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Hydrology and Estimation of Real Erosion in the Patria Nueva Micro-Basin for Five Return Periods

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Abstract

This paper will discuss the actual erosion estimation of the Patria Nueva micro basin in tons/ha/year (E), located in Tuxtla Gutiérrez Chiapas, Mexico. We used the universal soil loss equation (USLE), considered one of the best theoretical tools for planning and soil preservation in the USA and other countries. The actual erosion rates were estimated for 5, 20, 50, 100, and 500 years return periods (Rp), with elevated results due to high degrees of anthropogenic alteration of the micro-basin, especially in the last 50 years. High erosion rates generate the following problems: loss of soil, which is unfavorable for plant life, due to the soil being a non-renewable resource, the undermine can never renovate, the hydraulic area in the main channel reduces during the rainy season (when the river overflows). The sediment accumulates at the lower part of the micro-basin along with waste, garbage, and mud.

Keywords

Erosion, Return Periods, Basins, USLE, Sediment

1. Introduction

The micro-basin Patria Nueva is located in Tuxtla Gutierrez, Chiapas, Mexico (**Figure 1**). This micro-basin is one of fifteen that make up the sub-basin of the Sabinal River. Geo-graphically, the basin is 16˚45'51.80" north latitude and 93˚04'17.02" west longitude.

The micro-basin is completely urbanized and has serious anthropogenic effects due to deforestation, land-use changes, and the construction of houses and pavement roads. The process began in 1748 when Tuxtla's Town Hall was built, and unfortunately, construction has not stopped in the last four decades. The

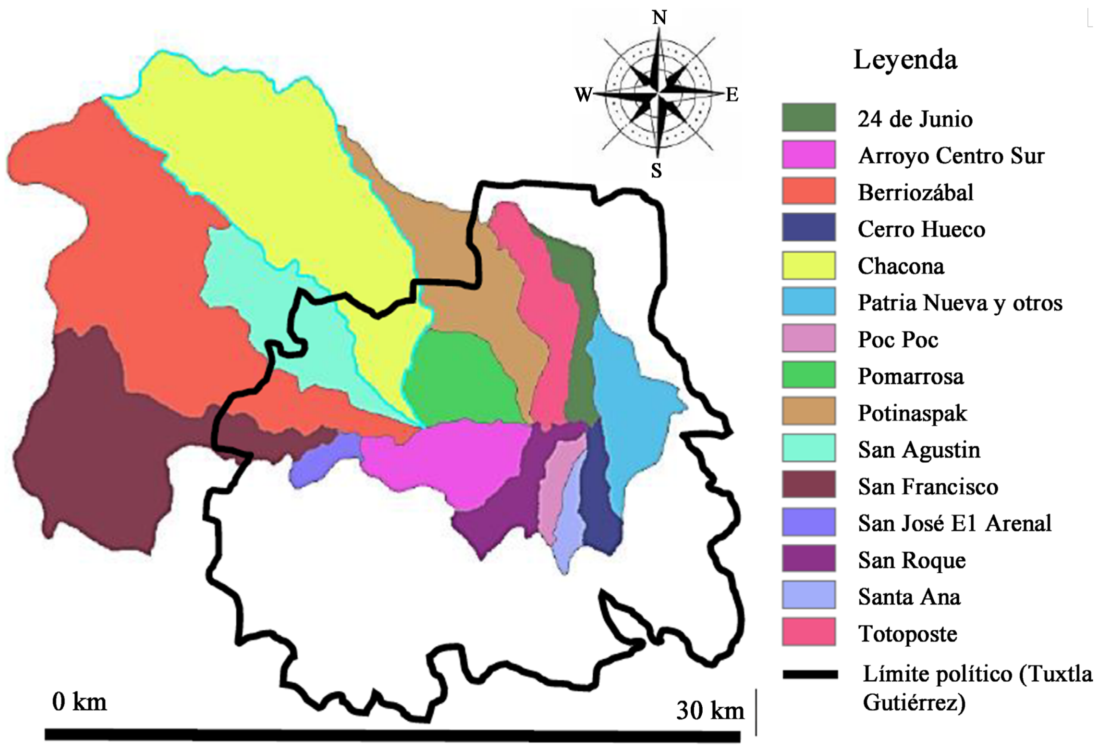

Figure 1. Patria Nueva Micro-basin, (light blue to the right).

Patria Nueva micro-basin is small, with a total surface area of 17.78 km^2. It is an exorheic basin with a main river length of 5.8 km. The main current slope is 0.0423 (calculated with the Taylor and Schwarz method). The basin order number is 2.

2. Background

There have been a number of projects carried out in the Sabinal River basin [1] [2] [3] [4] [5], addressing relevant themes such as floods, dam design, and civil protection. However, few projects focus on the studies of the Patria Nueva micro-basin. For this reason, the municipality of Tuxtla Gutiérrez Chiapas, Mexico, should carry out specific studies in the Patria Nueva micro-basin, such as those developed in the June 24 micro-watershed by

Gordillo, R.M., Castillo, S.M. [6] and ICIPLAM [7]. The first addresses the avoidance of flood disasters, and the second exposes diverse themes like soil erosion, floods, risk maps, and green infrastructure projects, as well the design of a small dam built with gabions to avoid flooding in the micro-basin. So, this study's objective is to determine the anual actual erosion rates of its surface due to the high level of environmental deterioration in the micro-basin. Therefore, the relevance of this work is that knowing the current erosion can you allow the municipal government of Tuxtla Gutiérrez to prioritize the Patria Nueva micro-basin to develop projects for the restoration it. For this reason, the municipal government of Tuxtla Gutiérrez must it: a. Reforest the eroded areas, b. Develop management practices to prevent the deforestation, c. Develop projects to prevent erosion of the micro-watershed, d. Develop projects in order to avoid flooding of the main stream river it.

3. Materials and Method

3.1. Materials

As part of our study, we used a topography chart, a vegetation chart, an edaphology chart, and elevation plans from National Institute of Statistics and Geography (INEGI, in its Spanish acronym). We also used Google Earth Pro 7.3.4.8573 [8], along with maps created with the Hydrographical Basin Water Simulation (SIATL, in its Spanish acronym), which has vector information created by INEGI, to generate the hydrographic network at 1:50,000 scale. The SIATL models the superficial drainage of a watershed and allows the user to consult and analyze information about hydrographic basins in Mexico.

3.2. Method

The equation was used USLE (Universal Soil Loss Equation) as our principal tool. Its origin dates back to the data compiled by the National Runoff and Soil Loss Data Center (CNDEPS in its Spanish acronym), Wischmeier, Smith, and others who developed the Universal Soil Loss Equation. This equation is considered one of the most efficient theoretical tools for planning and soil conservation, and it is used in the USA and other countries [9]. Thus, the potential erosion equals:

While the actual erosion is:

$$E = RKLS \quad (1)$$

$$E = RKLSCP \quad (2)$$

where: E is the soil loss (ton/ha per year), R is the rainfall erosivity (Mega joule mm/ha hr year), K is the soil's erodibility (ton/hr/Mj mm), L is the factor per slope length, S is the factor per slope degree, C is the factor per vegetation cover, and P is the factor per management practices. The last four variables are dimensionless.

R Factor. According to Cortes, T. H. [10], who regionalized rainfalls in Mexico for R (See Equations (1) and (2)), dividing 14 regions of the country. Our study uses the equation associated with the number 12 for the south of Mexico.

$$Y = 2.4619X + 0.006067X^2 \quad (3)$$

The R factor can be found in **Table 1** for the different precipitation measurements of each micro-basin, obtained for the return periods [11].

K factor. To know the K-value of the micro-basin Patria Nueva, we opted to use the [10]. **Table 2** shows some of the K values of the micro-basin.

LS Factor. According to Becerra, M. A. [12], the LS factor is obtained with the following equation:

$$LS = \frac{m}{22.13}\left(0.065 + 0.045S + 0.0065S^2\right) \quad (4)$$

The micro-basin slopes are shown in **Figure 2**. The red color indicates slopes between 0% and 2%, the green color between 2% and 15% and the yellow color between 15% and 30%.

C Factor. After consulting Wischmeier, W.H. and Smith, D.D. [13] and with

Table 1. *R* values.

Tr (Years)	*hp* (mm)	*R* (MJ·mm/ha·h)
2	67.72	194.5431
5	87.47	261.7610
10	99.89	306.4558
20	111.42	349.6232
50	125.95	406.3196
100	136.64	449.6679
500	161.09	554.0260

Table 2. *K* Factor.

Code	Texture	*K*
I + *Lc* + *E*/3	Fine	0.007
I/2	Medim	0.02
E + *Hh* + *I*/2/*L*	Medium	0.02
E + *Hh*/2/L	Medium	0.02
Vp + *Hh*/3	Fine	0.026

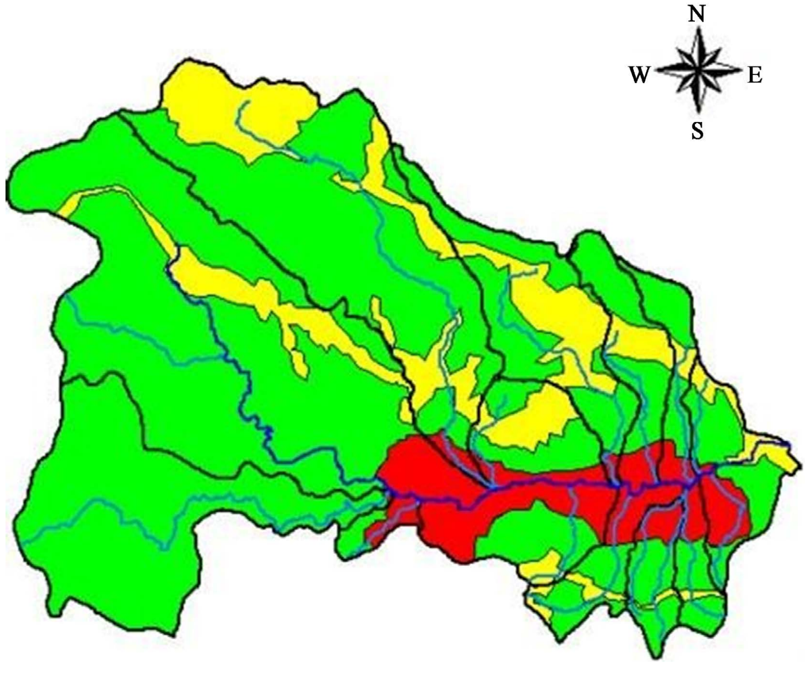

Figure 2. Micro-basin slopes.

the support of digital images taken on field visits, we determined the following **Table 3**.

P Factor. For the Patria Nueva micro-basin particular case, we did not find any evidence of management practices and soil preservation, thus *P* equals 1.

It is necessary to specify the universal soil loss equation (USLE) is used for assessing the erosion, but not used for predicting the gully erosion. The gully erosion, caused by concentrated water flow is not counted by this equation. On the other hand, the value of factor-*R* is the function of rainfall intensity; so it is not constant. While the *K* factor is constant for most of the sites in the catchment, but the factors *C* and *P* vary substantially with the erosion controlled measures, used.

4. Results

In **Table 4**, we show each USLE estimated variable for a return period of 500 years. In **Table 5**, we show the erosion rates in tons/ha/year, for various return periods. As you can see in these tables, the real erosion rate (*E*) is high and creates several problems in the basin. To begin with, the tolerance for soil loss has been exceeded. Wischmeier, W.H. and Smith, D.D. [13] estimated that in deep medium-texture soil with moderate permeability and a favorable substrate for plant life, soil loss can amount to around 125 t/ha/year. Other authors elevate that number between 13 and 15 t/ha/year, while the FAO [14] calculates the following erosive rates (see **Table 6**):

Table 3. *C* factor.

Soil use	Factor *C*
Infrastructure	0
Forest	0.002
Tall stubble	0.006
Low stubble	0.014
Grass	0.110
Crops	0.394
Bare ground	0.500

Table 4. Potential *E*, return period of 500 years.

Soil type	*K*	*LS*	*C*	*P*	*R*	*E*
I/2	0.02	11.5	0.56	1	554.02	71.45
E + *Hh* + *I*/2/*L*	0.02	11.5	1	1	554.02	127.59
Rc + *Hh* + *I*/2/*L*	0.02	8.73	1	1	554.02	96.73
E + *Hh* + *I*/2/*L*	0.02	8.73	1	1	554.02	96.73
I/2	0.02	8.73	1	1	554.02	96.73

Table 5. R_p versus actual erosion.

R_p	E (ton/ha/year)
5	276.91
20	369.76
50	430.79
100	475.59
500	585.96

Table 6. Tolerable soil loss.

TOLERABLE SOIL LOSS (FAO-UNESCO-PNUMA)	
PÉRDIDAS (t/ha/año)	DEGREE OF WATER EROSION
<10	Ninguna o ligera
10 - 50	Moderada
50 - 200	Alta
>200	Muy alta

It is evident that the actual erosion rates shown in **Table 6** exceed the FAO specifications [14]. Soil is not a renewable resource, so its loss creates desertification and undermines the rich-nutrient layers. On the other side, sediments are dragged to the low part of the basin, generating a reduction in the channel's hydraulic area, silt accumulation, and mud in the lowest part of the micro-basin.

5. Conclusion

This work estimates the real soil losses in the Patria Nueva micro-basin, using the USLE method to calculate them. Real erosion rates were calculated for the following return periods: 5, 20, 50, 100, and 500 years. Clearly, erosion rates in E are very high, and soil loss is creating the following problems in the micro-basin: Loss of soil layers, which is not favorable for plant growth, and eroded soil that can never be replaced, causing permanent effects on the ecosystem. As a result, the main channel's hydraulic area has been reduced, and during the rainy season (when the river over-flows), sediment accumulates in the lowest part of the micro-basin. Some perspectives are suggested that offer guidance for further studies in Patria Nueva micro-basin Patria: 1) To address the avoidance of flood disasters; 2) To develop diverse themes as: soil erosion, floods, risk maps, and green infrastructure projects.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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