Tropical Agricultural Hydrology
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2.4

Watershed Investigations for Development of Forest Resources of The Amazon Region in French Guyana

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The economic progress of French Guyana is dependent on the development of its vast forest reserves (90,000 km^2) that cover 98 per cent of its area. There is an increase in industrial need for timber and for the production of food and fibre. The forest ecosystem, characterised by slowly permeable and highly weathered soils derived from crystalline rocks with slopes ranging from 15 to 50 per cent and receiving annual rainfall of 3,000 to 4,000 mm, poses a challenge to ecologists and agriculturists for its proper development. Oversight of some important factors may lead to irreversible degradation of this vast natural resource. Established under the framework of Unesco's MAB program is the ECEREX (Ecoulement d' Ecologie, Erosion, et Exploitation) project that is jointly coordinated by ORSTOM, GERDAT, and IRFA (Dubreuil, 1963; Heinz and Dubreuil, 1963; Hoepfener, 1974; Hoorelbeck and Lemaitais, 1972). This project was initiated in 1976 to investigate; (i) the ecological conditions under the natural forest ecosystem, (ii) the changes in soil and hydrologic balance, and shift in floral composition by deforestation, and (iii) the effects of different management systems on production from a range of farming systems including pastures, silviculture, and seasonal crops.

The hydrological investigations include the measurements of water runoff and soil erosion.

2.4.1. MATERIAL AND METHODS

These investigations were carried out on 10 watersheds of 1 to 1.5 ha each. Two watersheds were kept under natural forest cover as control. The layout of these watersheds is shown in Figure 2.19. Changes in soil and hydrological parameters were investigated for 8 systems shown in Figure 2.20. These were: (i) natural regrowth without burning existing vegetation, (ii) natural regrowth after burning

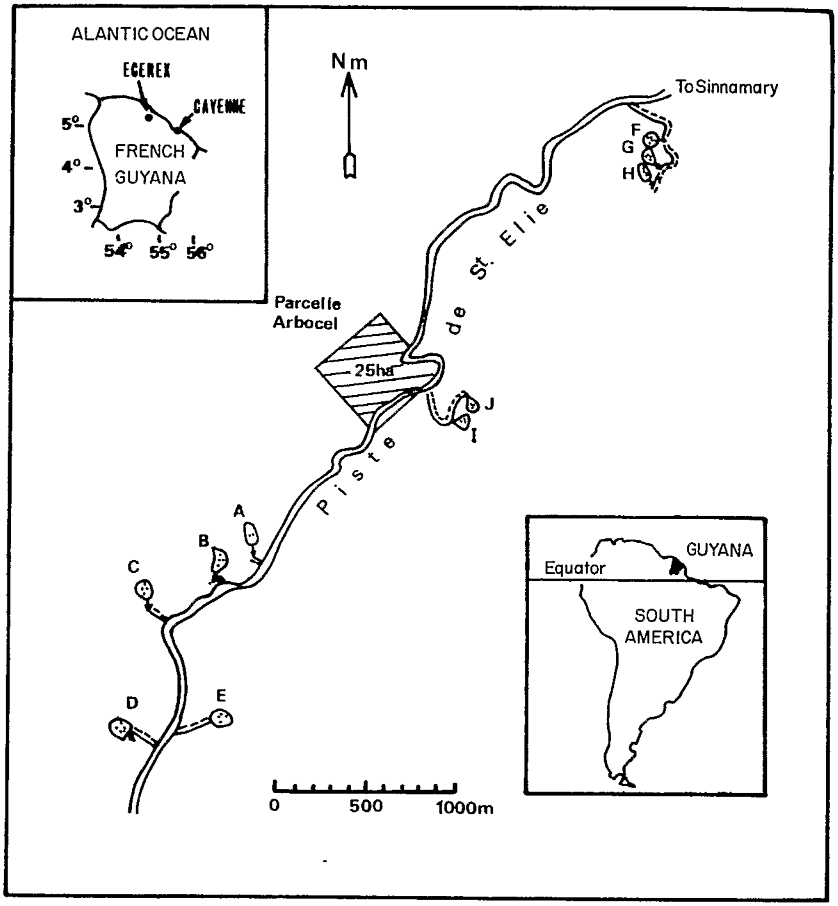

Figure 2.19 ECEREX Location of experimental watersheds

existing vegetation cover, (iii) Pinewood plantation, (iv) eucalyptus plantation, (v) citrus plantation, (vi) and (viii) two different pastures, and (viii) traditional farming. Prior to implementing these treatments, the initial baseline data under the forest cover was collected for two years. The observations on these watersheds were initiated over a period of two years from 1976 to 1978.

The soils of these experimental watersheds are representative of a large region. The hydrological and topographical characteristics of the soil are not homogenous among all watersheds. This variability should be kept in mind while interpreting the results.

Each of these 10 watersheds is equipped with a rain gauge and a V-notch or an H-flume and a water level recorder to monitor rainfall and runoff. Runoff samples are obtained for determining the sediment load.

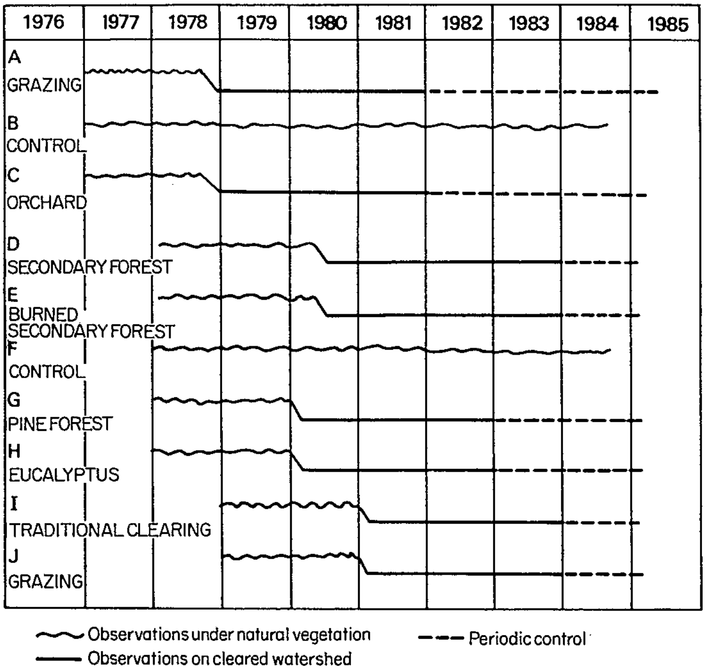

Figure 2.20 ECEREX Experimental watersheds management project

Runoff plots (100 m^2) have been established in the vicinity of these watersheds to monitor runoff and erosion on small plots. These plots are established on different soil types to investigate the magnitude of runoff and erosion from different soils of this region.

A methodology for comparative analysis of runoff and erosion from different watersheds has been reported earlier (Roche, 1978). The results of hydrological investigations were analysed for: (i) monthly and annual hydrologic balance, (ii) runoff/rainfall characteristics of individual storm events, and (iii) establishing cause-effect relationships among different parameters investigated. Simple correlation and regression were also computed between soil erosion and climatic erosivity factor, (R). Rainfall intensities computed on different time intervals were related to climatic erosivity factor (R), and to soil loss and runoff from each treatment.

Comparative analysis was also done for any specific hydrologic parameter for a given treatment with control, e.g. comparison of runoff characteristics from two watersheds for a single rainstorm event. These comparisons evaluate the effects of different types of rainfall events and of their temporal variability on hydrological characteristics. These effects are also evaluated for a range of farming systems at different stages of development.

2.4.2. RESULTS

2.4.2.1. Hydrologic Balance

2.4.2.1.1. Rainfall Characteristics

Rainfall amounts received over 1, 3, 5, and 10 minute intervals were not better correlated with runoff and soil loss than the total amount of rainfall received. Similarly, the multiple correlations of soil loss with rainfall erosivity (R), maximum intensity in 10 minutes, and an index of antecedent soil moisture regime did not improve the correlation compared with simple correlation with any of these variables.

Rains received in 1977 (3500 mm with 260 rainy days) were about normal, (Roche, 1977), although there were many high intensity rains with daily amounts exceeding 100 mm. One of the rainfall events totalled 350 mm in 54 hours and had a return period of 10 years. Runoff and erosion measurements were made for 415 storm events exceeding 3 mm. Rainfall events were distinguished from one another if they were separated by rains of intensity greater than 1.5 mm hr^{-1} for 1.5 hr. Rainstorm events of intensity ranging from 84 to 106 mm did not exceed their normal frequency.

2.4.2.1.2. Runoff

Runoff characteristics for watersheds A, B, and C, with slopes ranging from 15 to 25 per cent were monitored for 90 to 116 events, depending on the watershed. These watersheds have area of 1.5, 1.45, and 1.45 ha, respectively. The runoff was most frequently observed on watershed B.

Annual water yield was 925 mm, 845 mm, and 500 mm on watersheds A, B, and C with corresponding runoff coefficients of 27 per cent, 24 per cent, and 16 per cent respectively. The surface runoff from watersheds A, B, and C was 655 mm (19 per cent), 660 mm (19 per cent), and 230 mm (7 per cent) on watersheds A, B, and C, respectively (Figure 2.21). The highest monthly runoff coefficient of 32 per cent was observed on watersheds A and B, and one of about 8 per cent on watershed C.

2.4.2.1.3. Evapotranspiration and Groundwater Recharge

The difference between the rainfall and water yield from watersheds A, B, and C was estimated to be 2550, 2600, and 3000 mm yr^{-1} respectively. These values are more than 1600 mm yr^{-1} of evapotranspiration reported by ORSTOM for large Guyanese watersheds. This implies that the ground water recharge on watersheds A, B, and C was 950 mm, 1000 m, and 1400 mm, respectively. Interflow seepage, that was frequently observed in watershed C, and is a source of perennial flow in watersheds F, G, and H is caused by the groundwater recharge. Nevertheless, the seepage

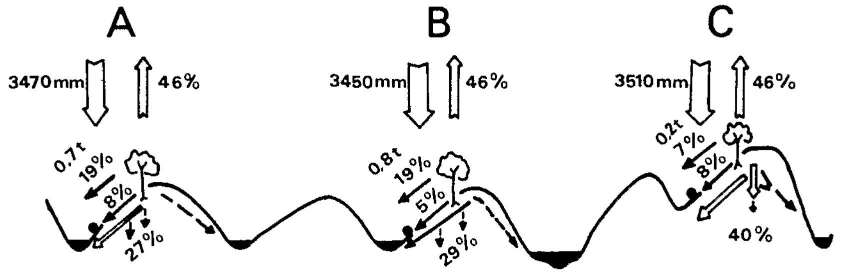

Figure 2.21 ECEREX Distribution of various terms of hydric balance of A, B, C, experimental watersheds, under forest. Example: rainfall on A basin was 3470 mm of which about 46 per cent was evapotranspiration, 19 per cent surface runoff, 8 per cent subsurface runoff, and 27 per cent infiltration. Soil erosion was 0.7 t ha^{-1} yr^{-1}

losses are difficult to quantify because the acquifer boundaries do not always coincide with the surface waterdivide.

The results presented indicate similarities in watersheds A and B, although runoff losses were slightly higher on watershed B. The runoff coefficient of watershed C is the lowest of the watersheds.

2.4.2.1.4. Runoff-Rainfall Relationship

Data in Figures 2.22 to 2.24 shows that total water yield from watershed A is more than from B, although the surface runoff was more from B than A. This difference between the two watersheds are attributed to water retention and transmission characteristics of the subsurface layers. The relationship between mean monthly runoff and rainfall are shown in Figures 2.22 to 2.24.

2.4.2.1.5. Soil Erosion

Under forest cover, the bed load was estimated to be 0.4 t ha^{-1} yr^{-1} from watersheds A and B, and 0.1 t ha^{-1} yr^{-1} from watershed C. The correlation between suspended sediment load and climatic erosivity factor (R) were computed to assess the soil erosion from unsampled storms. By using these regression equations, soil loss from suspended sediments was computed to be 0.34, 0.35, and 0.04 t ha^{-1} yr^{-1} with corresponding sediment density of 46, 36, and 12 mg l^{-1} for watersheds A, B, and C respectively. The soil erosion was also similar from watersheds A and B (0.7 and 0.8 t ha^{-1} yr^{-1}), but was significantly less from watershed C (0.2 t ha^{-1} yr^{-1}). In general, soil erosion under forest cover was low.

The concentration of dissolved constituents in water runoff ranged from 10 to 13 mg l^{-1}. This level of dissolved elements is lower than those reported for major Guyanese rivers. In addition to these elements, the concentration of dissolved silica was found to be 2 to 4 mg l^{-1}. The dissolved concentration in the ground

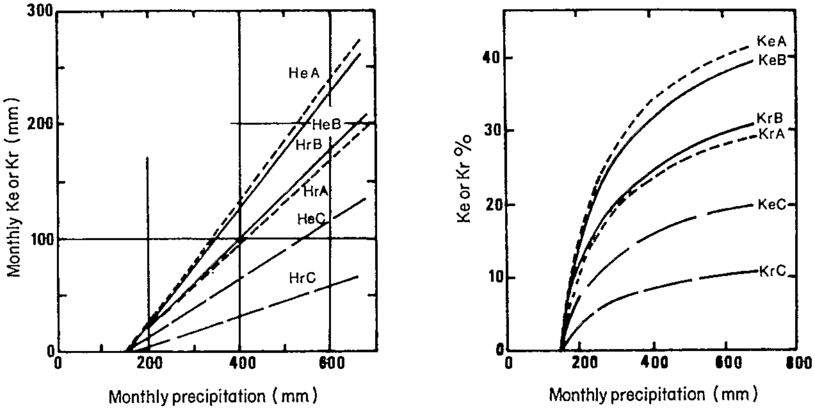

Figure 2.22 ECEREX (a) Correlation between the monthly water yield *He* or the monthly surface runoff Hr and the monthly rain intensity *P* on A, B, C, watersheds under forest. (b) Correlations between mean monthly water yield coefficients *Ke* or surface runoff coefficients *Kr* and the monthly rain intensity *P* on A, B, C, watersheds, under forest

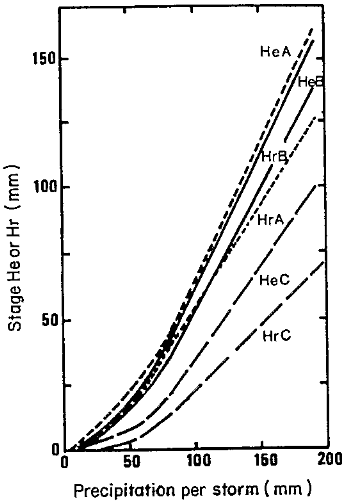

Figure 2.23 ECEREX Correlations between water yield *He* or surface runoff *Hr* for different storm events and the amount of rainfall per storm *P*, on A, B, C, watersheds under forest

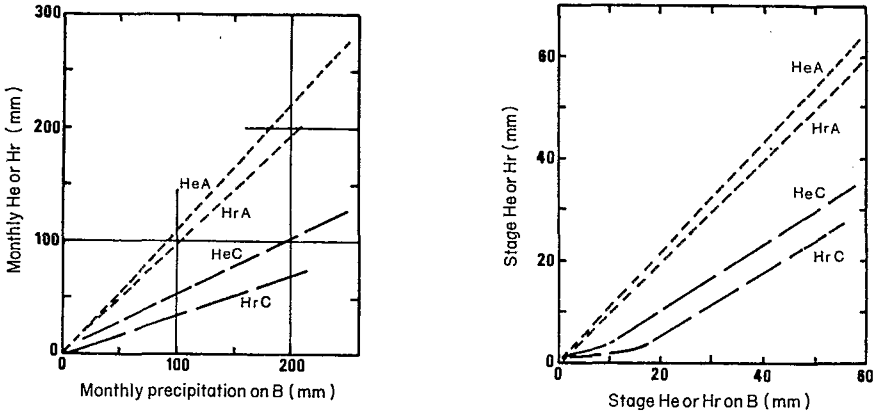

Figure 2.24 ECEREX (a) Correlation between monthly water yield *He* or surface runoff on A and C basins and the monthly water yield and surface runoff on the B check watersheds, under forest (b) Correlations between water yield *He* or surface runoff *Hr* for different storm events on A, C basins and the corresponding water yield or surface runoff on check watershed B under forest

water may be higher than in the surface water. Considering both surface and subsurface flow, about 0.5 t ha^{-1} yr^{-1} of dissolved nutrient elements may be removed from the basin as a whole.

2.4.3. CONCLUSIONS

A methodology has been developed to monitor runoff and soil erosion from watersheds under different land use. A computer program enables comparative evaluation of hydrologic phenomenon for different storm events, and for different watersheds. The preliminary results obtained indicate that soil erosion and runoff are influenced by hydrologic characteristics of the soil. For example, high vertical drainage of soils in watershed C is the reason for low surface runoff. Consequently, the soil erosion from watershed C is also low. On the contrary slowly permeable subsoil characteristics of watersheds A and B is responsible for 60 to 70 per cent runoff coefficient for intense rainstorms and for high erosion of about 1 t ha^{-1} yr^{-1}. Small soil erosion under forest cover is attributed to the protective effects of vegetation cover, and to the binding effects of roots and leaf litter.

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