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Maximum Avenue of Salsipuedes River, Effect of Land Use Change in San Gabriel Basin, Jalisco, Mexico

Ruben Dario Guevara-Gutierrez[1], Jose Luis Olguin-Lopez[1], Oscar Arturo Barreto-Garcia[2], Ma. de la Luz Beltran-Aldaco[2], Oscar Raul Mancilla-Villa[3], and Carlos Palomera-Garcia[4]

1. Department of Ecology and Natural Resources, Costa Sur University Center, University of Guadalajara, Mexico

2. Research Collaborator, Mexico

3. Department of Agricultural Production, Costa Sur University Center, University of Guadalajara, Mexico

4. Department of Health Sciences and Human Ecology, Costa Sur University Center, University of Guadalajara, Mexico

Abstract: The changes in land use caused by anthropic activities, the loss soil as a result of surface runoff and the flooding of river basins, make river channels exceed their capacity more quickly, generating flooding in the lower basin affecting human populations. The present study explains the hydrological phenomenon that occurred on June 2019 in the community of San Gabriel in the state of Jalisco. This happened as a direct result of the atypical rainfall, and an increased deforestation and change of land use and forest fires that have occurred in previous years in pine-oak areas in the upper basin. The study was done using Geographic Information Systems, supported by measurements of the cross-section of the Salsipuedes River, and suspended sediments and ditches that occurred in the bed of the river. The results show a record of severe erosion (> 300 t ha^{-1} per year) and atypical runoff that affects the economy of the municipal capital of the Municipality of San Gabriel and impacts resources in the middle and upper hydrographic basin. From these results, it is concluded that the introduction of high commercial cash crops, with the inherent removal of forest cover is one of the causes of agricultural expansion and agents that negatively impact the conservation of natural resources and municipal sustainability.

Key words: anthropic activities, loss soil, surface runoff, deforestation, forest fires

1. Introduction

Studies on land use provide with elements for decision making as well as with information that help understand the trends of deforestation, land degradation, desertification, and biodiversity loss [1]. Land uses refer to all the human activities and changes that take place over a territory [2]. Farina [3] recognizes that these changes, or uses, affect biotic and abiotic processes, which end up altering terrestrial ecosystems. Cincotta et al. [4] and Velazco [5] recognize that the loss of forest masses goes hand in hand with the increase in world population. The official promotion of agricultural programs worldwide has led to the accelerated disappearance of rainforests, which, associated with the growth and openness of the population in mountainous areas, has led to the drastic change in land and vegetation use [6]. Human communities are identified as factors of ecological deterioration and pressure on natural resources, due to the expansion of livestock, hillside agriculture, forest fires and commercial logging [7], among others. Hillside agriculture is a primary practice that not only modifies traditional forms of cultivation adapted to the environment, but causes deforestation, erosion and forest fires, which are used in clearing for agricultural crops and pastures, and to control weeds [8]. Fire, together with overgrazing, favors deforestation processes, soil erosion, biodiversity reduction, air pollution, and modifies the hydrological regime and

Corresponding author: Ruben Dario Guevara-Gutierrez, Dr..; research ares/interest: management and conservation of watersheds. E-mail: rguevara@cucsur.udg.mx.

promotes the loss of habitat for wildlife [9].

Deforestation is related to population growth and agricultural activities (logging in border areas), and the expansion of forage crops [10], as well as the expansion of crops with great commercial potential. Velazco [5] relates these activities to the poor vigilance of authorities towards forested areas, which causes irregular and even illegal changes in land use. Given this fact, until December 2007, the state agency of environmental protection (known as Procuraduria Federal de Proteccion al Ambiente (PROFEPA)) in Jalisco had identified 16 areas in these conditions, a figure that in certain regions caused 70% of the registered fires. Castillo (1) documents the case occurred in the Nevado of Colima National Park, which affected almost 3,000 ha, causing a disorderly change in land use and deforestation. In this sense, UNESCO [11] remarks that the local alterations produced by human beings can have global implications of great impact. Heede [12] states that the effect of soil management (specific in forestry or agricultural areas), increases the flow of surface water in the lower areas of the basin. Olguín et al. [13] establish that anthropogenic alterations, in addition to the physiographic and geomorphological composition in a region's hydrographic and hydrological basin, are conditions that modify the hydrological cycle. The present investigation estimated the maximum avenue of the Salsipuedes river in the San Gabriel hydrographic basin in the state of Jalisco-Mexico. We calculated the amount of suspended soil carried by this event, the effect of rainfall precipitation records, the management of the soil, as well as the number of forest fires, and their intensity, that occurred in 2019.

2. Materials and Methods

2.1 Description of the Study Area

The municipality of San Gabriel, Jalisco (Fig. 1), has an area of 723 km^2 with an average altitude of 1260 m.a.s.l. (oscillating between 880 and 3900 meters); 47% of the municipality is mountainous with slopes greater than 15%. Its climate is subhumid semi-warm, with temperatures ranging from 7.5 to 29.9°C, with an average annual rainfall of 860 mm. Regosol (33%) and Cambisol (31%) dominate the soil composition. Agriculture comprises the main vegetation type (38%), followed by temperate oak and pine forests (36%), and tropical dry forest (23%) [14].

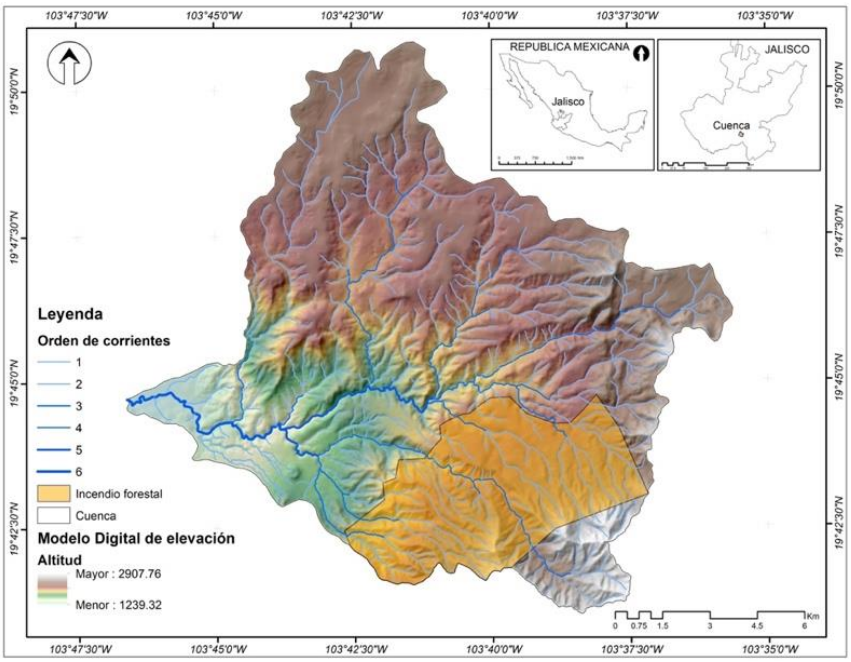

Fig. 1 Location of the San Gabriel basin, Jalisco-Mexico.

2.2 Methods

The average drained volume was estimated by the ratio:

Vm = Ce Pp A

Where Vm, average volume (m^3); Ce, runoff coefficient (obtained from C.P., 1992); Pp, rainfall (mm); A, Pixel area (m^2).

The digital coverage considered the following variables: soil texture, basin's slope (%), land use and vegetation cover using satellite images from 2003 and 2009, as well as current land use. The southeastern part of the basin was affected by forest fires in 2019, presumably to open land for avocado plantations; the maximum rainfall, estimated for June from the 1970 to 2013 period was based on the stations: Canoas, Cd. Guzmán, Venustiano Carranza, El Nogal, Tapalpa, Tolimán, Zapotitlán de Vadillo and the one recorded in the upper San Gabriel basin. Information was processed in GIS through ArcMap V. 10.5.

Finally, the maximum runoff was estimated using the simplified method of maximum footprints. On this flow, the suspended sediments were estimated by direct sampling in the channel, while the deposited sediments, once the flow decreased, using the cylinder method by measuring their apparent depth and density both in the river and street ditches.

3. Results and Discussion

The extension of the hydrographic basin is 17,708.00 ha; it is considered exorheic due to the type of runoff, with a dendritic and sub-dendritic drainage model which influences the rapid hydrological response to the occurrence of rain events [15], order of currents 6 but predominance of orders 1 and 2, which represent a terrain of irregular topography with the presence of ravines and steep slopes [16].

The dominant land use and vegetation type was pine-oak forest with 53% of the total area for 2003 and 39% for 2009. This decrease represents a 5% land use change rate. This vegetation type is presently threatened by the increase in avocado plantations, a crop with great commercial export potential. In addition, pine-oak cover in 2019. Forest fires damaged an area of 2,439.28 ha. Regarding agricultural and livestock activities, both represent 23% of the total area in each year considered (Fig. 2).

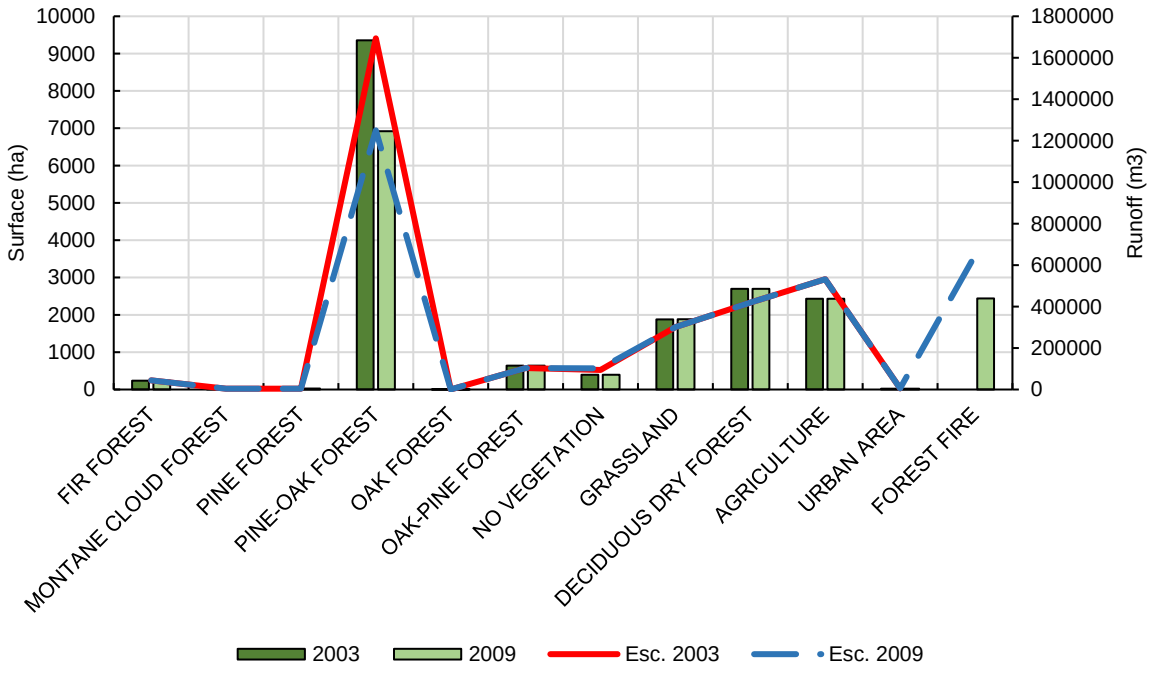

Fig. 2 Average runoff in 2003 and 2009 by vegetation type and land use.

An increase of 6.6% In reference to the estimation of the average runoff for the basin, between the years considered of vegetation cover, (210,470.05 m^3) was observed, a response that is influenced by atypical records of rainfall this year, but accelerated by the productive activities of the human being, as well as by the records of forest fires, since on this burned area, a runoff of 646,866,234 m^3 was estimated, reflecting 19% of the total runoff for the hydrographic basin (Fig. 3).

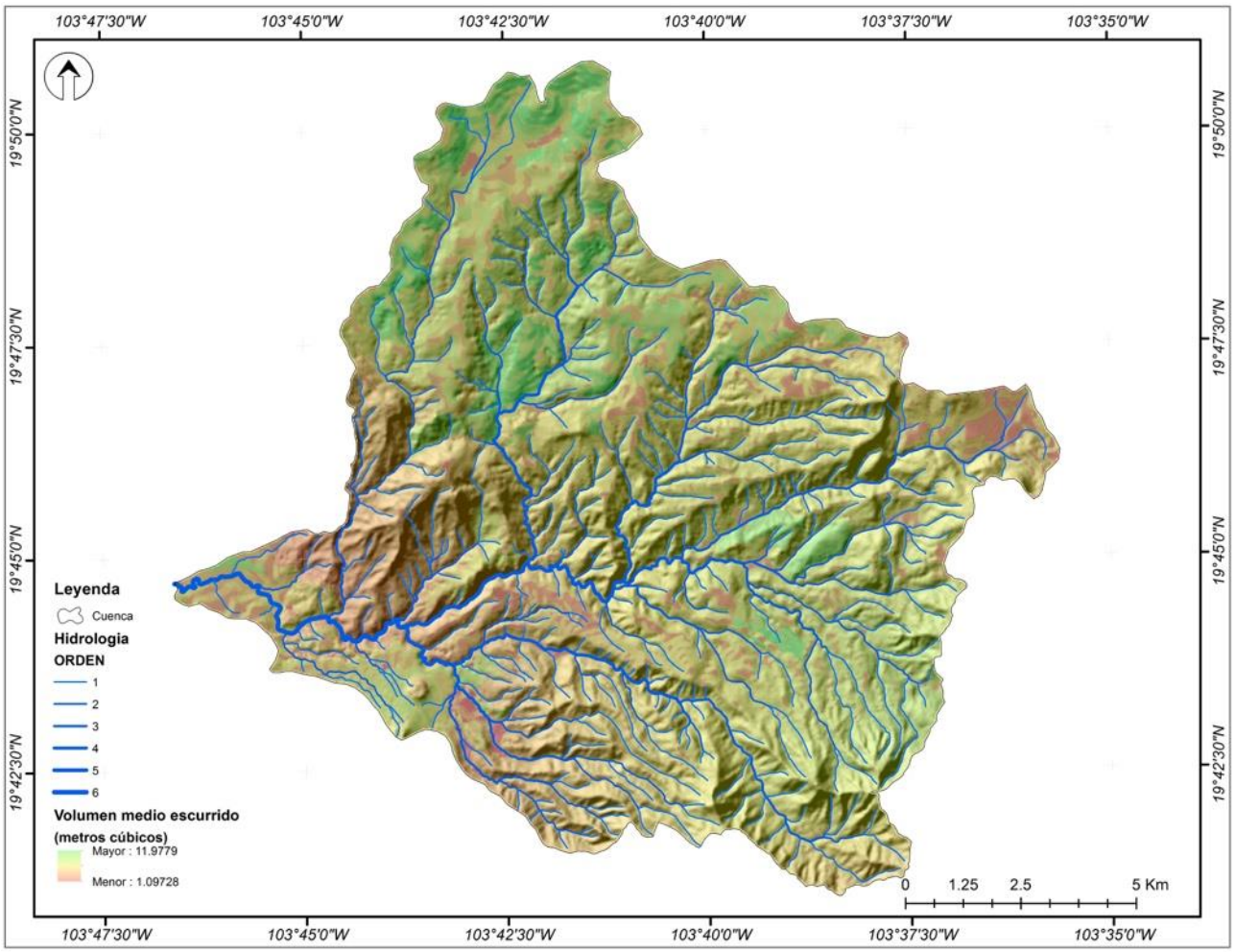

Fig. 3 Estimation of the average runoff distribution of the area of the San Gabriel watershed, Jalisco, Mexico.

The measurement of the natural hydraulic area of the Salsipuedes river is 39.45 m^2, with a maximum length of the water mirror of 23.4 m. Residents of San Gabriel mentioned that this stream has hardly overflowed over time as a result of "floods" of surface runoff (maximum avenues), and that these are generated in the upper basin during the rainy season. However, on Sunday, June 2, 2019, at approximately 4 p.m., an atypical intense rainfall (> 120 mm hr^{-1}) was recorded in the upper basin, which produced landslides from areas previously deforested and also affected by forest. This set of events generated an extraordinary atypical maximum avenue of an hydraulic area of 225,731 m^2 and a length of the water mirror of 88.4m, almost four times its normal length (Fig. 4).

The estimated drained volume of the maximum avenue was 50.368 Mm^3 s^{-1}, a condition that caused the drag of suspended particles. These were measured through direct sampling, estimating an amount of 81,646,512 t. The amount of silts was variable as these

completely covered the hydraulic area in various sections of the Salsipuedes river, increasing in areas with reduced dimensions, such as pedestrian and vehicle crossings bridges. In addition to these sites, dusts were captured on the streets. The amount of dusts was estimated only on a section of the stream channel, considering an average apparent density of 1.20 g cm^{-3}, average depth of 3 m and a hydraulic area of 1,170.00 m^2. The resulting average value per registered ramp within the stream was of 4,212.0 t (Fig. 5).

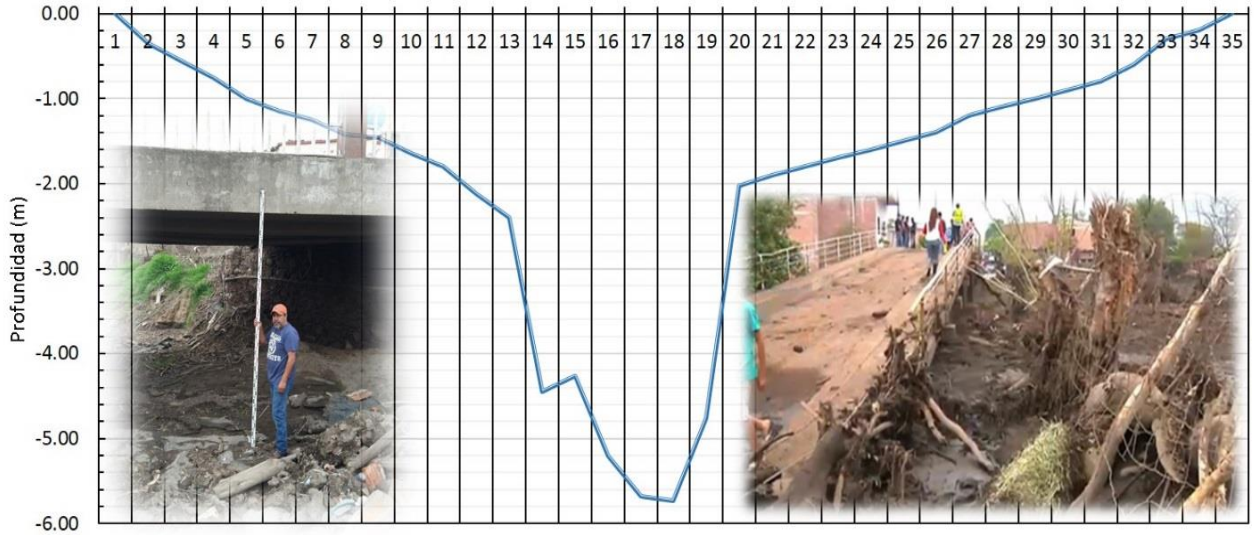

Fig. 4 Cross section (graphic scale) of the Salsipuedes river, San Gabriel, Jalisco.

Fig. 5 Images of silts generated by the maximum avenue of the Salsipuedes river.

There are different laws in Mexican Legal system in reference to land use change and its effects on productive activities carried, and which also aim on sustainability use of resources. Among these, the Congress of the Union mentioned in its General Law of Ecological Equilibrium and Environmental Protection [17], that the regulation of land use should be one of the objectives of ecological management programs; therefore, those who carry out agricultural activities must implement preservation, mitigation, sustainable use and restoration practices, necessary to avoid soil degradation and ecological imbalances, in order to achieve soil's rehabilitation. The General Law of Sustainable Forest Development [18] identifies the

Ministry of Environment and Natural Resources (SEMARNAT) as the institution that authorizes land use change in forest lands. The permits are based on technical opinions of the State Forest Council and technical studies supporting documents. In addition, the Jalisco's State Law of Ecological Equilibrium and Environmental Protection [19] establishes criteria for the sustainable use of soil and its resources. However, the Political Constitution of the State of Jalisco [20] in its article 80, mentions that the municipalities "will be empowered to authorize, control and monitor the use of land in their territorial jurisdictions". The latter becomes an obstacle as municipalities are not economically nor politically independent to apply law, as economic resources are not sufficient.

4. Conclusions

The expansion of crops of great commercial potential in the San Gabriel basin, as well as in other areas, is recognized as one of the causes of the extension of the agricultural frontier. This is also an agent that promotes land use change which increases surface runoff, movement of large masses of soil with ash and plant debris that result from deforestation. These events occurred in the upper basin of our area of study, causing the flooding event that affected the community of San Gabriel.

Sustainability is framed in normative aspects that govern the country; the observance is not excluded only from local laws. However, corruption and the interest in local resources and easy profits of a few have affected not only the environment, but also the society they belong to.

Finally, the lack of a contingency plan that supports and favors affected communities in the event of extraordinary environmental phenomena is observed. This, as well as trained personnel to help in emergency events should form part of every government's agenda.

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