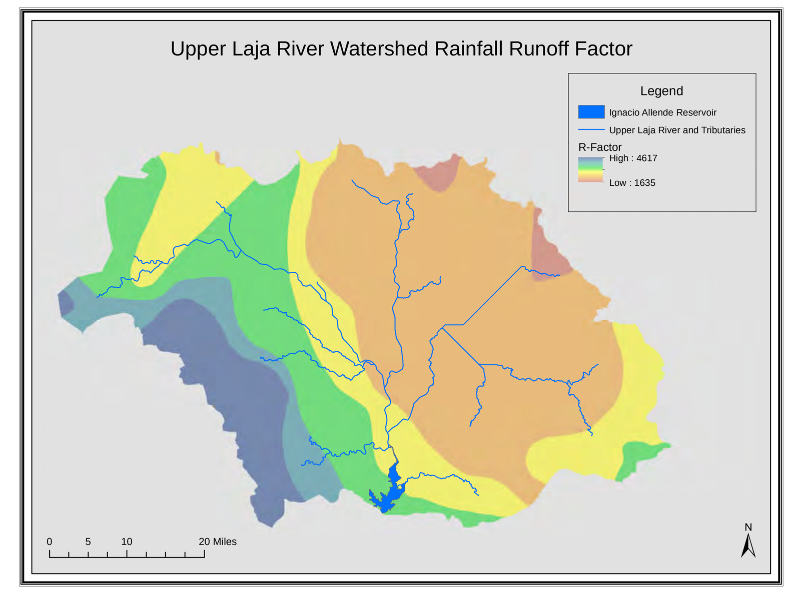

Figure 3. This factor is typically measured by taking the product of the total kinetic energy of a storm (E), and its maximum 30-minute intensity (I)—EI^{30}. The average EI^{30} value over a 22-year period of record represents that location's R factor. However, because this data is unavailable for much of the industrializing world, other approximations serve as substitutes. The following binomial was applied in this project:

$Y = 2.8959X + 0.002983X^2$

Where:

$Y = EI^{30}$ MJ mm ha^{-1} hr^{-1} yr^{-1}

X = Annual rainfall (mm)

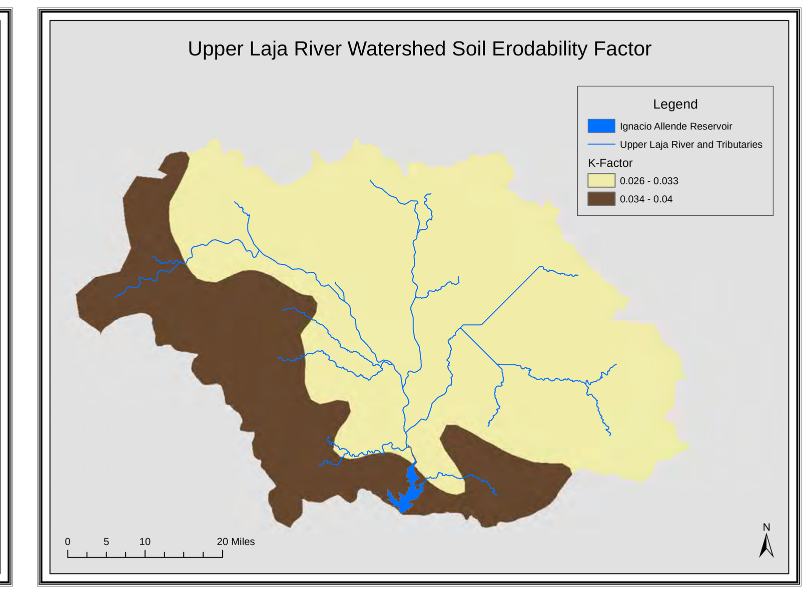

Figure 4. This factor is a measure of resistance to detachment. Soil particle size and shape are important in determining how a type of soil will react to rain and runoff conditions. Two types of soils dominate the study area: Phaeozems and Vertisols. Phaeozem soils are dark in color, high in organic material and are found in temperate/humid grasslands and forests. Vertisols are typical of Mediterranean climates with a marked wet/dry seasonality. Despite their high fertility, Vertisol soils are hard to plough due to high clay content (SEMARNAT, 2008).

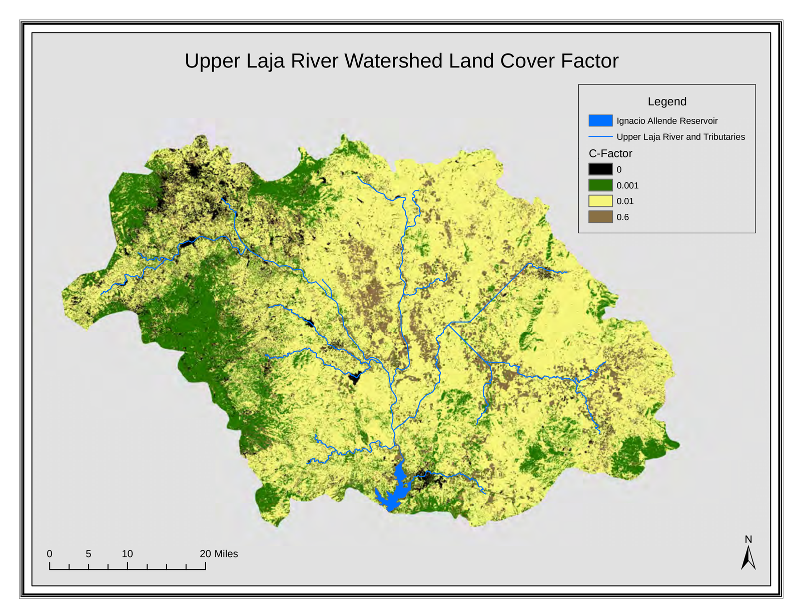

Figure 5. This factor translates the roughness of various surface cover types into a percentage of erosion that would have occurred under continuous fallow conditions (Institute of Water Research, 2002). The three primary cover types within the present study are temperate forest (green), temperate grassland and barren land (yellow), and cropland (brown).

Land cover data was derived from Landsat 8 images provided by USGS. A supervised, maximum likelihood classification was applied at the watershed scale.

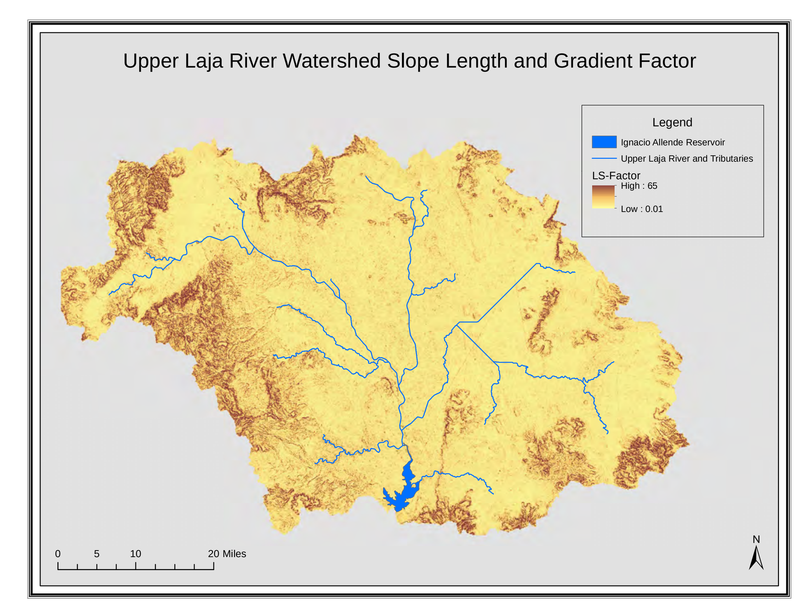

Figure 6. This factor represents the cumulative effect that slope length (L) and slope steepness (S) have on erosion. Both measures are ratios that compare to benchmark conditions of a unit plot that is 72.6 feet in length and of 9% steepness (Institute of Water Research, 2002).

A prewritten C + + executable program was used to compute the LS factor (Remortel, et. al., 2004). Digital elevation models were provided by USGS.

Results and Conclusions

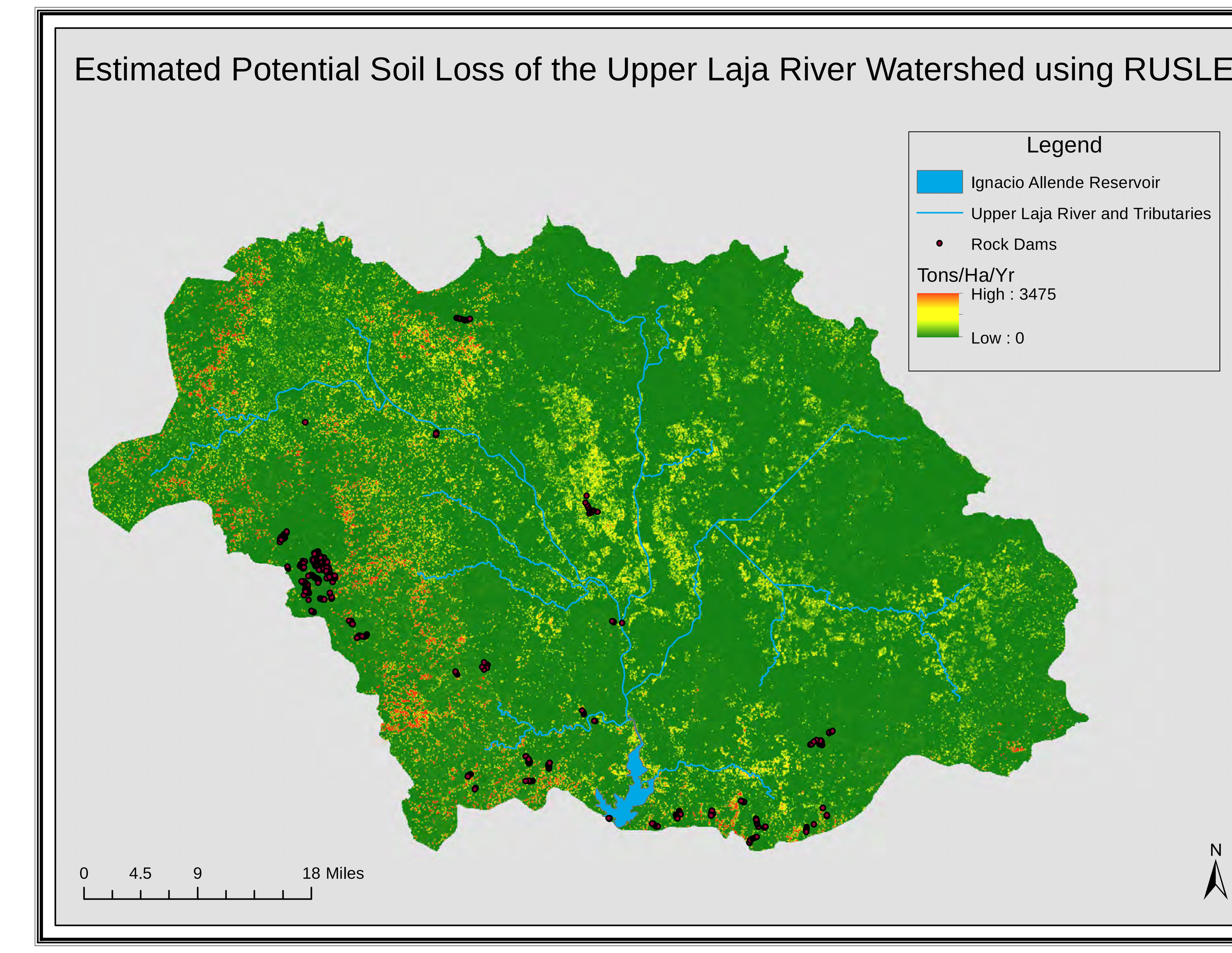

Figure 7. After each factor was calculated, the resulting raster layers were resampled to 100 m^2 cell size. Lastly, a raster overlay was performed to produce an overall RUSLE output. The results show the distribution of estimated potential soil loss throughout the watershed. In addition, past restoration sites (rock dams) are shown.

Mean potential soil erosion within the watershed was estimated at 15.7 tons per hectare per year. Of the RUSLE factors, rainfall erosivity was notably high. This is due to the high intensity of rainfall during the wet season (June-October). The RUSLE model indicates areas within the watershed that may benefit from further restoration/erosion management actions. Further investigation at the site scale would be needed to verify the accuracy of this project's results.

RUSLE model accuracy would improve with application at larger scales. For example, a more detailed vegetation cover classification would yield a more accurate spatial distribution of C factor values.

References

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