Long-Term C, N and P Losses by Sediment Yield in Five Watershed in a Mexican Tropical Deciduous Forest Ecosystem

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Abstract: The present study describes the losses of C, N and P by sediment yield in five small catchments over a six-year period in a tropical deciduous forest ecosystem in western Mexico. The sediment yields were highly variable among years due to the high variability of rainfall. The distribution of rainfall within year explains sediment yield, rather than annual rainfall. C, N and P losses also were highly variable among years, explained mainly by losses of mass sediment. Although nutrient losses by sediment yield are negligible in relation to nutrient budget under forest cover, this values can increased significantly after deforestation. The high variability of nutrient losses suggests that the effects of soil management on soil nutrients losses could be very unpredictable among years.

Keywords: tropical ecosystems, soil erosion, rainfall variability, nutrient losses, runoff

1 Introduction

The losses of nutrient by sediment yield are considered as a main degradation processes in watershed under deforestation (Walling 1988). In a Tropical Deciduous Forest (TDF), Maass *et al*. (1988) reported that soil nutrient losses by erosion are greater than nutrient losses by runoff. However, little is know about the dynamic of sediment yield in watershed with natural vegetation cover in tropical areas. The estimation of sediment yield in watershed with natural vegetation can give us a baseline of soil and nutrient losses without watershed management. The nutrient associated with sediment yield can also allow estimated the nutrient budget under natural conditions, thus it can also permit to evaluate any watershed management.

On the global basis, nearly 42% of tropical land area is classified as TDF, which has the highest pasture conversion rate, with 78% of the total original area already converted to pasture (Houghton *et al*. 1991). In the Pacific coast of Mexico, soil erosion is the main degradation factors, which is strongly affected by rainfall erosivity during year following perturbation, which is very variable among years (García-Oliva *et al*. 1995a). The main objective of the present study is describe the losses of C, N and P by sediment yield in five small catchments over a six-year period in a tropical deciduous forest ecosystem in western Mexico.

2 Methods

The study was conducted in the Estación de Biología Chamela, UNAM, on the Pacific coast of Mexico (19°29' N and 105°01' W). The landscape is dominated by low hills with steep slopes (>20°). The principal soil parent materials are Cretaceous rhyolite (Campo *et al*. 2001a). Soils are sandy clay loams, poorly developed, that are classified in the USDA system as Orthents (Solís 1993). Kaolinite is the dominant clay mineral (Campo *et al*. 2001a) and the pH is 6.9 (García-Oliva *et al*. 1999). Soil organic matter is generally less than 5% and approximately 30% of SOM is concentrated in the top 5 cm depth (García-Oliva & Maass 1998). The mean annual temperature is 24.9°C (Bullock 1986) and the average annual precipitation is 763 mm (1983—2000). The rainy season starts in June and ends in October; September is the wettest month on average (García-Oliva *et al*. 1991, García-Oliva *et al*. 1995). Around six storms occur each year; they are very intensive, giving an average annual erosivity of 6525 MJ mm $ha^{-1} \cdot yr^{-1}$ (García-Oliva *et al*. 1995b). Deciduous trees dominate the forest, leaf flushing is evident after the first major storms (Bullock & Solís-Magallanes 1990), and maximum litterfall occurs between

November and December (Matínez-Yrizar & Sarukhán 1990, Maass *et al*. 1995). Annual litterfall is 3,564 kg • ha^{-1} (Martínez-Yrízar & Sarukhán 1990) and total net primary productivity averages 12,060 kg • ha^{-1} • y^{-1}, corresponding to 43% of belowground productivity (Martínez-Yrízar *et al*. 1996). In this site, a long-term ecosystem research project has been established in 1981 to understand the structure and function of this tropical deciduous forest (TDF), using five small catchments (between 12 and 28 ha each, Sarukhán & Maass 1990). At the present, all watersheds are gauged and are being analyzed under undisturbed conditions. The sediments were collected in three 10 cm, 5 cm and 2 cm mesh nets at the weir during six years period (1994—1999). The material was collected after a big runoff event or at the end of the year. All material in each tramps were moist weighted and a two subsamples were taken for chemical analysis. The subsamples were dry weighted for determination of water content, were sieved (2 mm mesh) and grounded with a mortar and pestle. C was determined by using automated analyzer CO_2 UIC Mod. CM5012, and nitrogen and phosphorous by semi-Kjeldahl method (Technicon Industrial System 1977).

3 Results and Discussion

The sediment yields were highly variable among years due to the high variability of rainfall and among watershed (Table 1). For example, the values of watershed 2 (WS2) ranged from zero (1994, annual rainfall: 427 mm) to 373 kg • ha^{-1} • yr^{-1} (1999, annual rainfall: 1,131 mm). In contrast, 46 kg • ha^{-1} • yr^{-1} was the maximum sediment yield in watershed 5 (WS5). The sediment yield did not correlated with the watershed area, but it correlated positively with the calculated mean of runoff velocity by Cervantes *et al*. (1988). WS1 and WS2 had the highest values (0.32 km • h^{-1}) and WS5 the lowest (0.16 km • h^{-1}). For this reason, WS1 and WS2 are more susceptible of nutrient losses by sediment yield than the other watersheds.

Table 1 Annual rainfall and annual sediment yield (kg • ha^{-1}) in five experimental watersheds at Chamela, Mexico over a six-year study period (1994—1999).

	Year					
	1994	1995	1996	1997	1998	1999
Rainfall (mm)	427.0	780.6	920.5	627.5	1261.0	1131.0
	Sediment yield (kg • ha^{-1})					
WS1	0	20.64	78.03	2.54	47.02	157.04
WS2	0	11.13	13.63	2.62	37.24	373.89
WS3	0	9.95	4.20	3.05	32.80	52.36
WS4	0	13.48	23.01	4.95	51.80	119.70
WS5	0	6.89	4.88	0.39	12.12	46.86

The annual rainfall is very variability among years, because is strongly affected by tropical cyclones (García-Oliva *et al*. 1995b). This high variability is also result of the El Niño phenomenon, which affects the western of Mexico. For example, El Niño and La Niña were affected Mexico in 1997 and 1998, respectively. El Niño reduced and La Niña increased the annual rainfall amount and thus, the sediment yield increased 13 times from 1997 to 1998 (Table 1). However, annual sediment yields did no correlate with annual rainfall (Fig. 1). It seems that this correlation is more complicated, because of the effect of threshold values and the distribution of rains event within year. For example, 1994 had no sediment yield with 427 mm of annual rainfall, while 1997 had sediment yield with annual rainfall of 627 mm. In the same way, 1998 and 1999 had similar annual rainfall, but 1999 had in average 4 times higher sediment yield than 1998 (Table 1). 1999 had a more homogeneous monthly rainfall pattern in the wet season than 1998 (Fig. 2), which maintain soil humidity constantly and enhance superficial runoff. These results suggest that the sediments yields are strongly affected by the distribution of rainfall events within year, which it is very unpredictable.

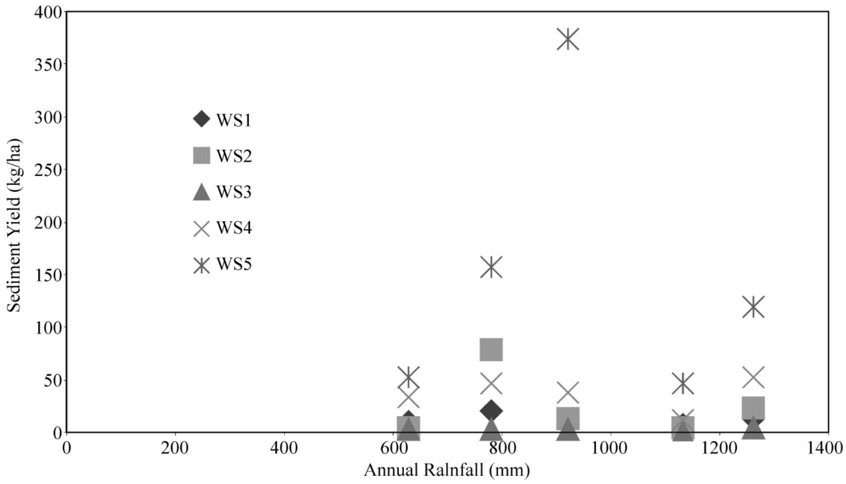

Fig.1 Relationship between sediment yield and annual rainfall of five experimental watersheds at Chamela, Mexico.

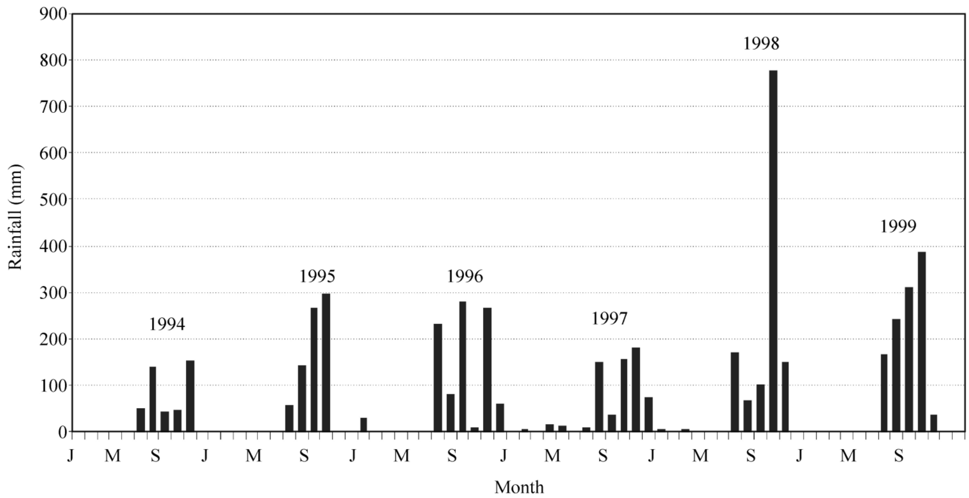

Fig.2 Monthly rainfall at Chamela, Mexico over a six year study period (1994—1999)

Table 2 shows the average of C, N and P losses by sediment yield calculated from the five watersheds. The values of nutrient losses were explained by sediment mass, rather than changes in nutrient concentrations. For this reason, the nutrient losses patterns among year were similar to sediment mass pattern.

Table 2 Average of C, N and P losses by sediment yield (kg ha^{-1} yr^{-1}) at Chamela, Mexico over a six-year of study period (1994—1999). The average is done with the data of the five experimental watersheds

	Carbon	Nitrogen (kg ha^{-1} yr^{-1})	Phosphorus
1994	0.000	0.000	0.000
1995	0.156	0.018	0.003
1996	0.502	0.034	0.005
1997	0.050	0.005	0.001
1998	1.204	0.068	0.012
1999	2.253	0.212	0.033

C, N and P losses also were highly variable among years; C, N and P losses ranged from 0.95 to 7.23 kg $Cha^{-1}yr^{-1}$, from 0.006 to 0.671 kg N ha^{-1} yr^{-1} and from 0.001 to 0.067 kg P ha^{-1} • yr^{-1}, respectively in the WS2. These results suggest that nutrient losses by sediment yields is very sensible to rainfall characteristic of each year, although soil is covered by non-perturbed forest, as our study site. The nitrogen losses by sediment yields were lower to the losses by N_2O fluxes measured at these experimental watersheds (0.60 kg • ha^{-1} • yr^{-1}; García-Mendez *et al*. 1991). In the same way, the losses of P by stream water (average 0.064 kg • ha^{-1} • yr^{-1}) were higher than the P losses by sediment yield (Campo *et al*. 2001b). These results suggest that the output of nutrient by sediment yields is negligible with forest cover. However, slash-and-burn accelerated significantly the losses by soil erosion (Maass *et al*. 1988, García-Oliva *et al*. 1995a). For example, Maass *et al*. (1988) found that soil erosion increases about 650 times when forest cover is converted to maize crop in only one year in the same study site. Our results suggest that the effects of soil management on soil nutrients losses could be very unpredictable.

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