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HYDROLOGICAL-ENVIRONMENTAL CHARACTERIZATION AND ESTIMATION OF AREAS SUBJECT TO WATER EROSION IN THE ARROLLO PRIETO MICROBASIN GUANAJUATO

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Abstract: The estimation of water erosion was carried out in areas of the Arroyo Prieto micro-basin in the Bajío Guanajuatense in the southeast of the state of Guanajuato and part of the state of Michoacán, including the municipalities of Yuriria, Puruándiro, Moroleón and Valle de Santiago. The delimitation of the study area, calculation of morphometric parameters and estimation of erosion was carried out using the processing software for Geographic Information Systems ArcGis10.3. To estimate annual soil loss, a raster layer was generated for each factor of the Revised Universal Soil Loss Equation (RUSLE) and a multiplication of the layers was carried out, resulting in a map of erosion levels for each scenario. The total surface area of the study area is 50,959.33 ha, with a main land use in irrigated agriculture, a pelic Vertisol soil type and a main channel of 48.34 km. It was found that the potential erosion of the area is from low to medium, the good vegetation coverage that exists makes real erosion important in some restricted areas of the basin, in which some strategy for soil conservation must be carried out and monitoring the evolution of land uses in order to eliminate high erosion rates from which there is no opportunity to return to a balanced state.
Keywords: Characterization, erosion, morphometry, RUSLE.

INTRODUCTION

The increase in the population of our country has caused great pressure on its natural resources, such is the case of the ecosystems that develop in the semi-arid, which are being pressured by local populations to continue depending on low subsistence agriculture. productive (Hernández, 2011) or to increase its urban borders, which directly leads to the deterioration of its base natural resources such as soil, vegetation, water and biodiversity (Bareiro, 2017).

Among the effects that cause these impacts, those originating from vegetation and soil degradation stand out, drastic changes in the landscape affecting the climate impact (Uribe, 2015). The soil is degraded mainly by anthropogenic activities, increasing erosive processes and thereby altering its physical, chemical and biological properties (López, 2002).

In the Arroyo Prieto micro-basin in the southeast of the Bajío Guanajuatense, one of the most productive areas in basic crops in our country, there are plant communities formed by small tropical deciduous forests, xerophytic scrublands and mesquite trees typical of semi-arid climates characterized by a high degree of disturbance. inducing successional vegetation (Rzedowski 1978). It is currently subject to a large amount of ecological disturbances, mainly in its upper and middle parts, generating decreases in its vegetation and increasing erosive processes and impacting water infiltration (García and Sánchez, 2014).

In the region there are no studies related to the degree of erosion, and very few of its vegetation cover (García and Sánchez, 2014, Sandoval, 2017, Ramírez and García, 2000), so it is difficult to make a proposal for sustainable use for its conservation. In addition to this, the area is subject to a deforestation process, since the lack of knowledge and interest in knowing the importance and diversity of the existing vegetation and its diversity of uses has been causing the destruction of natural habitats. The alterations suffered by the vegetation mainly affect the soil resource, which mainly leads to an erosive process, the loss of its fertility and compaction, which has a direct impact on the recharge of groundwater tables and sometimes on human safety., mainly in the lower part of the micro-basin destined for grain production and human settlements (Sandoval, 2017).

Therefore, the purpose of this research was to provide the characterization of the microbasin emphasizing the erosive process to provide some technical bases and propose some soil conservation alternatives.

METHODOLOGY

DELIMITATION AND MORPHOLOGY

The delimitation of the study area was carried out semi-automatically with the Geographic Information Systems software ArcGis10.3 ®, a DEM with a resolution of 15 m and water current data in shape format was used. To calculate its morphological parameters, established equations and some functions of the ArcGis10.3 ® Software were used.

EROSION ESTIMATION

The Revised Universal Soil Loss Equation (RUSLE) was used, using data on precipitation, soil, vegetation cover and topographic values obtained from FAO and CONAGUA, following the methodology proposed by Martínez, 2005 for our country. The Equation includes 6 factors and is expressed as follows at the international level:

A = R*K*LS*C*P

Where:

A= soil loss in t/ha.year.

R= rain erosivity factor in Mjmm/ha.year.

K= the soil erodibility factor in (t/ha)/(Mj.mm/ha.h)

LS= the length and slope factor of the terrain (dimensionless)

C= the vegetation cover and management factor (dimensionless)

P= the conservation practices factor (dimensionless)

Rain erosivity factor (R). The R factor represents erosivity due to rainfall and is a function of the climate at a particular location. Normally this factor is determined with rainfall data, that is, the maximum rainfall intensity in thirty consecutive minutes is obtained and the associated kinetic energy is determined. The product of both is the erosivity of rain. Due to the lack of information related to the intensity in such short periods of time, it was decided to use the Average Annual Precipitation (APA). The following table presents the equations used to estimate the value of R, which includes 14 regions delimited by the erosivity of rainfall proposed by Becerra (1997):

Region	Equation	R^2
1	1.2078*P + 0.002276*P2	0.92
2	3.4555*P + 0.006470*P2	0.93
3	3.6752*P – 0.001720*P2	0.94
4	2.8959*P + 0.002983*P2	0.92
5	3.4880*P – 0.000188*P^2	0.94
6	6.6847*P + 0.001680*P^2	0.90
7	(-0.0334)*P + 0.0061*P^2	0.98
8	1.9967*P + 0.003270*P^2	0.98
9	7.0458*P – 0.002096*P^2	0.97
10	6.8938*P + 0.000442*P^2	0.95
11	3.7745*P + 0.004540*P^2	0.98
12	2.4619*P + 0.006067*P^2	0.96
13	10.7427*P – 0.001008*P^2	0.97
14	1.5005*P + 0.002640*P^2	0.95

Table 1. Regionalized equations for the Mexican Republic

Source: (Becerra, 1997).

The equation R= 3.4880*P – 0.000188*P2 was selected, which belongs to region 5, according to the location of the Arroyo Prieto microbasin. To obtain the R factor it was necessary to have the annual precipitation data from the meteorological stations within the study area and substitute them into the equation. From the geographical coordinates of each of the meteorological stations, a layer of points was generated to which the values of altitude, average annual precipitation and rain erosivity were assigned, which was processed to obtain the R factor raster.

Soil erodibility factor (K). The K factor represents the erodibility of the soil and shows its vulnerability to the action of water, that is, the ease with which it is detached by the splashing of drops during a rain event, surface flow or by the action of both phenomena. (Montes, Uribe & García, 2011). The K factor is influenced by soil hole size, organic matter content, aggregate strength and particle size. Because there is no detailed information to use the traditional methodology, the Provisional Methodology for the Evaluation of Soil Degradation of the FAO (1980) was used, where only knowledge of the soil unit and its texture is required. The values were reviewed and assigned to the generated point layer for this factor.

Land length and slope factor (LS). The relationship between erosion and LS factor is directly proportional, that is, erosion increases as the length of the land in the direction of the slope increases (factor L) and the inclination of the land becomes greater (factor S).

Coverage factor and vegetation management (C). Vegetation represents the natural protection of the soil against different erosive agents, such as precipitation and wind, since aerial components, such as leaves and stems, absorb part of the energy of raindrops, moving water and of the wind, so their effect is less than if they acted directly on the soil, while underground components, such as root systems, contribute to the mechanical resistance of the soil (Morgan, 1997).

Its value varies between 0 and 1 and decreases as the vegetation cover increases. This factor is decisive in the retention flow of the soil. The value of C is worth unity when the soil is completely unprotected and will decrease as there is better coverage (Becerra, 2005), the coefficient associated with this factor was assigned with the INEGI information on land use and vegetation, corresponding to the Land Use and Vegetation Charter (Montes, 2011).

Conservation practices factor (P). Because there is no information on the conservation practices carried out in the study area, this factor has not been taken into account in the calculation of the USLE.

Average annual soil loss (P). This value was calculated by multiplying the four-raster generated for each of the calculated factors (factors R, K, LS and C), the result was the map that presents the areas of greatest pressure due to water erosion in the microbasin.

RESULTS AND DISCUSSION

CHARACTERIZATION AND MORPHOLOGY

The micro-basin is located in the third largest hydrological-administrative region in the country, RH 12 Rio Lerma-Santiago, which includes 332 municipalities in the states of Guanajuato, Michoacán, and Jalisco. It has a continental area of 192,722 km^2 (SEMARNAT, 2013) and is home to 15 million inhabitants, that is, 16% of the national population; of which 97% of the state is located in the Lerma-Santiago Basin, and 78% of the territory of Guanajuato and is part of the Santa María sub-basin. The dominant type of climate is (A)C (wo) which represents 59.86%, which is a semi-warm subhumid of group C, average annual temperature greater than 18°C, although C (w1) is also found, which is a temperate, subhumid climate, (A)C(w1) which is a semi-warm subhumid climate of group C, and C(wo) which is a temperate, subhumid, with average annual temperature between 12 and 18 °C (Figure 1). The dominant soil type is pelic Vertisol.

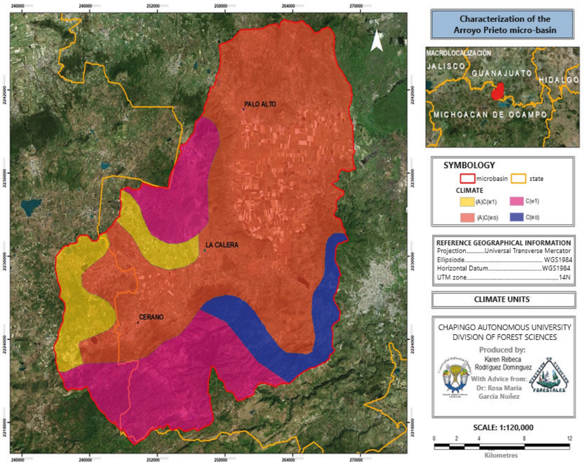

Figure 1. Types of climates in the Arroyo Prieto micro-basin

With respect to land use, annual rainfed agriculture occupies the largest surface area of the micro-basin, followed by irrigated agriculture, secondary shrubby vegetation of low deciduous forest, secondary arboreal vegetation of low deciduous forest, secondary shrubby vegetation of oak forest, oak forests, induced grassland, bodies of water such as the Yuriria lagoon, and urban settlements (Figure 2).

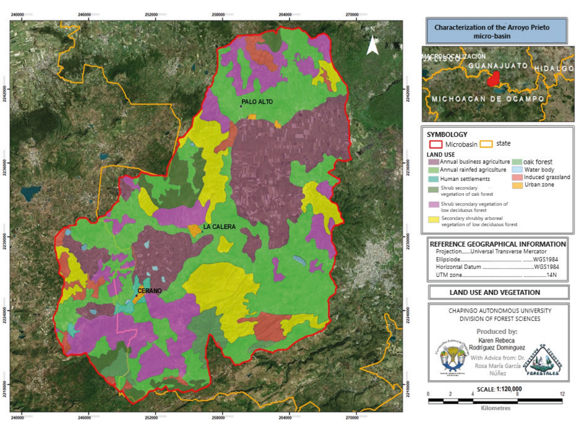

Figure 2. Land use of the Arroyo Prieto micro-basin

The drainage network is of the detrital type (Figure 3), which is the most common drainage pattern. It develops freely in all directions, on any type of lithological material, which reveals the lack of structural control; It can generally occur on gentle slopes.

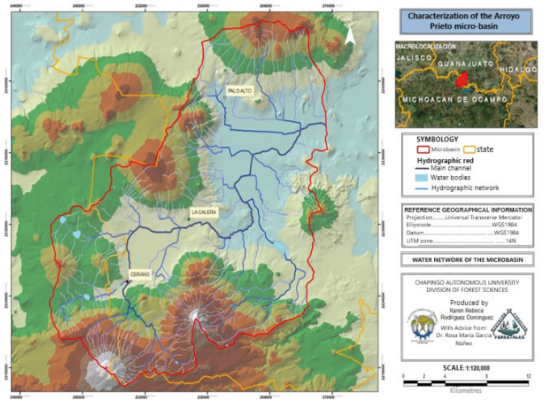

Figure 4. Hydrology of the Arroyo Prieto micro-basin

Its currents reach up to the 5th order (Figure 5), the small ones are runoff from the higher parts and that join together until they reach the main river that flows into the Yuriria lagoon.

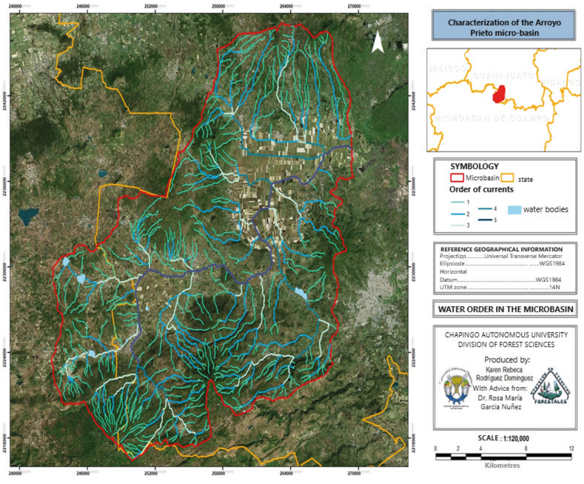

Figure 5. Order of currents in the study microbasin

The length of the water network was 466.9 km, (Table 2) with a drainage density of 0.92 km/km $^{2.}$ on an average slope of 6.7% suggesting average runoff.

Parameter	Units	Value
Basin area	Ha	50 959.33
Basin perimeter	km	158.7
Average basin slope	%	6.7
Basin mean elevation	msnm	2274
Main channel length	km	48.34
Gravelius index	A	1.39
Form factor	A	0.22
Order of currents	A	5
Current density	Currents/km ^{2}	0.92
Drainage density	km/km ^{2}	0.92
Length of the water network	km	466.9

Table 2. Morphometric parameters of the microwatershed

ESTIMATION OF WATER EROSION

The different factors that intervene in water erosion are presented according to the Revised Universal Soil Loss Equation.

Erosivity factor (R). In the area covered by the Arroyo Prieto micro-basin there are 16 rural communities, below (Table 3), the R factor of those that presented the maximum and minimum values is presented.

Clue	Name	Precipitation	R
16231	The barrier crossings	894.4	2415.71
16104	Puruandiro	817.15	2263.331
11047	Moroleon	814.3	2256,764
16017	White House	790.1	2206.522
11010	Cerano	701.7	2014.233
11158	Piñicuaro	570.3	1702,993
11133	Santa María Sanabria	553.6	1661.261
11146	The jicamas	476	1460.901

Table 3. R factor value for each precipitation value

Among the factors that most influence erosion is rain, since depending on the intensity, quantity and duration, it affects the movement of the particles that make up the soil. In the micro-basin there are semi-warm to temperate climates, from sub-humid to humid levels, the minimum values of R are from 1460.9 to 2415.71 MJ/ha*mm/hr, with rainfall of 476 to 894.4 mm/year. The highest R values occurred in Cruces Barreras, followed by Puruándiro and Moroleón, which are the locations with the highest rainfall. On the other hand, Jicamas presented the lowest value.

Erodibility factor (K). Of the 50,546.64 ha in the microbasin, the type of soil with the largest surface area is pelic vertisol with 45,634.75 ha. They are clay soils that are characterized by the presence of wide and deep cracks that form in the dry season due to loss of moisture and consequent contraction of its particles. The chromic luvisol is found in 4,763.18 ha, which are stony soils and are found on igneous materials. And the chromic vertisol with only 148.71 ha, which are practically forestry soils susceptible to erosion. According to the type of soil and its texture, FAO (1980) determines K values of 0.026 for fine-textured pelic and mollic vertisol and 0.04 for medium-textured chromic Luvisol.

This factor indicates the susceptibility of a soil to erosion, and since the fine-textured pelic vertisol, corresponding to a value of 0.2410275 (ton*h/MJ*mm), is found mostly in the microbasin and with an average capacity to store and transmit water, it is inferred that this soil is moderately erodible.

Vegetation cover factor (C) and LS factor. The values for Factor C were obtained from Montes (2011), for the different vegetation coverage in the Arroyo Prieto microbasin (Table 4).

Land and vegetation use	C-Factor
Human settlements	0.0
oak forest	0.1
Water body	0.0
Induced grassland	0.7
Annual irrigation agriculture	0.8
Annual rainfed agriculture	0.8
Shrub secondary vegetation of oak forest	0.11
Shrub secondary vegetation of low deciduous forest	0.11
Secondary arboreal vegetation of low deciduous forest	0.11

Table 4. C values for soil and vegetation use

Source: Montes, 2011.

Topographic factors (LS) influence proportionally, that is, the lower the value of the LS factor, the lower the value of water erosion. Values ranging from 0.03 to 16.62 were found and since the average slope of the basin is 6.7%, which represents a very low slope, a level with low erosive potential is inferred.

ANNUAL SOIL LOSS

The result of the multiplication of the factors of the RUSLE equation obtained from the DEM with a resolution of 15 m, the different levels of erosion in the Arroyo Prieto microbasin were obtained (Table 5) and the highest correspond to a combination of levels of high slopes, high rainfall and little soil protection, that is, little vegetation cover.

Soil losses	Interpretation
0 (t/ha and year)	Zones without erosion (urban spaces, roads, reservoirs)
0.1 to 10 (t/ha and year	Very low levels and tolerable soil losses
10 to 50 (t/ha and year)	Medium erosive processes
50 to 200 (t/ha and year)	Areas with serious erosive processes.
More than 200 (t/ha and year)	Extreme erosion levels

Table 5. Erosion levels in the Arroyo Prieto micro-basin

Source: (Dumas, 2012).

With these different levels of erosion present in the microbasin, the annual soil loss map was prepared (Figure 6).

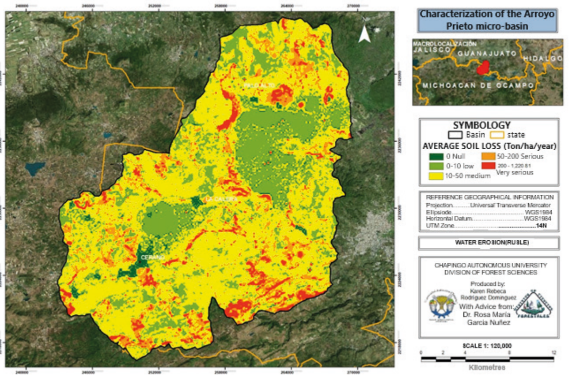

Figure 6. Map of erosion categories.

The predominant erosion in the microbasin is of a medium degree, and according to the results shown in Table 5, approximately 10 to 50 tons/ha/year are lost and is present in 59% of the total area of the microbasin. while only 7% of the surface does not present erosive problems.

The degree of erosion present must be taken into consideration, since it is at the midpoint, where it is possible to rescue the ecosystem to a state very similar to the original; however, if the necessary recovery measures are not applied, it is possible that the erosion reaches levels so serious, where soil conservation works will not be enough. Therefore, in this micro-basin, reforestation programs must be promoted using native species that increase the existing plant diversity, since Sandoval 2017 found that there is still a medium ecological diversity, but there are tree species that are very underrepresented, such as mesquite. (*Prosopis laevigata* Humb.), pirimo (*Verbesina pietatis* McVaugh) and garambuyo (*Myrtillocactus geometrizans* (Mart.) Console), however, the palo dulce or palo azul (*Eysenhardtia polystachya* (Ortega) Sarg.) and the huizache (*Acacia farnesiana* (L).Willd.) are those with the highest abundances. Furthermore, for the selection of species it is highly recommended that local multiple uses be taken into consideration.

CONCLUSIONS

A medium degree of erosion was estimated in the Arroyo Prieto micro-basin, so management and conservation alternatives must begin to be considered, mainly in the upper and middle parts of the micro-basin since the main economic activity in the region is the production of basic crops in its lower part. Firstly, activities must be implemented to revalue tree and shrub species, highlighting the value they have in the diversity of uses and the impact on soil retention, among others.

In addition, the development of soil conservation works must begin mainly in the high parts where erosion is mainly of a medium degree (10 - 50 tons/ha/year), a slope of 30 to 60% and the main vegetation is forest. oak and low deciduous forest vegetation, the most useful will be those that reduce runoff, increase soil humidity and provide organic matter to favor the development of forest species and natural vegetation and that reduce the slope, which means a decrease in erosion and thereby increasing the process of recharging groundwater tables.

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