RUNOFF CHARACTERISTICS IN THE SERRA DO MAR, SÃO PAULO, BRAZIL.

FUJIEDA, M. Runoff characteristics in the Serra do Mar, São Paulo, Brazil. **Bulletin of the Forestry and Forest Products Research Institute**, Japan, v. 369, p. 63-152. 1995.

RESUMO

The relationships between gross rainfall (Pg) and throughfall (Pt), stemflow (Ps) and crown interception (Ic) are expressed by the following equations:

$$Pt = - 0.584 + 0.839\ Pg \qquad (1)$$

$$Ps = - 0.044 + 0.012\ Pg \qquad (2)$$

$$Ic = 0.603 + 0.155\ Pg \qquad (3)$$

Crown interception at the watershed, 18.2% of annual rainfall, was intermediate compared with results of several types of tropical forest in Brazil. Annual surface runoff from the experimental test plot was only 0.61% of annual rainfall. However, monthly surface ratio varied from 0.00% to 1.55% depending on storm characteristics and soil moisture content. The minimum rainfall intensity required for the generation of surface runoff on the test plot may be more than 10 mm h^{-1}.

Differences existed in physical soil properties between the riparian area the hillslope. Mean porosity and the saturated hydraulic conductivity of hillslope soil were 51.4% and 10^{-3} $cm.s^{-1}$, respectively. Those of riparian area were 45.1% and 10^{-4} to 10^{-5} $cm.s^{-1}$, respectively. Thus the hillslope is more permeable than riparian area, which suggests that surface runoff rarely occurs on the undisturbed hillslope and almost all the water which falls on the forest floor enters the soil where it may contribute to soil moisture and groundwater recharge.

The volumetric water content of soil profile (θ) and soil moisture storage (S_s) were calculated by following equations:

$$\theta_A = \theta_{(0.6)} - \theta_{(50)} \qquad (4)$$

$$S_s = \sum \theta_{Ai} . Z_i \qquad (5)$$

Where, $\theta_{(0.6)}$ and $\theta_{(50)}$ are the volumetric water contents at potentials of -0.6 Kpa and -50 Kpa (From the soil water release curve), θ_A is the volumetric water capacity for any soil horizon, and Z_i is soil depth interval (mm). The soil moisture storage in the top of 150 cm of soil, the mean soil depth in watershed A, was about 180 mm. On the other hand, the maximum abstraction which was estimed by relationships between rainfall and abstraction showed almost as the same value as S_s. The calculation of S_s may be useful to estimate mean soil moisture storage in watershed.

The process of direct runoff generation in the watershed is comprised of three phases derived from a hydrograph analysis. The first phase is surface runoff from streams (satured overland flow) and the riparian wetlands. The second is subsurface return flow from grassed hillslope and interflow from seep zone. The last phase is surface runoff from the whole riparian area that is satured by heavy rainfall and increasing interflow

from the hillslope. Volume of direct runoff increased in the order of these phases. The monthly direct runoff rations during the rainy season range from 0.018 to 0.579 with mean of 0.095, those during the dry season range from 0.0 to 0.128 with mean of 0.044. The monthly direct runoff ratio is almost the same as the ratio of riparian wetland area to total drainage area. This indicates that riparian wetland mainly contributes to generate direct runoff during storms. Thus these riparian wetlands are considered source areas for the watershed. Annual direct runoff was only 11% of annual rainfall.

Annual baseflow comprised about 84.1% of annual streamflow and supplied streams throughout the year. The seasonal changes of monthly streamflow follow a counter-clockwise loop from October to September. Monthly streamflow during the May-August dry season is much more than monthly rainfall during this period. Monthly baseflow during the period lagged monthly rainfall by 1.5 to 2.0 months. This phenomenon is caused by basin storage. It was assumed that the magnitude of the loop and the time-lag may depend chiefly on the size of the riparian area in which soil moisture and groundwater are stored. The constant rate of unconfined groundwater recession was 0.003 day^{-1} to 0.005 day^{-1} . Compared with similar sized forested watersheds in Japan those values were 0.03 to 1.0 -fold with a mean of 0.13 -fold.

The contribution of annual rainfall distribution to components of hydrologic cycle in the watershed show that rainfall-runoff processes are controled by rainfall, interception, soil moisture storage, groundwater storage and baseflow. The time-lag of water movement is caused the sustained flow of streams or the temporal relese of baseflow from the forested watershed. This lag is an important hydrological feature controled by basin characteristics such as physical properties of soil, depth of soil mantle and vegetation cover.

A simple conceptual rainfall-runoff model that consists of three storage zones (interception, soil moisture, groundwater) and is a the function of direct runoff generation was developed to better understand the hydrologic responses in the watershed. The model was based on following the hydrological equation:

$$P(t) + R_D(t) + R_G(t) + I_T(t) + E_T(t) = S(t) - S(t-1) \qquad (6)$$

where: $P(t)$ = daily rainfall (mm)
$R_D(t)$ = daily direct runoff (mm)
$R_G(t)$ = daily baseflow (mm)
$I_T(t)$ = daily interception (mm)
$E_T(t)$ = daily evapotranspiration (mm)
$S(t)$ = Current day's basin storage (mm)
$S(t-1)$ = Previous day's basin storage (mm)

In this model, a watershed is simplified as consisting of hillslope and riparian area. Dominant water movements in the hillslope are functions of rainfall, interception, soil moisture storage, groundwater storage and baseflow, while, those in the riparian area, especially at the source area that will expand with storm size, are functions of rainfall and direct runoff. These process are described by both physically and empirically based equations. The model requires daily rainfall, daily streamflow, and an estimate of daily potential evapotranspiration (such as Hamon method). The parameter values in this model are determined from hydrological experiments and from computer optimization techniques.

There was good agreement the observed and calculated annual hydrographs for the eight water years from 1983 to 1990 based on daily streamflow. The mean relative error of annual streamflow during the period is 0.073; that of daily streamflow is 0.138. This indicates that daily streamflow in the watershed can be predicted by the model with acceptable accuracy.

The distribution off annual rainfall was partioned into four elements of the water balance watershed A, direct runoff R_D , baseflow R_G , interception I_T and evapotranspiration E_T . The percentages of R_D , R_G , I_T and E_T relative to annual rainfall were 10.8%, 58.0%, 13.7% and 16.8%, respectively. Change of basin storage (ΔS) estimated by subtracting predicted output from annual rainfall, was +0.7%. However, ΔS varied from 50 mm year^{-1} to 200 mm year^{-1} for each year.
Characteristics of basin storage fluctuation were estimated using the model throughout the period from 1983 to 1990. Mean monthly soil moisture storage during the November-May rainy season was about 110 mm of field capacity, however, moisture storage during the May-October dry season decreased to 80 mm with a minimum in July. Moisture recovered to field capacity during the rainy season. This seasonal fluctuation of soil moisture storage and soil moisture measurements in lysimeters indicate that the watershed may always have a water supply adequate for potential evapotranspiration. Mean monthly groundwater storage could be described as a parabol's function, with a maximum and minimum at the begining of autumn and spring, respectively. The monthly range in groundwater storage varies from 550 mm in October to 770 mm in March . This annual cycle of groundwater storage is well correlated with average monthly streamflow. Futher, there was two month lag-time between fluctuations of monthly rainfall and fluctions in monthly groundwater storage.
Results of hydrological measurements and modeling of rainfall-runoff processes in the forested watershed, show that sustained flow of streams are directly influenced by (1) The partitioning of annual rainfall to various hydrologic components, (2) Changes in basin storage, and (3) The lag-time of water movement in the watershed. The analysis of these functions in any watershed may provide useful information for development and management of water resources in headwater areas.