Avances de un sistema de monitoreo de la erosión hídrica y calidad del agua en cuatro microcuencas forestales del campo las cruces

Progress of a water erosion and water quality monitoring system in four micro forest catchments of las cruces field

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Resumen

La erosión hídrica de origen antrópico es una de las formas de degradación del suelo y del agua más importantes en México y en el mundo, causante de la desertificación en las zonas semiáridas y subhúmedas de nuestro país, afectando 32 millones de ha de suelos de ladera con vocación forestal (SEMARNAP, 1998).

La zona eminentemente forestal del municipio de Texcoco, está sujeta al impacto causado por talas clandestinas, el sobre pastoreo, los incendios, así como al cambio de uso del suelo de forestal a agricultura de ladera, minería y urbano; lo que incrementa la compactación del suelo, disminución de las tasas de infiltración y percolación, incrementando el número de escurrimientos superficiales erosivos durante el año que disminuyen la fertilidad del suelo y su capacidad de retención de humedad lo que

conduce a mediano plazo a la disminución de la disponibilidad de agua de calidad y la desertificación del paisaje.

El desarrollo económico de la zona baja del municipio de Texcoco depende del abastecimiento de agua superficial y subterránea proveniente de las cuencas de alta montaña de la zona oriente; así mismo los núcleos de población que habitan en estas, dependen de la productividad forestal y agropecuaria del suelo, por lo cual se debe buscar una relación equilibrada entre las actividades que impactan la cubierta vegetal en la zona alta con la planificación del uso y aprovechamiento del recurso agua en la zona baja.

En este proyecto se tiene como objetivo estimar algunos indicadores de la degradación del suelo forestal y de la cantidad y calidad del agua, que permitan demostrar la importancia del buen manejo forestal de las zonas de ladera y mejorar las bases de cuantificación y planificación del recurso hídrico como un servicio ambiental, que a la vez proporcionen elementos técnicos de gestión para mantener y mejorar la producción forestal en el municipio de Texcoco.

El presente es un proyecto aprobado por la DGIP de la UACh en 2009, que se considera de mediano y largo plazo, cuya base metodológica consiste en el establecimiento de microcuencas experimentales que permitan monitorear la erosión hídrica y la cantidad y calidad del agua proveniente de la lluvia bajo distintas condiciones de suelo, uso del suelo y estrato geológico; siendo el aporte científico del presente proyecto la integración de un sistema de monitoreo a largo plazo de la degradación del suelo y calidad del agua a nivel regional, ante el impacto del Cambio Climático Global y la escases del recurso. Los avances obtenidos durante 2009 y 2010 son los siguientes: Caracterización fisiográfica, estudio hidrológico, ubicación y delimitación e instrumentación básica de 4 microcuencas experimentales.

Palabras clave: Monitoreo, erosión, escurrimiento, calidad y microcuenca.

Abstract

The anthropogenic water erosion is one of the forms of land degradation and water in Mexico and most important in the world, causing desertification in semi-arid and sub-humid areas of our country, affecting 32 million hectares of hillside soils suitable for forestry (SEMARNAP, 1998).
Mainly forest area of the municipality of Texcoco, is subject to the impact of clandestine logging, overgrazing, fires, and the land use change from forest to hillside farming, mining and urban, which increases compaction soil, reduced infiltration and percolation rates, increasing the number of erosive surface runoff during decreasing soil fertility and moisture holding capacity leading to medium term to the decreasing availability of quality water landscape and desertification.trial, at which they presented their arguments orally and the court issued a ruling.

Key words: Monitoring, erosion, runoff, and watershed quality.

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Introduction

Water erosion is one of the most important forms of soil degradation in Mexico and in the world, causing desertification in the different climatic conditions of our country, affecting 60% of the national territory; of this area, 32 million hectares belong to hillside soils with a forestry vocation, which have been subject to inadequate management (SEMARNAP, 1998).

Soil degradation by water erosion is closely related to the loss of the ecosystem's capacity to maintain adequate levels of agricultural or forestry production (Kirkby, 1994), as well as the quality of environmental ecosystem services related to water capture and carbon fixation.

The process of water erosion has been studied from different approaches, but being a physical process generated by surface runoff, it is advisable to approach its study from the point of view of the hydrographic basin, in which it is possible to quantify different variables or related indicators. with its advance (Mutchler, et al., 1988, cited by FAO, 2003).

The municipality of Texcoco occupies 41,869 ha, being the largest in the eastern part of the State of Mexico. 61.96% of the area is for forestry and 23.58% for agriculture. The H. Ayuntamiento recognizes that at least 17% of the forest area is affected by severe erosion caused by changes in land use.

The arboreal vegetation cover of this municipality is made up of fir, oak, pine forests and combinations thereof, which are subject to the impact caused by clandestine logging, overgrazing and forest fires, as well as to the change in use of the land. forest soil to hillside agriculture, urban use and mining (H. AYUNTAMIENTO DE TEXCOCO, 2009) which generates a decrease in the infiltration and percolation rate, a greater increase in erosive surface runoff, increasing accelerated erosion, soil compaction, loss of nutrients and loss of organic matter; invariably leading to the aridization of the landscape and loss of the recharge capacity of the Oriente aquifer of the State of Mexico (Intersecretarial Commission for the Lake Texcoco Plan, 2002); aspect that is reflected in the average annual availability of water in the municipality, which is estimated at 144 m3/year/inhabitant, considered the lowest in the country, and is expected to decrease each year due to the increase in population, a problem that It is already manifested in the lack of drinking water service in 10% of the houses (H. Ayuntaminto, 2009).

Philosophically, this project is part of the general strategy to combat desertification caused by man's productive activities, but accelerated by Global Climate Change, and operationally it is conceived as a medium- and long-term project for integrated watershed management

2. OBJECTIVES

In alignment with the National Water Program 2007-2012 (CONAGUA, 2007), this project seeks to estimate five indicators of forest soil degradation and the quantity and quality of surface water from rain and captured by micro-watersheds. Said indicators will allow to improve the bases of planning of the water resource, as well as the capacity of capture, storage and distribution of said resource, providing technical elements to value, maintain and improve the forestry production in the eastern zone of the municipality of Texcoco and maintain the recharge. of aquifers.

According to the above, the general objective is: to determine the water-soil-vegetation ecosystem relationships in subhumid temperate climate forests of the eastern region of the Valley of Mexico (municipality of Texcoco, State of Mexico), by quantifying the hydric erosion, production and quality of water, and its relationship with the infiltration and recharge of aquifers, as hydrological ecosystem services.

Its specific objectives are:

1) Determine the relationship between the type of tree vegetation with the rate of water erosion and concentration of sediments that are generated in each rain event.

2) Determine the relationship between the type of tree vegetation with respect to the quantity and quality of surface and subsurface water.

3) Quantify in situ the surface runoff and the infiltration rate, as bases for the estimation of the average annual availability of water.

4) Estimate the economic value of the hydrological ecosystem services provided by the temperate climate forest.

3. GOALS

1) Consolidate the forest use of 17,000 ha of the municipality of Texcoco, located in the high mountain area and subject to inappropriate changes in land use.

2) Benefit 16 rural communities located in the high mountain area of the municipality of Texcoco and owners of the area under forest use.

3) Estimate the water capture capacity of 17,000 ha of forest use in the municipality of Texcoco.

4) Estimate the sediment retention capacity of 13,067 ha of forest use in the municipality of Texcoco.

5) Promote the entry into the payment program for environmental services of 13,067 ha likely to be benefited in the municipality of Texcoco.

4. CONCEPTUAL FRAMEWORK

The evaluation of the effects and changes caused in the environment, by the productive actions without planning carried out by man, currently has as a useful tool the application of monitoring systems; which, applied to wooded masses, have been reported since the 1790s in some European countries (INIF, 1965), but in light of the development of geographic information systems, they continue to be useful instruments for planning and evaluating economic, social and environmental, as in the case of the RESEL project in Spain (Ministry of the Environment, Rural and Marine Affairs, 2008) and the experimental micro-basin monitoring project conducted by the Austral University of Chile (UACh, 2010).

Monitoring allows determining the occurrence, size, direction and importance of the changes that occur in key indicators of the quality of resource management. The changes in this case are related to a natural community (a forest or jungle) that is being managed and impacts soil and water resources, WWF. (2004).

The hydrographic basin from the geomorphological point of view, is a set of geoforms built by the constant wear of the surface currents or the drainage network, also called the hydrographic network, which consists of a main channel and smaller tributary currents that provide it with water. Water.

From the point of view of its hydrological functioning, García (1985), Corpocuencas (2000) and Lynne (2000) establish the general concept of a basin, as the natural drainage area divided by an imaginary line that establishes the direction of water flow. from precipitation. Arellano (1999) from the generic concept of land, conceives the basin as a hydrological continuum; a hydrologically homogeneous territorial unit where processes and phenomena of exchange and flow of matter and energy associated with water take place continuously.

Due to its hydrological functionality, the hydrographic basin is conceived as a planning unit; The United States Agency For International Development (USAID, 1999) points out that all natural processes take place in hydrographic basins, which is why it constitutes the natural and logical unit for agricultural, environmental and socioeconomic development. Martínez (1999), complements the above by stating that the basin is the natural unit that allows planners to observe all the consequences of runoff in a given area and develop the necessary plans for its control.

The hydrographic basin as part of the landscape, is the geomorphological unit that integrates all the physical, biological and anthropogenic factors, conjugates them and expresses them directly in its hydrological behavior; In this way it is possible to study the behavior of some components of the hydrological cycle in the short, medium and long term, and establish trends that allow the planning of land, vegetation and water use.

For any purpose, the study of the hydrographic basin begins with the physical characterization, which basically consists of delimiting its area of influence, determining its shape and characterizing the drainage network (López, 1998). According to this same author, the most useful parameters to characterize the drainage network and the hydrological behavior of the basin are the length of the main stream, slope, drainage density and concentration time.

WORK DEVELOPMENT

Description of the study area. The municipality of Texcoco is located in the eastern part of the State of Mexico and is part of the Metropolitan Zone of the Valley of Mexico, belongs to the economic Region XI Texcoco; It is located at an average altitude of 2,246 meters above sea level (m.a.s.l.) and occupies an area of 41,869 ha, bordered to the north by the municipality of Tepetlaoxtoc, to the south by Ixtapaluca, to the east by the states of Puebla and Tlaxcala. and to the west with the Federal District

(Figure 1).

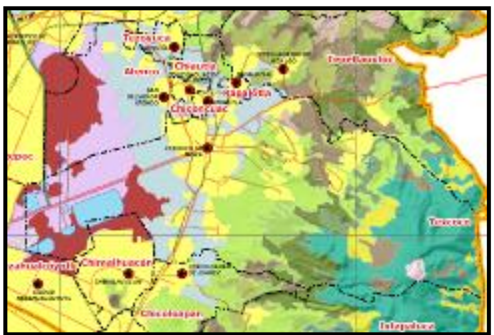

Figure 1. Political location of the municipality of Texcoco and the main hydrographic basins that feed the aquifer of the same name

Geographical location of the Las Cruces Experimental Forest Field. The Las Cruces experimental forestry field is located in the eastern part of the municipality of Texcoco, it is part of the drainage area of the Chapingo and San Bernardino river basins. Geographically it is located between the meridians: 98.83° and 98.80° West Longitude of the Greenwich Meridian and between the parallels: 19.45° and 19.47° North Latitude, and has 325 ha. Figure 2.

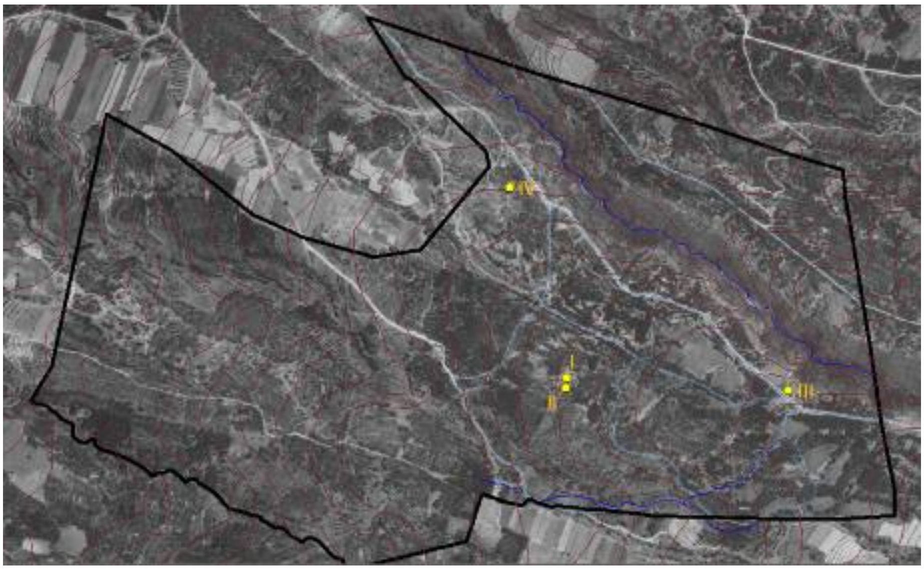

Figure 2. Delimitation of the Las Cruces Experimental Forest Field and geographical distribution of the experimental micro-watersheds.

Design of the investigation

In accordance with the existing types of vegetation in the municipality, as well as the objectives and goals proposed in this project, it is proposed to establish 6 hydrological experiments, including a control, within the area occupied by the Las Cruces Experimental Forest Field. Each experiment will be represented by a micro-basin instrumented with a water and sediment measurement system.

Characteristics of the microbasin. Homogeneous area in terms of tree, shrub and herbaceous vegetation cover, soil and surface geology; Naturally bounded by a watershed, with a well-defined channel and a main outlet point. The size of each micro-basin will vary according to the conditions of the land, between 0.25 to 0.5 ha. Each experimental micro-basin will be representative of some type of vegetation in the forest zone of the municipality of Texcoco.

The control experiment is defined as a micro-basin with a forestry vocation but under agricultural use or with intense grazing, without soil conservation works and in the process of physical and chemical degradation.

Measuring system. Each micro-basin will be instrumented by means of a rectangular channel at the discharge point, a staff gauge, a dosing channel, a trap pond, rain gauges and a sleep gauge. Likewise, the installation of a digital weather station is contemplated throughout the Experimental Forest Field.

The variables to be measured are: Temperature, precipitation, vegetation interception rate, evapotranspiration, hydraulic flow rate, infiltration rate, sediment load, erosion rate, nutrient loss, and organic carbon loss. The results obtained will be possible to analyze looking for a relationship of variables between different experiments and within each one of them with respect to the control.

Extrapolation of results. The results obtained for each variable may be scaled at the regional level through a Geographic Information System.

RESULTS OBTAINED

Location and description of micro-watersheds

Location. Four experimental micro-watersheds were located, which cover four conditions of tree and shrub cover of the Las Cruces Experimental Forest Field and the eastern zone of the State of Mexico.

The location of micro-basins was carried out by means of field trips and spatial analysis of the orthophoto corresponding to the study area, which allowed selecting small drainage areas with the following characteristics: shape and hydrological behavior of the hydrographic basin, drainage area not greater than 2,500 m2, slope of 8 to 10%, with some type of arboreal, shrubby or herbaceous vegetative cover dominant in the forest area of the municipality, with homogeneous soil and in the process of erosion by water erosion.

Delimitation. Each micro-basin was delimited on the ground by means of a detailed altimetric survey, using a total station.

Isolation. In order to prevent the entry of water and sediment from the surrounding area and to have a well-defined area, the drainage area of each micro-basin was isolated. Isolation consisted of opening the stump along the watershed, placing a 30 cm wide and 2.5 m long board lined with greenhouse-type plastic.

General description

Micro-basin I. Elongated shape, with an axial length of 120 m, a maximum width of 65 m, an almost straight main channel of 140 m in length, with a slope that varies from 3 to 5%, deep and with almost vertical slopes that extend more towards the right slope. The soil belongs to the haplic Faeozems and has been totally eliminated, leaving in its place the outcropping of yellowish-reddish volcanic tuff. It is considered a witness micro-basin.

Micro-basin II. It is a micro-basin that is considered to be in the process of being restored. Elongated shape, with an axial length of 110 m, a maximum width of 60 m, a straight main channel 120 m long, with a slope that varies from 3 to 5%, very shallow and with slopes extended almost symmetrically. The soil belongs to the 80 cm deep Haplic Feozems, influenced by the restoration actions carried out in the area during the 1980s. The vegetation cover is characterized by an almost unique tall tree layer made up of Eucalyptus calmaldulencis 25 to 30 m high and a herbaceous layer made up mainly of grasses and other grasses. As a whole, it is characterized by being a dense vegetation cover, with high protection for the soil against water erosion.

Due to the characteristics of the soil and the condition of the vegetation, it is considered a representative micro-basin of the restored areas of the study area, where little runoff and a low rate of water erosion are expected.

Micro-basin III. The outstanding morphological characteristics are the rounded shape, with a total area of 800 m2, a maximum length of 35 m and a width of 30 m. Shallow channel, not more than 30 cm deep and with a uniform slope of 5 to 6%. The soil is representative of the Leptosols of the study area and are characterized by having a depth of no more than 20 cm, stony and in the process of water erosion. The geological stratum on which these soils have developed belongs to the volcanic agglomerates, formed by the cementation of volcanic rocks such as andesites and rhyolites mainly.

The vegetation cover is characterized by a scattered tree layer formed by Cupressus Lindley with an average height of 12 to 15 m, as a result of restoration actions in the 1980s. The herbaceous stratum is represented by grasses and other grasses, which cover the soil surface by 50% and moderately protect it from the erosive processes generated by the rain.

Due to the characteristics of the soil and tree cover, this micro-basin is considered representative of the areas with scattered Cupressus spp but with good grass cover..

Micro basin IV. Micro-basin located in the northern part of the study area. It has a rounded shape, a maximum length of 85 m and a maximum width of 50 m, with an incipient but well-defined main channel, so that the runoff that occurs moves almost in a laminar fashion. Average slope of 10% with slopes extending very gently to the sides.

The soil belongs to the Eutric Cambisols Unit and is observed to be deep to moderately deep, in the process of accelerated water erosion. The vegetation cover is made up of a very disperse Cupressus Lindley shrubby layer and a sparse and mottled herbaceous layer. Due to its soil and vegetation cover characteristics, it is considered representative of the areas with scattered cupresus and without superficial vegetation cover.

Measuring system

To measure hydrological variables such as runoff and sediments, hydraulic infrastructure was installed that allows their systematic measurement. The type of infrastructure used in each micro-basin varies according to its size and the amount of water and sediment that it is estimated will contribute during maximum floods.

Mycobasin I and II were instrumented with a modified Parshall flume, staff gauge, dosing chute and a sediment trap cistern.

The modified Parshall channel is 6 m long, 0.44 m wide and 0.8 m high in micro-basin I, as well as 6 m long, 0.44 m wide and 0.50 m high in micro-basin II.

The dosing chute (Figure 3) in both cases has a width of 0.44 m, 2.20 m in length and variable height in each section of 0.50 m. It consists of a 20-gauge sheet gutter, which captures all the runoff and sediments that the Parshall channel conducts, it starts with an opening equal to that of the channel, at a distance of 0.5 m it releases 50% of the runoff and sediments, at a distance of 1 m releases 75% of the runoff and the last 25% of the liquid and solid waste is conducted to the cistern trap, in which it discharges freely.

The tank trap (Figure 4) is a concrete tank located 2.20 m downstream from the mouth of the micro-basin with the capacity to capture 1 m3 of water with sediment. It is provided with a millimeter scale and a quick discharge system by means of a 2” diameter tube and a stopcock. The dimensions of each cistern trap vary from one micro-basin to another, which depends on the slope of the land in the immediate section downstream of the Parshall Canal. When the slope allows rapid discharge, the cistern trap is higher and vice versa when the slope is smoother.

Micro-basins III and IV will be instrumented only with a dosing gutter and cistern trap. In these cases, the dosing gutter will be embedded in the nozzle, on the stump and connecting with the board and insulating plastic, in such a way that the runoff and sediments fully enter the conduit and are channeled and dosed towards the tank trap.

Figure 3. Water and sediment dosing channel seen longitudinally through the inlet nozzle.

Figure 4. Cistern Trap where 25% of the runoff and sediments generated in each rain event will be collected.

Calibration of measuring equipment

At the beginning of 2011, the measurement equipment was calibrated, which consisted of mounting a device at the entrance of the modified Parshal canal and the dosing gutter, through which water discharges were carried out with volumes of 20, 40, 60, 80, 100 and 120 L, each discharged volume was repeated four times during the same day, which allowed obtaining a simple linear regression line with a coefficient of determination (R2) of 0.99; which indicates that in general the dosing chute distributes the expense well in 50 and 25% respectively.

Observation of some rain events

The atypical rains that occurred on February 3, 4 and 5, 2010 made it possible to observe the hydraulic operation of the Parshall canal installed in micro-basin I. This micro-basin, being the one with the least vegetation cover, generated significant runoff with a high concentration of sediments, during more than 6 hours that the rain event lasted.

Figure 5 shows the concentration of surface runoff generated at the outlet of the micro-basin and at the entrance to the Parshall canal. Figure 6 shows the hydraulic operation of the channel before the flow of water, in which it is possible to measure the speed and depth of said flow and figure 7 shows the expense generated in this rain event. The previous observation indicates that the Parshall channel can be a good measurement instrument and motivates the execution of this project.

Figure 5. Concentration of runoff at the outlet of micro-basin I and entrance to the Parshall canal.

Figure 6. Hydraulic operation of the modified Parshall channel in micro-basin I.

Figure 7. Hydraulic flow recorded in the Parshall channel of micro-basin 1, during the atypical rain event of February 2010.

In the 2011 rainy cycle, it was only possible to record 12 rain events and refine the methodology for taking water and sediment samples. Due to the lack of a laboratory, it was not possible to analyze the amount of sediment, but according to turbidity, three of the micro-basins generate runoff with a high concentration of sediment. The same number of precipitation data was also recorded, but the corresponding analysis was not performed.

conclusion

By means of simple equipment such as a modified Parshall channel, a galvanized sheet dosing channel and a trap tank with a capacity of 1 m3, it is possible to measure with good precision the total volume runoff per rainfall event in forest micro-watersheds no larger than 2000 m2. , in the eastern part of the municipality of Texcoco.

The control micro-basin registers runoff and a high concentration of sediments from rainfall greater than 8 mm, while the micro-basin restored with Eucalitus camaldulensis requires 12 mm of rain to register any surface runoff.

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