EROSION PREDICTION IN THE MOCA RIVER, DOMINICAN REPUBLIC

Geographical Information Systems in Water Recourses

Term Paper

By Marleny Santana

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Report Prepared For:

Dr. David G. Tarboton, Dr. David R. Maidment

INTRODUCTION

Erosion is one of the main factors of river degradation in developing countries, causing serious, negative impacts in the environment (Li and Eddelman, 2002; Thamer et al, 2008). In the tropics, erosion is mainly aggravated by destructive agricultural practices, what raises many concerns regarding the often weak or non-existent land management (Millward and Mersey, 1999). The extent of soil erosion in this context depends on the complex interaction of a number of aspects such as the resilience of the river itself, the institutional conditions, population growth and the policy environment (Ananda and Herath, 2003).

This study is part of a master's thesis focused on developing an integral strategy for river restoration in developing countries that identifies techniques for flooding control, water quality improvement and informal settlements upgrading. As part of this, erosion control is an important factor that contributes to all the above mentioned objectives. Knowing the patterns of sediment erosion and deposition is crucial because they cause channel and bank instability that eventually leads to flooding disasters. Possible techniques for erosion control were identified in the thesis, but locations for where to implement them need to be located in the case study of Moca River, Dominican Republic. Therefore, the purpose of this project is to complement the thesis work by identifying locations of high erosion rates using ArcGIS and the Revised Universal Soil Loss Equation (RUSLE) in the Moca River Watershed.

DESCRIPTION OF THE AREA

Moca River is a third order river, which main stream has a length of 21.63 km (13.44 miles). It rises at approximately 900 mamsl (2952 ft) up in the Cordillera Septentrional ("Northern Mountain Range"), north of Moca, the capital city of Espaillat Province and it flows southwest until joining with the Licey River at an elevation of 100 mamsl. The total area of the watershed is approximately 58 sqkm (22.40 sqmi), a surface that links two municipalities: San Victor, where it born, and Moca (Figure 1). Slopes change dramatically within the watershed. At the lower watershed, the majority of the terrain presents slopes from 0% to 6% with small areas ranging from 7% to 18%. At the upper watershed, the majority of slopes are between 19% and 63%. Streams in this area have faster flow and carry more sediments (Figure 2).

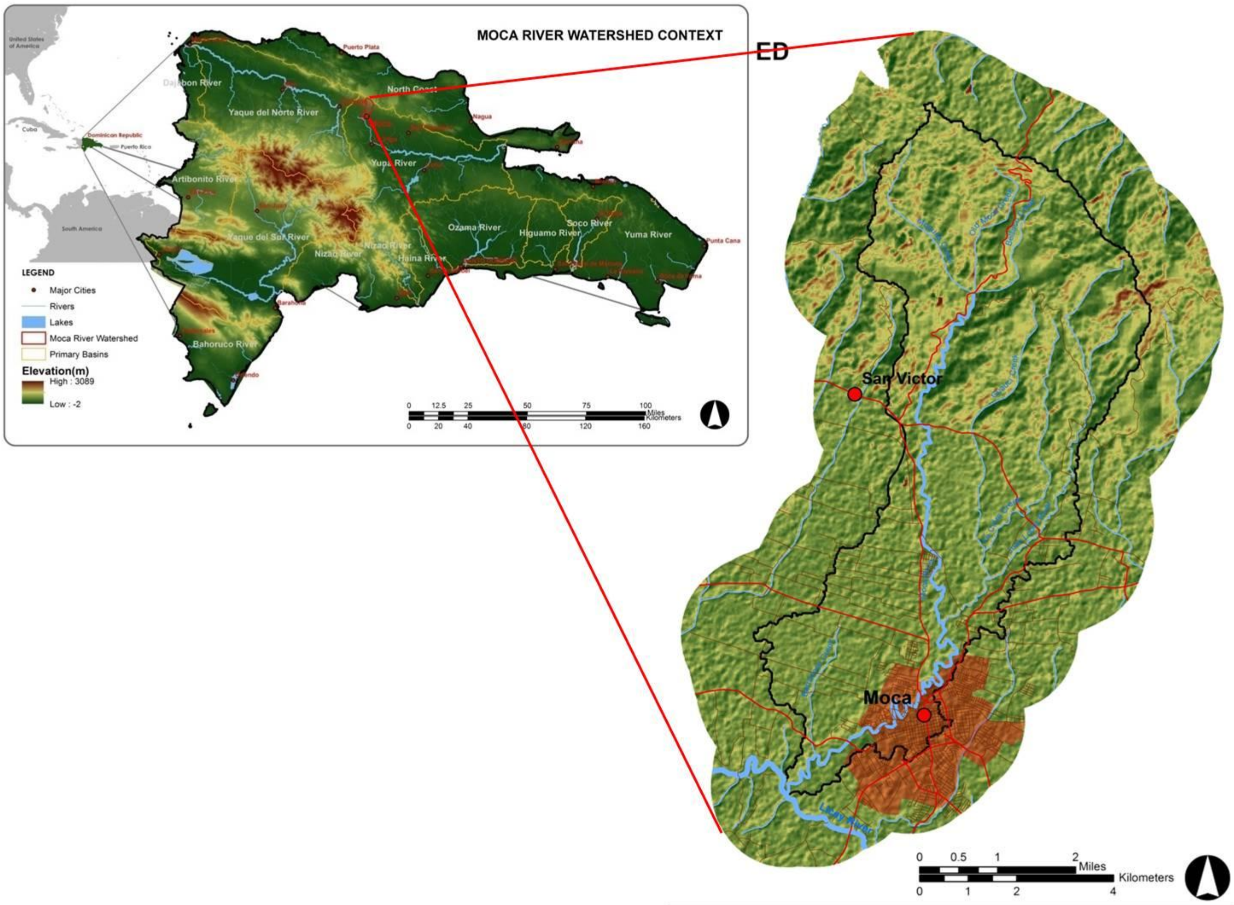

Figure 1. Location of Moca River Watersed

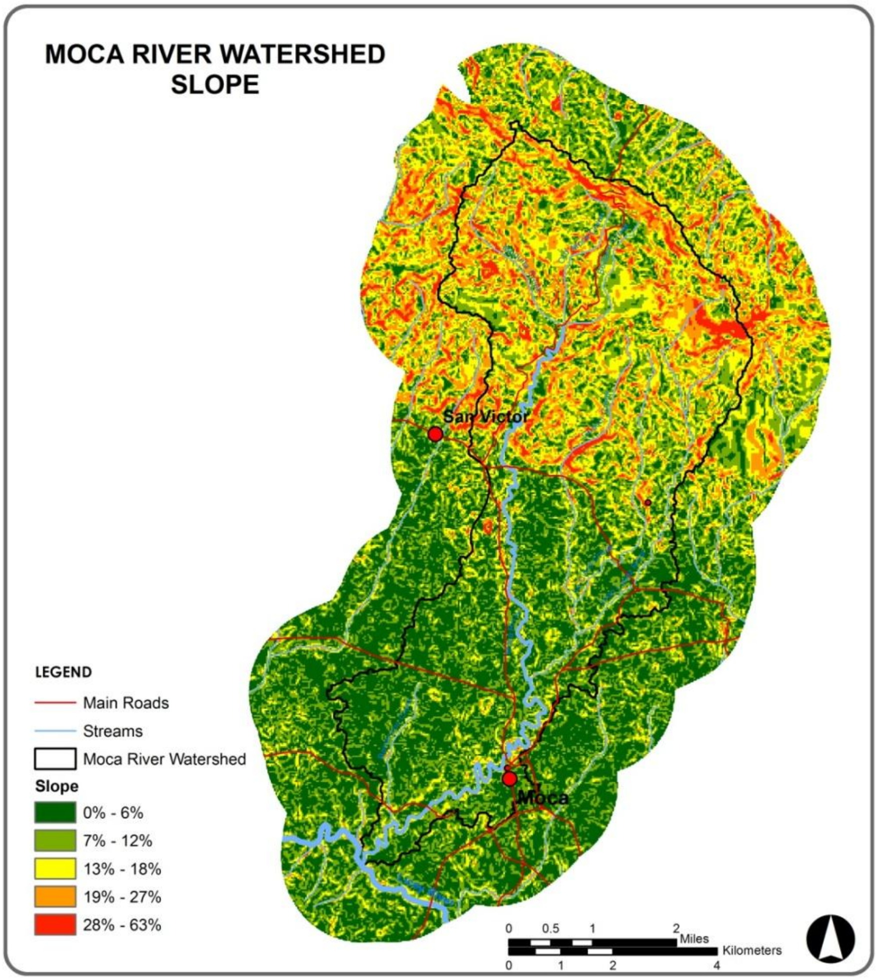

Figure 2. Moca River Watershed Slope

The climatic system of the watershed is mainly influenced by the presence of subtropical anticyclones and the trade winds direction, which are dominant in most part of the year. Rainfall is higher most frequent during the months of April to December, with varying intensity according to the topographic location (Moca Municipal Development Plan, 2011). An interpolation analysis of the nearest gages around the watershed indicates that the annual average precipitation in the watershed is 1,180 ml (46 in) with a maximum of 2360.5 mm (92.93 in) and a minimum of 985.8 mm (38.81in) for the years 1970-1985 (author; BUYH, 2013). There is no record of the Streamflow data from the watershed, but, according to a gage located at Paso de Moca, a community between Moca and San Victor, the calculated flow of the Moca River in July of 2011 was 0.33 m3/s, with a mean velocity of 0.55 m/s, a PH of 8.5 and conductivity of 642 uS. (INDRHI, 2011).

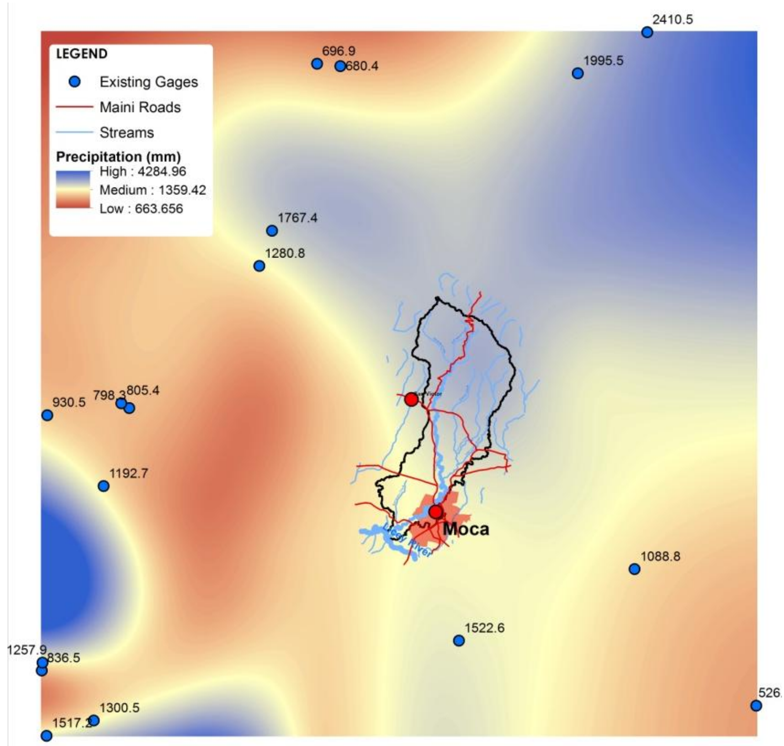

Figure 3. Gages used for Interpolation

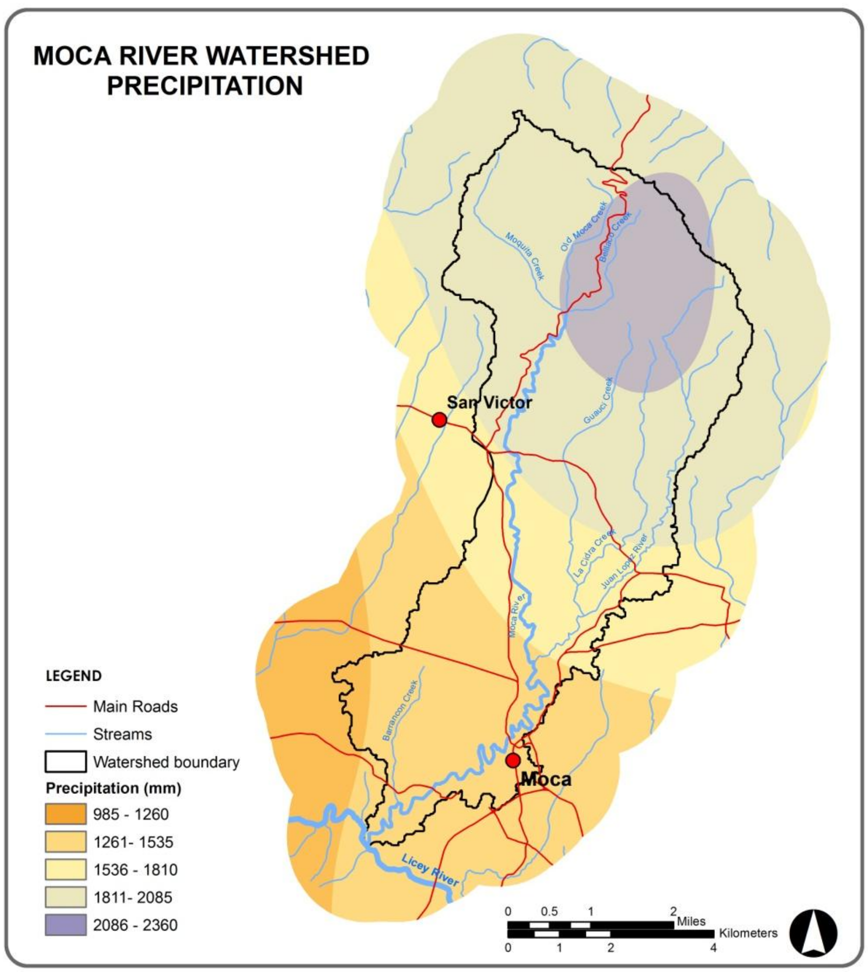

Figure 4. Moca River Watershed Precipitation

There is a variety of land cover within the watershed. Broadleaf humid forest is distributed in upstream areas between 500 and 1,000 meters (International Resources Group, 2001). Along with this forest, it can be seen traditional coffee and cacao plantations and other mixed agriculture. Grazing also occurs mainly upstream. Downstream land cover is represented by intensive crops, broadleaf shrubland and populated areas. Dry shrubland, grows along the river stems, as well as various species of cactus and other xerophytes (International Resources Group, 2001).

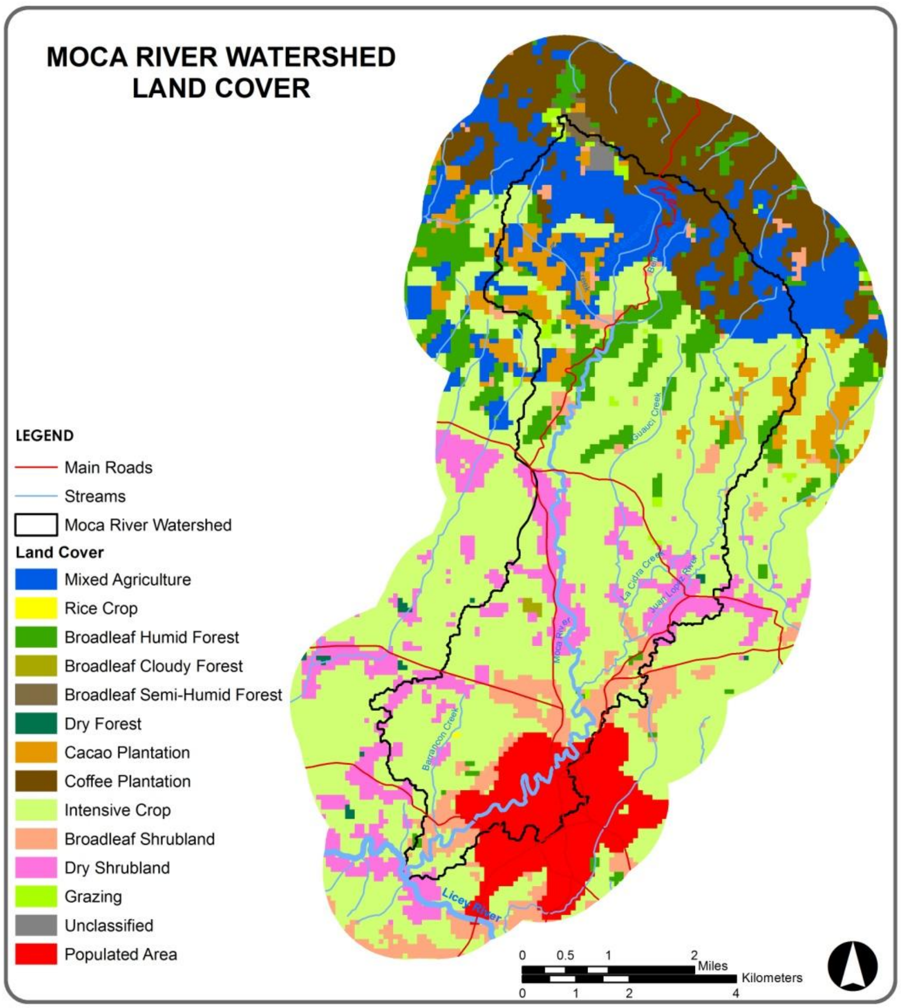

Figure 5. Moca River Watershed Land Cover

There are three types of soils within the Moca River watershed. Upstream catchments have a mix of sandstone, sandy loam and olistolites soils. Middle catchments have quaternary alluvium, while a small portion around the joining with the Licey River is limestone and calcareous siltstone (Ministry of Environment and Natural Resources, 2009).

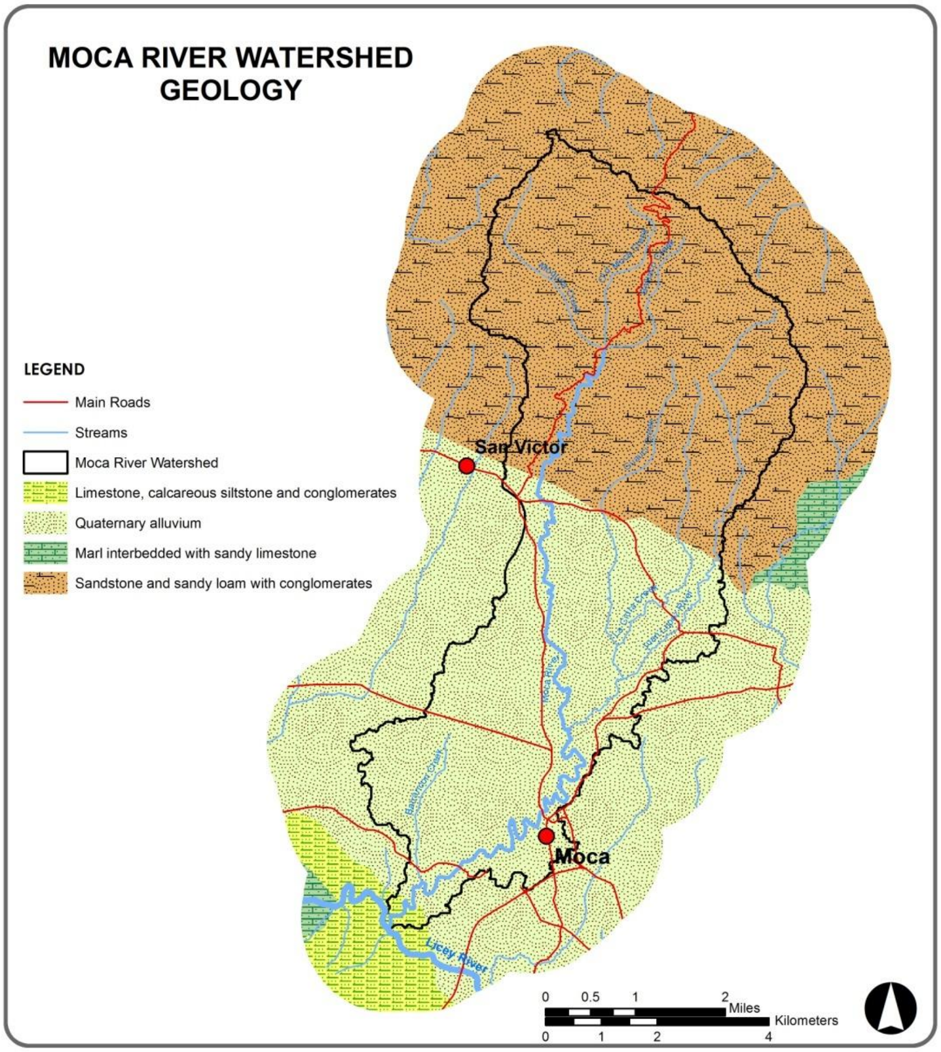

Figure 6. Moca River Watershed Geology

METHODS

The procedure of this term project followed the next steps: data gathering and mapping, RUSLE calculation of soil loss, results interpretation, and conclusions.

Data Gathering and Mapping: to determine the annual erosion that occurs at the Moca River Watershed, certain data were obtained through various agencies and organizations. A 30m DEM for the Dominican Republic was downloaded from the LP DAAC Global Data Explorer website. Shapefiles containing streams, soil type, land cover and precipitation gages location of the whole country were obtained through The Nature Conservancy, Caribbean Program. As the gages did not have any precipitation values within their attribute table, excel files were downloaded from Brigham Young University HydroServer (http://byuhydro.byu.edu/).

To determine the watershed boundary, the process of watershed delineation done in exercise 4 was followed. First, the DEM was filled using the Fill tool under Hydrology. Then, flow direction and flow accumulation were calculated. Next an outlet point was used to define the watershed boundary upstream from the point. A buffer of 1500meters was done from the resulting boundary in order to get an outside context. Then, all shapefiles and the DEM were clipped/masked to it. The DEM was used to calculate the slope and slope lengths of the watershed. With all these, the base maps of the study were done.

RUSLE Calculation of soil loss: the Revised Universal Soil Loss Equation (RUSLE) is a method developed by the US Department of Agriculture to compute sheet and rill erosion estimates for a landscape profile. Although this method is was not designed for lands where no overland flow occurs or undisturbed areas, it has been extensively used for these types of studies because it is straightforward (De Roo, 1998).

The Revised Universal Soil Loss equation is: A=R*K*LS*C*P, where,
A = soil loss per unit area (t/ha)
R = Rainfall-Runoff erositivity (Mj*mm/ha*h*yr)
K = Soil erodibility (t*ha*h/ha*Mj*mm)
L = Slope length factor
S = Slope steepness factor
C = Crop (land cover) factor
P = Practice (erosion controls) factor

Rainfall-Runoff erosivity

This factor measures the effect of rainfall intensity and total storm energy. To calculate this factor, annual precipitation was calculated from the excel sheets of the three nearest gages to the watershed. Then, this values were added in GIS in a new field to the attribute table of the gages shapefile. As these gages were not within the watershed, an interpolation tool (spline) was used to get a precipitation raster. Then the factor was calculated by using the next equation with the raster calculator tool:

R= -3172 + 7.562 (P) where P is the precipitation in mm (Mikhailova et al. 1997).

Since the annual precipitation varies highly from upstream to downstream, the rainfall factor also varies, ranging from 5,000 to 13,000 Mj*mm/ha*h*yr, respectively (Figure 7).

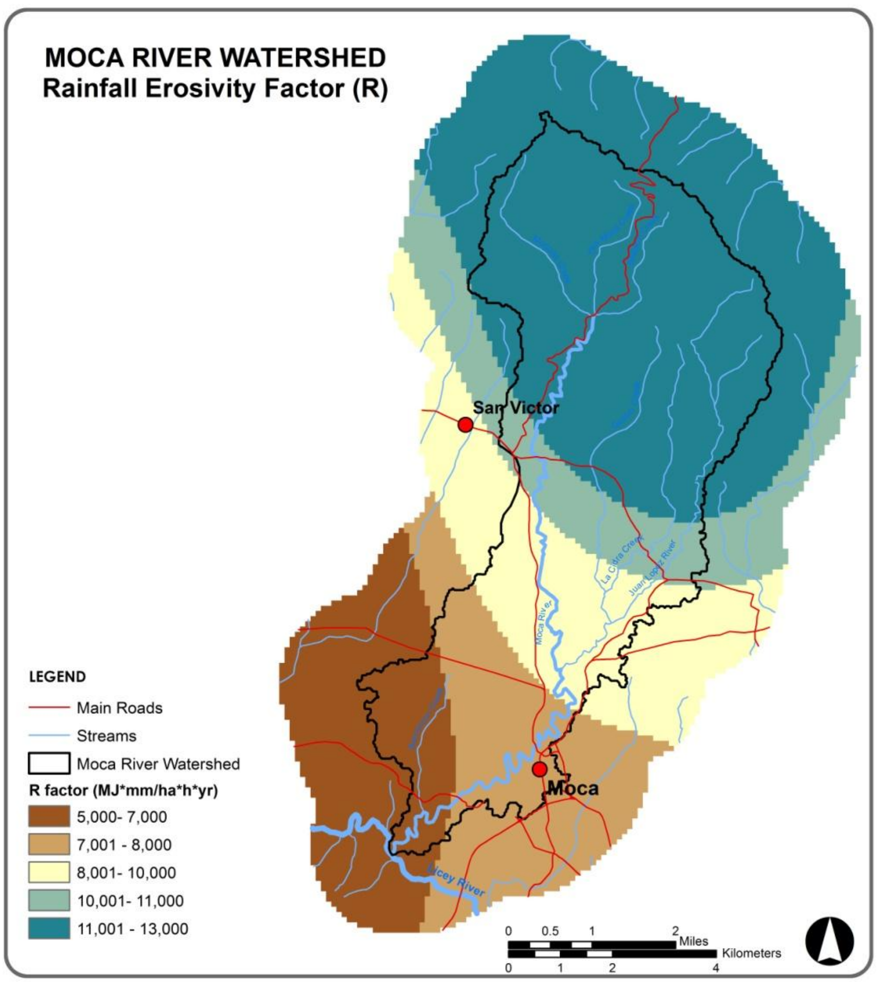

Figure 7. R factor

Soil erodibility (K)

This factor indicates how susceptible soil particles are to detachment and how easily water moves and is retained in the soil profile (Hoyos, 2004). Since there are no records of detailed soil studies for this watershed, soil erodibility factors were determined by associating the soils types in the watershed with the established factor from Ramírez, (1992).

The values of the factors were add to the attribute table of the soils layer as a new field called K factor. Then this shapefile was converted to a grid or raster, choosing the K factor as the attribute to use. At the upstream catchments, a value of 0.3 correspond to sandstone, sandy loam and olistolites soils. Downstream, quaternary alluvium and calcareous siltstone have a factor of 0.5 and 0.4, respectively (Figure 8).

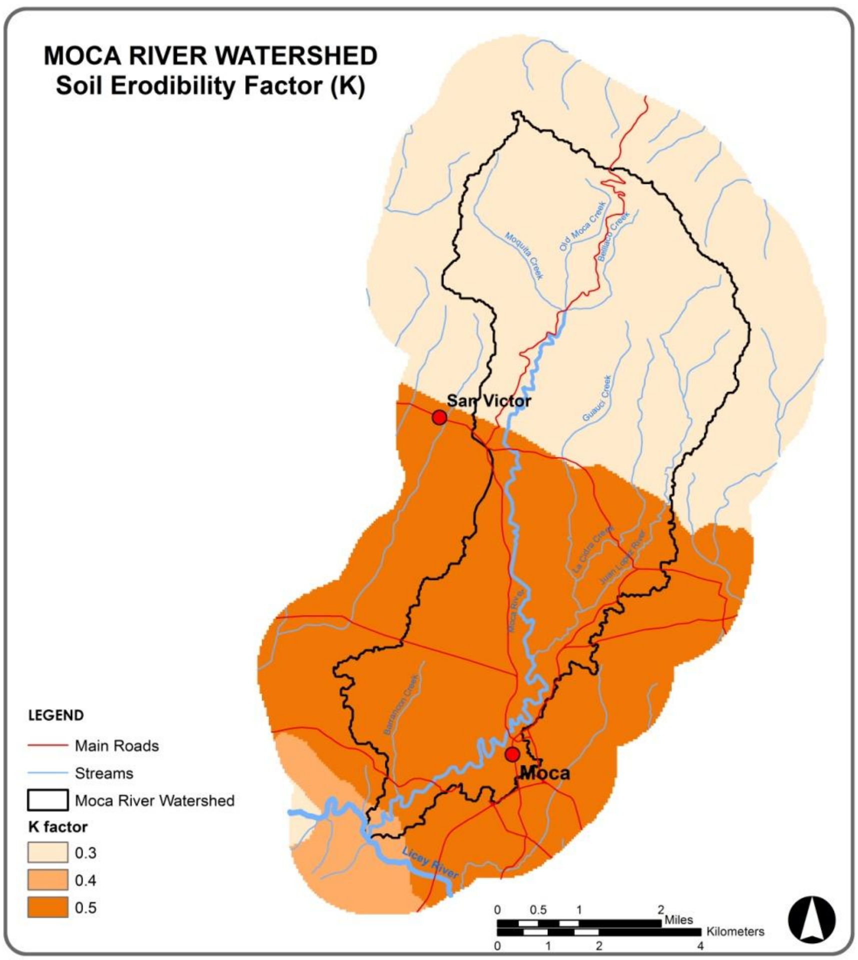

Figure 8. K factor

Slope Length and Steepness (LS)

In executing the RUSLE, the length and slope factors are combined into the LS factor or topographic factor. This factor measures the effects of the steepness and length of the slope on erosion. The combined LS-factor was computed following the next equation, as proposed by Moore and Burch (1986a,b):

$$1.6 \times (\text{Flow accumulation} \times \text{DEM resolution}) / 22.1)^{0.6} \times (\text{Sin slope} \times 0.01745/0.09)^{1.3}$$

To compute this equation, flow accumulation and slope steepness rasters were extracted from the DEM using ArcGIS Spatial analyst and arc hydro extension. Flow accumulation indicates the accumulated upslope contributing area for a given cell. The factors range from 0 to 14.5. Majority of the watershed has LS values of 5-12 at the upstream and 0-0.25 downstream (Figure 9).

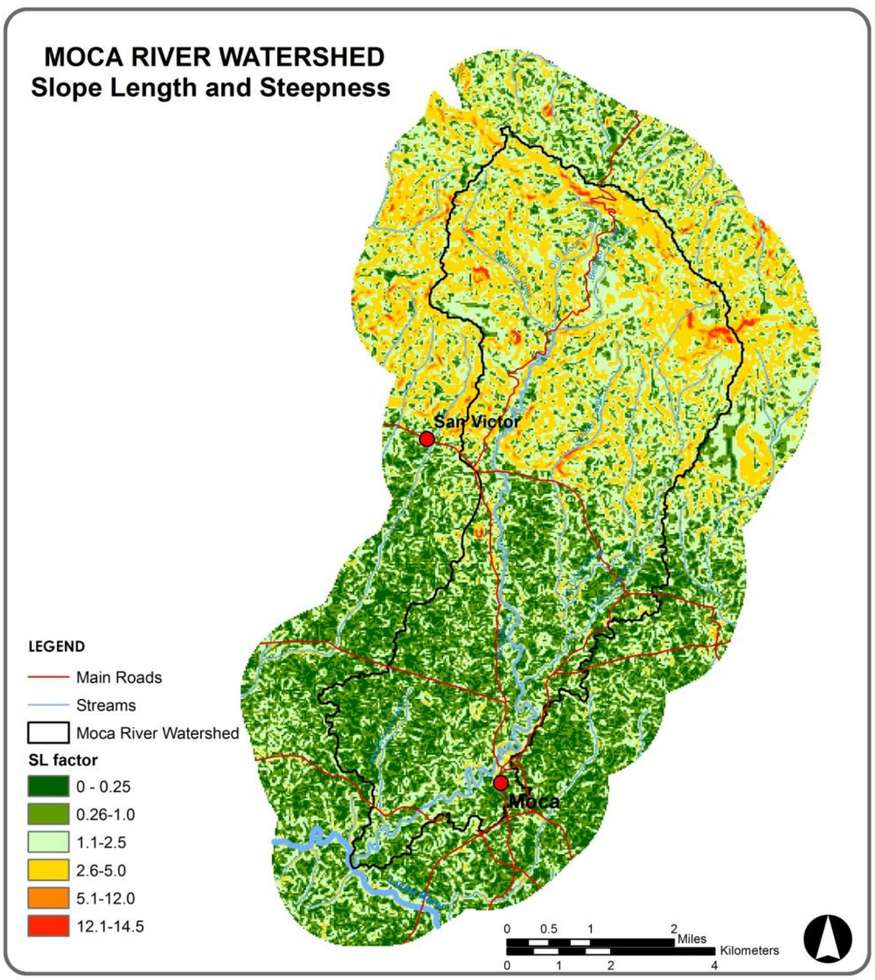

Figure 9. LS factor

Land Cover Factor (C)

This factor measures the soil loss under specified field conditions according to the loss from the standard soil plot. The factor values were added to the different land cover to the different land cover types according to the ones proposed by Ramírez (1992) after Wischmeier and Smith, (1978). The majority of the watershed presents C values of 0.3, corresponding to intensive crop, with exception of forest land and coffee plantation which C value ranges from 0.005-0.09.

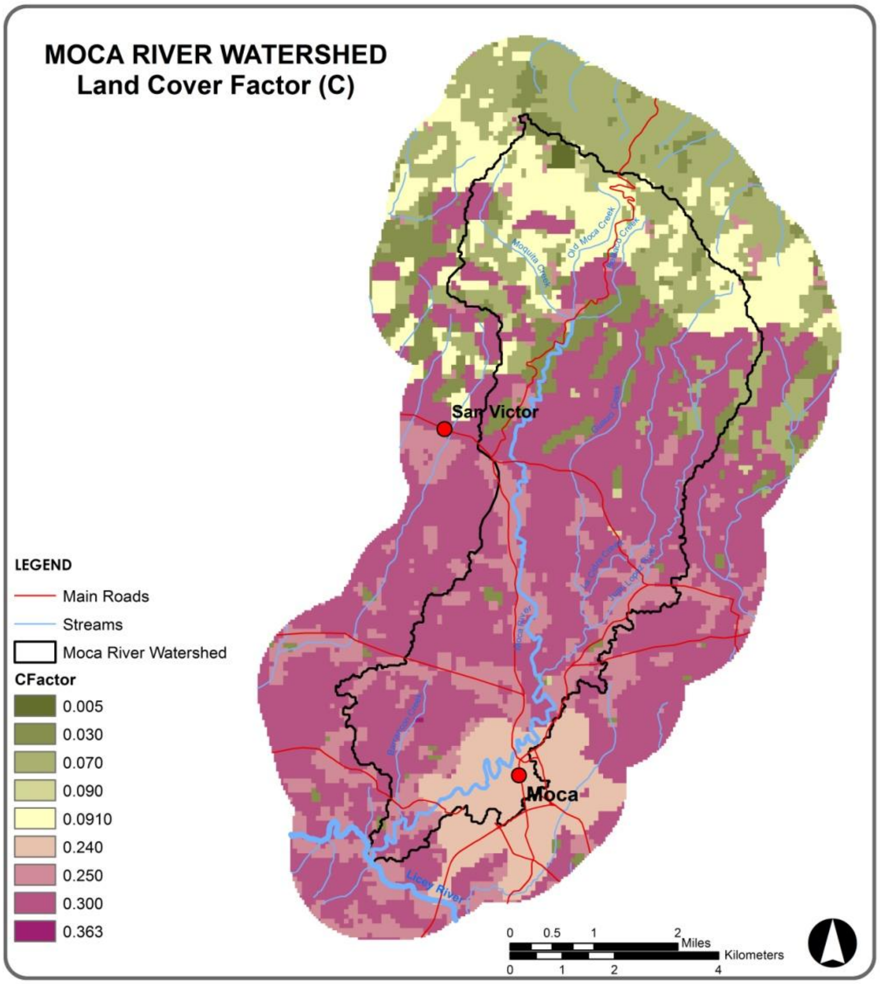

Figure 10. C factor

The P factor for soil conservation practices will be assumed to be 1, since there are no record of erosion controls in the watershed.

RESULTS

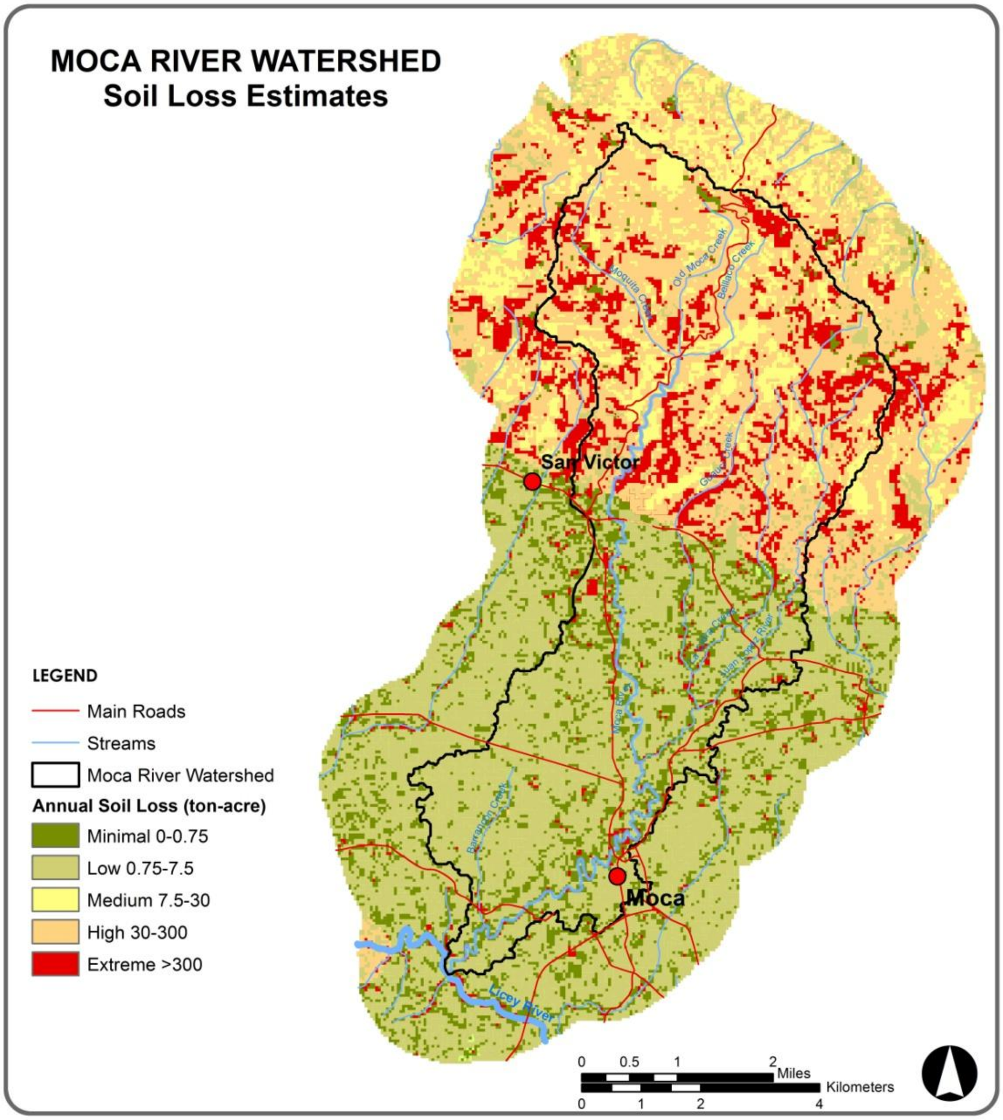

Figure 11. Annual Soil Estimates

Figures11 illustrates the annual soil estimates in the Moca River Watershed, which is a strong reflection of the LS factor and K factor of the watershed. Extreme soil loss, >300 ton-acre-year, appear at the highest SL values upstream, while minimal and low annual soil loss, 0-0.75 ton-acre, occurs downstream where SL values are smaller. Annual soil loss values from this study are close with values for other similar basin at Haiti (Morales, 2012). As a result, the estimated erosion soil based on the RUSLE can be of a reasonable magnitude. However, these need to be compared with further measurements of erosion soil in other closer watershed.

In addition, this study presents uncertainty in some of the evaluated factors for the calculation of the RUSLE equation. For instance, the rainfall interpolation using data from surrounding gages can be more exact. Also, any existing values for the P factor should be included and evaluated on an annual field by field basis. Also, some sources may be outdated, for example, the precipitation dates or the land cover which are from previous decades.

CONCLUSION

In conclusion the objective of this project was to identify quantitatively the areas in the Moca River watershed that have high erosion potential, to suggest land practices or erosion control techniques. The RUSLE equation offers a practical method to estimate soil erosion in a case study like the previously presented. However, much additional research and analysis is needed to validate the results of the soil loss estimated for the Moca River Watershed. Micro-scale data on rainfall intensity, soil texture and land cover can increase the prediction and accuracy of RUSLE-GIS based analysis.

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