Sediment Budgets (Proceedings of the Porto Alegre Symposium, December 1988). IAHS Publ. no. 174, 1988.

Erosion studies in Sumé, a semiarid region in the northeast of Brazil

V. S. SRINIVASAN, H. P. GOMES
Department of Civil Engineering, Centre for Sciences and Technology, Federal University of Paraiba, Campina Grande, Paraíba, Brazil

J. C. LEPRUN
Empresa Brasileira de Pesquisas Agropecuária - EMBRAPA/SNLCS & ORSTOM (France), Rio de Janeiro, Brazil

I. G. SILVA
Superintendencia para Desenvolvimento do Nordeste - SUDENE, Division of Hydrometeorology, Recife, Pernambuco, Brazil

Abstract To evaluate the effects of land use, slope and vegetal cover on the sediment production rates, several experimental plots of 100 m^2 and four micro-basins were installed within the representative basin of Sumé. All basins were equipped with sediment collectors, automatic water level recorders and means for collecting a cumulative suspended sediment sample. The erosion plots were submitted to different slopes, vegetal cover and management. Measurements of surface runoff and soil erosion have been carried out since 1982. The results show the large influence of the natural vegetation on surface runoff and erosion.

Etude de l'érosion à Sumé, une région semi-aride du nordest du Brésil

Résumé Dans le but d'évaluer les effets de l'occupation du sol, de la pente et de la couverture végétale sur les taux de production de sédiments, plusieurs parcelles expérimentales de 100 m^2 et quatre micro-bassins ont été mis en place sur le bassin expérimental de Sumé. Les micro-bassins ont été équipés de collecteurs de sédiments, d'enregistreurs automatiques de niveau d'eau et d'échantillonneurs permettant d'accumuler les apports de sédiments en suspension. Les érosion ont été observées sons différentes conditions de pente, de couverture végétale et d'usage du sol. Les mesures de l'écoulement superficiel et de l'érosion du sol ont été faites depuis 1982. Les résultats indiquent une forte influence de la végétation native sur l'écoulement et l'érosion.

INTRODUCTION

The region of Sumé lies within a large zone of frequent droughts in the northeastern part of Brazil. The rainfall is irregular and is concentrated in about three months of the year. The mean annual precipitation is 590 mm with a coefficient of variation of about 0.5 (Nimer, 1979). The soil cover is relatively thin, underlain by bedrock and there is an ever-increasing area brought under cultivation by the removal of plant cover. The effect of these activities on surface runoff and land erosion, however, are not known quantitatively. This information would be of great importance in land-use management of small basins and could serve as a very useful input in the regional planning process (Cadier *et al.*, 1983). To evaluate the influence of factors such as slope, land use, cultivation practice and natural vegetal cover on the production of runoff and sediment yield, an experimental basins in the region of Sumé was selected where four micro-basins and five erosion plots were put in operation in 1982; since then, four more plots have been added. The main objective of this paper is to present the findings of this study up to the end of 1987.

FIELD INSTALLATIONS AND DATA COLLECTION

The experimental area is located on a farm called "Fazenda Nova" forming a part of the Umburana sub-basin (10.7 km^2 area) which in itself is a part of the representative basin of Sumé (137.4 km^2). More than 85% of the basin is covered by brown non-calcic "vertic" soils, typical of semiarid regions (Cadier *et al.*., 1983). The bulk of the precipitation occurs between January and May with February to April being the most rainy quarter (Cadier & Freitas, 1982). Consequently almost all the data collected fall in the period January–May.

The four micro-basins were selected so as to typify the prevailing vegetal covers and slopes. Two were located in the zone of natural vegetation consisting of small-sized trees and medium-height bush of 1–2 m. The other two were located in the area where the native vegetation had been completely removed and some contour planting had been carried out earlier. All the remnants of earlier planting were removed to expose the bare soil. Table 1 gives the physical characteristics of these basins. The micro-basins were equipped with rectangular sediment collectors with a capacity of nearly 2300 l, terminating with a 90° triangular weir capable of a maximum discharge of 270 l s^{-1}. The water level within the collector was registered by a water

Table 1 *Characteristics of the micro-basins*

Basin no.	*Area (ha)*	*Perimeter (m)*	*Mean slope (%)*	*Vegetal cover*
1	*0.62*	*398*	*7.0*	*Natural bush and small trees*
2	*1.07*	*466*	*6.1*	*Natural bush and sm ll trees*
3	*0.52*	*302*	*7.1*	*All vegetation cleared*
4	*0.48*	*270*	*6.8*	*All vegetation cleared*

level recorder. Three sampling points at intervals of 10 cm starting from the crest level of the weir were provided in order to siphon off a small part of the water-sediment mixture that would overflow. The sampling points were connected to closed auxiliary cans from which smaller samples could be obtained.

The erosion plots were the standard 100 m^2 Wischmeir type ones (Wischmeir, 1960) with a length of 22.1 m and a breadth of 4.5 m subjected to different surface treatments and slope. Five plots were initiated in 1982, two more in 1983 and two additional plots in 1986. The slope and surface treatments of these plots are shown in Table 2.

Table 2 *Characteristics of the erosion plots*

Plot no.	*Year*	*Slope (%)*	*Surface cover*
1	*1982*	*3.8*	*bare soil clear of vegetation*
2	*1982*	*3.9*	*mulching with the removal of natural vegetal growth*
3	*1982*	*7.2*	*as above*
4	*1982*	*7.0*	*bare soil clear of vegetation*
5	*1982*	*9.3*	*natural bush and small trees*
6	*1983*	*4.0*	*cactus planted along the slope*
7	*1983*	*4.0*	*cactus planted in contour*
8	*1986*	*4.0*	*ploughed bare and loose soil*
9	*1986*	*4.0*	*renewed natural bush*

The runoff and eroded sediments were directed to a 1000 l capacity collection tank with an inner calibrated bucket to collect small outflows. The overflow from this tank was partitioned by nine equal-sized, symmetrically-placed tubes, the central one being led to the second collection tank of 1000 l capacity and the other eight left to spill out. The tanks were pre-calibrated.

In addition, several recording and non-recording rain gauges were installed in the vicinity of the plots and micro-basins. A weather station forming a part of the experimental basin was also centrally located. Additional details of the field installations can be found elsewhere (Cadier *et al.*, 1983).

PROCEDURE AND COLLECTION OF DATA

The data were collected for natural precipitation only and as such the total surface runoff and the quantity of sediments leaving the experimental area were the main concern. For the erosion plots, the total runoff was obtained by addition, to the volume collected in the first tank, nine times the volume that flowed over to the second one. In the case of the micro-basins, the total runoff was calculated by adding the volume of the weir outflow hydrograph, if any, to the volume retained in the collector tank.

The outflow hydrograph itself was obtained by utilizing the weir calibration curve and the water level recorder charts.

The quantity of sediments produced in each event was determined indirectly by sampling the sediment-water mixture and determining the weight concentration for each of the representative volumes associated with the sample. For micro-basins the sediment production was obtained by adding the amount of sediments retained in the collector (estimated by sampling the mixture) to the quantity of sediments carried out in suspension over the weir determined by the concentration of sediments in the volume siphoned into the auxiliary cans. Whenever possible, additional samples were collected directly from the weir outflow during the event for a better estimation of the average concentration of the outflow. In the case of the erosion plots, samples of sediment-water mixture were collected from the inner bucket of the first tank, the volume collected in the first tank and the collected volume of the second tank if there was overflow to the second.

The samples collected were of 5 l or 1 l volume and in order to reduce the bulk and the cost of transportation to the laboratory, they were reduced to a sample of lower volume by a process of reconcentration, in which 2 ml of aluminium sulphate solution was added for each of 1 l volume of the sample and the clear fluid decanted after 24 h. Whenever a 5 l sample contained very few sediments, it was reduced to a volume of 1 l in 24 h and a volume of 200 ml in the next 24 h. If the sediment content was high, the second reduction of 1 l sample to 200 ml was not carried out. Except for very high concentrations, or initial volumes of less than 1 l, all 1 l samples were reduced to 200 ml by reconcentration.

For the purposes of comparison, the same surface conditions were maintained in micro-basins 3 and 4 and plots 1 and 4. Removal of any surface vegetation to expose the bare soil was carried out in all of them at the same time. Plots 2 and 3 were maintained under similar conditions of mulching by an identical maintenance procedure.

RESULTS AND DISCUSSION

From the beginning of 1982 till the end of 1987, about 160 events had occurred for which data were collected. Though the number of events registered seems large enough, the events producing very little runoff are predominant and the range is not uniformly covered. Consequently any attempts to evaluate quantitatively the basic relationships would be not well founded at this stage. However, the trend and the qualitative aspects of the investigation seem to be quite well established.

The influence of the native vegetation in reducing the surface runoff and erosion became very clear from the observations in micro-basins 1 and 2 and plot no. 5. Only large precipitations produced any runoff and in the case of the micro-basins 1 and 2, only events of more than 30 mm precipitation produced notable surface runoff. Even for events of the order of 90 to 100 mm of rain the runoff did not exceed about 9%. In terms of sediments, the erosion was very small even for the largest of the events. This is in sharp contrast with respect to the micro-basins 3 and 4, devoid of any vegetal cover. A plot of the runoff against the precipitation showed a large scatter but a clear trend could be noted with the introduction of an antecedent precipitation index *IH* defined for any given day *i* as $IH_i = K(IH_{i-1} + P_{i-1})$ where the subscript $i - 1$ refers to the previous day, *K* is a reduction factor found equal to 0.95 for the region, and *P* is the precipitation in mm. When this index was used as a parameter the precipitation-runoff relation showed two distinct trends; one for $IH < 100$ and the other for $IH > 250$. This relationship is shown in Fig. 1. The sediment production expressed in kg ha^{-1}

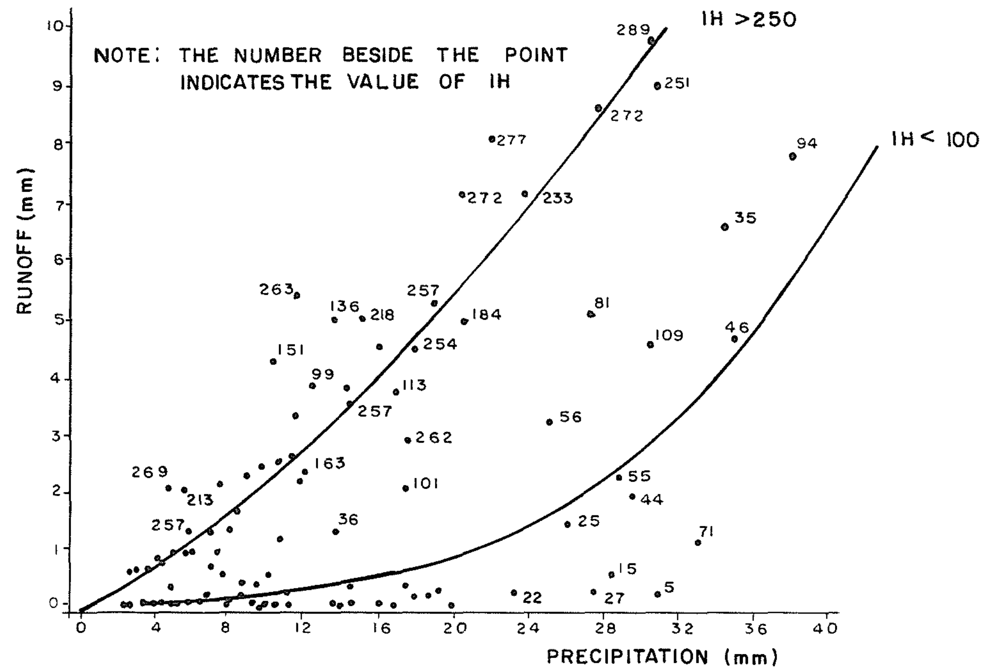

Fig. 1 Precipitation-runoff relationship for micro-basin no. 3 with the antecedent precipitation index as parameter.

did not show any clear trend when related to either the precipitation or the corresponding runoff. Any trend was detectable only when the soil loss was related to the erosivity index EI_{30} where E (t ha^{-1}) is the kinetic energy of the raindrops and I_{30} (mm h^{-1}) is the maximum 30 min intensity of the precipitation (Wischmeir & Smith, 1958). In the case of the micro-basins 3 and 4, there is a large concentration of events with low yields of sediments and very few events with a production of more than 1600 kg ha^{-1}. Thus only a central trend could be noticed with no indication of the influence of the effect of antecedent precipitation (Fig. 2). In general, it was found that the natural vegetation reduced the surface runoff and erosion by 90% or more for events of less than 50 mm of rain.

With reference to the erosion plots, a similar trend as that of the

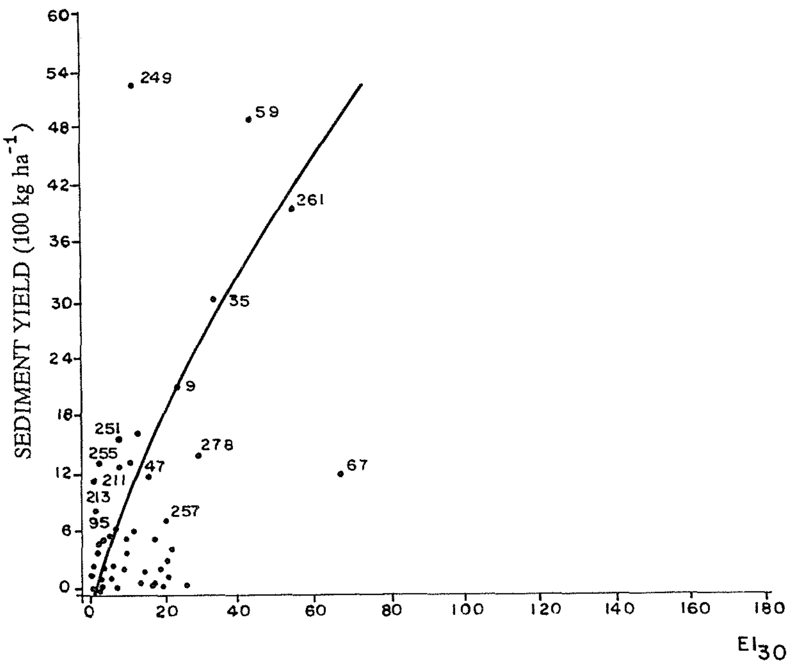

Fig. 2 Sediment yield-erosivity index relationship for micro-basin no. 3 with the antecedent precipitation index as parameter.

micro-basins was noted. The scale effect seems to be quite important and invariably the soil loss and runoff per unit area proved to be higher in the case of erosion plots than in the micro-basins of similar characteristics.

The relationships between precipitation and runoff as well as soil loss (erosion) and erosivity index showed far lesser scatter and a better defined trend in the case of 100 m^2 plots. For example, in the case of plot no. 4 two distinct trends could be seen for $IH < 150$ and $IH \geqslant 250$ for both runoff and soil loss (Figs 3 and 4). A comparative study of the observations in different plots showed the effects of surface cover and slope over runoff and erosion. In the case of mulching the average reduction, compared with bare soil condition, of runoff was about 50% and soil loss more than 60%. The effect of slope as observed between plot 1 (3.8%) and plot 4 (7%) showed an interesting situation. On the average the runoff in the two cases seemed quite similar but the soil loss was consistently higher for the larger slope. Similarly the effect of contour planting as in the case of plot no. 7, reduced by more than 50% on the average, the erosion rates when compared to planting along the slope (plot no. 6). The reduction in the case of runoff, however, was of the order of only 20%.

FUTURE STUDIES

In spite of the substantial data collected in the present study, the range is not uniformly covered by the number of events and it is necessary to have more

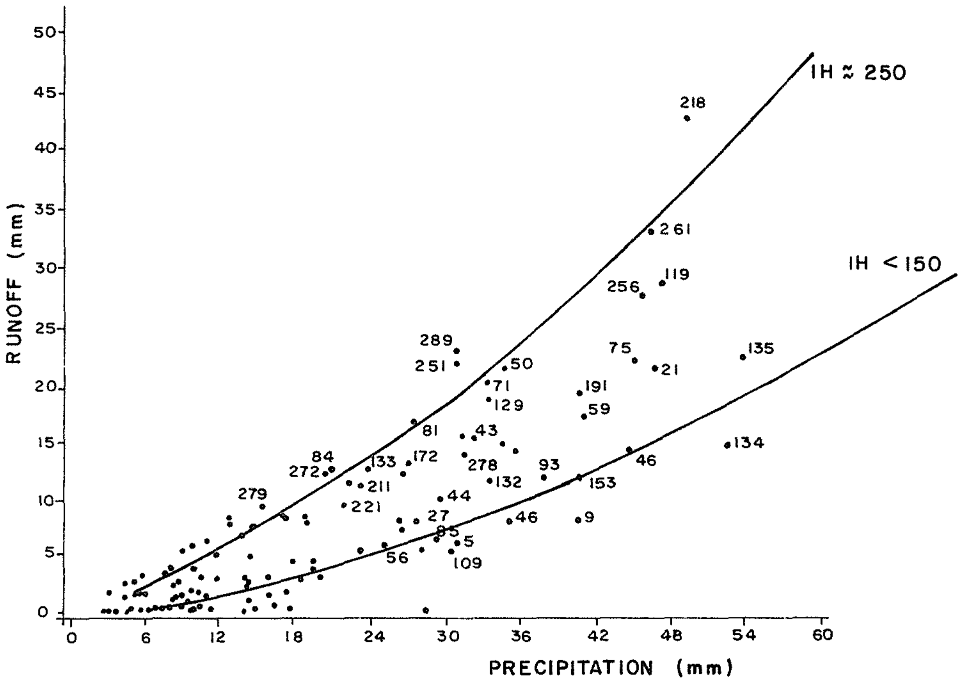

Fig. 3 Precipitation-runoff relationship for plot no. 4 with the antecedent precipitation index as parameter.

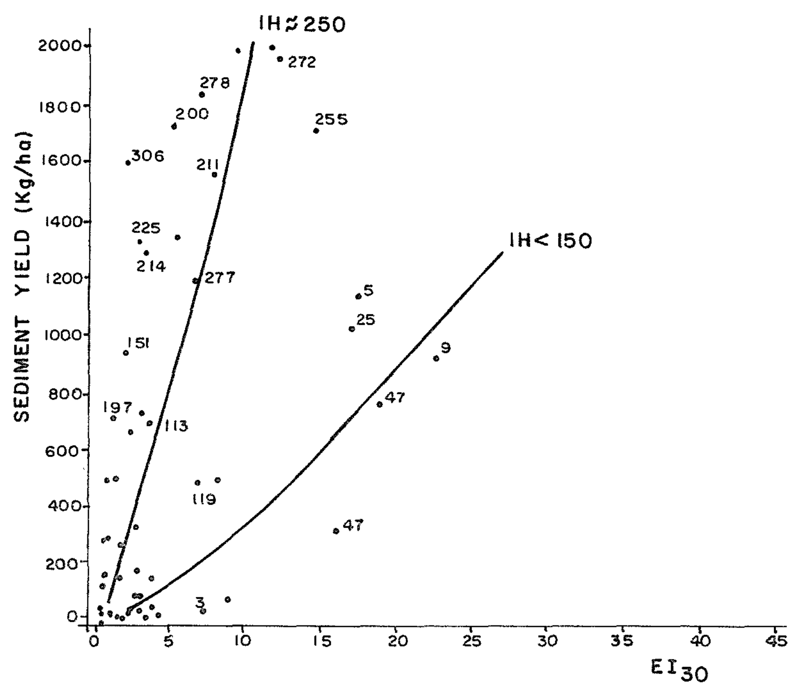

Fig. 4 Sediment yield-erosivity index relationship for plot no. 4 with antecedent precipitation index as parameter.

data in the band of medium and high erosion rates. It is expected that future observations will fill this gap. Once this has been achieved it should be possible to develop quantitative relationships for the soil loss and runoff in terms of the various basic factors. The data would also be a very useful basis for calibrating an appropriate regional sediment yield model.

Acknowledgements This study is supported through a financing plan (PDCT/NE) by the National Council for Scientific and Technological Development (CNPq) of Brazil. It was initially supported jointly by ORSTOM (France) and SUDENE (Brazil). The contribution of Eric Cadier (ORSTOM-SUDENE) is greatly appreciated.

REFERENCES

Cadier, E. & Freitas, B. J. (1982) Bacia Representativa de Sumé. Primeira estimativa dos recursos de água (Representative Basin of Sumé - The first estimate of the resources of water). *Série Hidrológia no. 14, SUDENE, Recife, Pernambuco, Brazil.*

Cadier, E., Freitas, B.J. & Leprun, J. C. (1983) Bacia Experimental de Sumé - Instalação e primeiros resultados (The experimental basin of Sumé - Installations and preliminary results). *Série Hidrologia no. 16, SUDENE, Recife, Pernambuco, Brazil.*

Nimer, E. (1979) *Climatologia do Brasil* (Climatology of Brazil). Fundação IBGE, Rio de Janeiro, Brazil.

Wischmeir, W. H. (1960) Cropping management factor evaluations for a universal soil loss equation. *Proc. Soil Sci. Soc. Am.* **24** (4), 322-326.

Wischmeir, W. H. & Smith, D. D. (1958) Rainfall energy and its relationship to soil loss. *Trans. AGU* **39**, 285-291.