FEASIBILITY OF SCS-CURVE NUMBER METHOD OF RUNOFF ESTIMATION FOR SMALL SLOPING WATERSHEDS OF WESTERN GHATS

By

MINIL KUMAR K. X.

NARAYAN NAIR

RAJESH KUTTY

PROJECT REPORT

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Department of Irrigation and Drainage Engineering

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DECLARATION

We hereby declare that this project report entitled **"Feasibility of SCS-Curve Number Method of Runoff Estimation for small Sloping Watersheds of Western Ghats "** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place : Tavanur

Date : 25-5-1998

Minil Kumar K.X.

Narayan Nair

Rajesh Kutty

CERTIFICATE

Certified that this project report, entitled, **"Feasibility of SCS-Curve Number Method of Runoff Estimation for small Sloping Watersheds of Western Ghats"** is a record of project work done jointly by Minil Kumar K.X., Narayan Nair and Rajesh Kutty under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

Place: Tavanur
Date: 25-5-1998

Er. Abdul Hakkim V.M.
Assistant Professor
Department of Irrigation and
Drainage Engineering
K.C.A.E.T. Tavanur.

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Minil Kumar K.X.

Narayan Nair

Rajesh Kutty

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SYMBOLS AND ABBREVIATIONS

Agric.	-	Agricultural
Amer.	-	American
ASAE	-	American Society of Agricultural Engineers
ASCE	-	American Society of Civil Engineers
Assoc.	-	Association
Bull.	-	Bulletin
cm	-	centimetre (s)
cm/hr	-	centimetre per hour
CN	-	Curve Number
Co.	-	Company
con.	-	concentrated
Conserv.	-	Conservation
contd.	-	continued
CSWCRTI	-	Central Soil and Water Conservation Research and Training Insititute
CWRDM	-	Centre for Water Resources Development and Management
Engrg.	-	Engineering
et al.	-	and other people
etc.	-	etcectra
FAO	-	Food and Agricultural Organisations
Fig.	-	Figure
Geol.	-	Geological
Geophys.	-	Geophysics
ha	-	hectare (s)
hr	-	hour
ICRISAT	-	International Crop Research Institute for Semi Arid Tropics
i.e.	-	that is

Inter.	-	International
I.S.	-	Indian Standard
J.	-	Journal
kg	-	Kilogram
km	-	kilometre (s)
km^2	-	square kilometre (s)
Ltd.	-	Limited
m	-	metre (s)
m^2	-	square metre (s)
m^3	-	cubic metre (s)
min	-	minute
ml	-	millilitre (s)
mm	-	milli metre (s)
m^3/sec.	-	cubic metre per second
N.J.	-	New Jersey
N.Y.	-	New York
No.	-	Number
pp	-	pages
Proc.	-	Proceedings
Pvt.	-	Private
Res.	-	Research
Resour.	-	Resources
sci.	-	science
SCS	-	Soil Conservation Service
sec.	-	second (s)
ser.	-	service
soc.	-	society
surv.	-	survey
Tech.	-	Technical
Trans.	-	Transactions
Univ.	-	University
U.S.	-	United States

USDA	-	United States Department of Agriculture
Viz.	-	Namely
Vol.	-	Volume
Vs	-	Versus
&	-	and
>	-	Greater than or equal to
<	-	Less than or equal to
/	-	per
%	-	per cent

INTRODUCTION

Kerala, the southernmost state of Peninsular India occupies a unique position on the map of the country. It is hemmed between the mighty Western Ghats and the Arabian sea. The average width of the state is only 70 km with a length of about 700 km. Within this narrow strip of land we have regions lying few metres below mean sea level and peaks with an altitude of more than 1000m above mean sea level. The abundance of rainfall and natural fertility of the soil have made Kerala essentially an agricultural region. Diversity of crops and heterogeneity in cultivation are the peculiarity of agriculture in the State. The highland is mainly under plantation crops like tea, coffee, rubber and cardamom while the low land is virtually monopolised by paddy and coconuts and the midland is under a host of major and minor crops often cultivated inter mixed with one another. Kerala is blessed with many rivers and backwater lakes. All the forty four rivers of Kerala originate from the Western Ghats and most of them are harvested for irrigation and hydel power. The land use pattern in the catchment area of the river has its own effect on the disposition of rainfall in a given climate zone. It affects the surface runoff, ground water recharge, sediment production and transport and the microclimate. Their responses can be well studied on small watersheds under different land uses.

A watershed refers to the area lying above a common drainage point and can be defined as the area from which the surface water drains through a definite drainage point . A watershed can be defined as a natural integrator of all the hydrologic phenomena pertaining to its boundaries and as such it is a logical unit for planning optimum development of soil and water resources. It has no physical limits and may vary from less than a hectare or thousands of hectares depending upon the point of reference.

A distinct characteristics of any small watershed is that the effect of overland flow rather than the effect of channel flow is the dominating factor affecting the peak runoff. Consequently a small watershed is very sensitive to high intensity rainfalls of short duration and to land use. Therefore a small watershed may be defined as one that is so small that its sensitivity to high intensity rainfalls of short duration and land use are not suppresed by the channel storage characteristics. The upper limit of the area depends on the condition at which the above mentioned characteristics sensitivities become practically lost due to channel storage.

The Western Ghats of South peninsular India lie between 8° - 14° north latitude and 75° - 77° east longitude. It has a average elevation of 1000 meters with peaks ranging from 2500m to 3000 m above mean sea level. This region is the origin of all river systems that sustain the agro-economy of Kerala. Effect of deforestation and other land use changes brought about by human activities on hydrologic cycle continues to be of great concern. Such changes often influence the response of the drainage basin condition its output through the channels down and modify the hydrologic characteristics of the basin.

The amount of water moving out of a watershed depends on the rainfall, vegetation, the depth and water holding capacity of the soil and the surface runoff. Runoff is that portion of rainfall which moves down to the stream, channel, rivers or ocean as surface or subsurface flow.

In the design of Soil and Water Conservation measures, quantitative estimates of runoff and their distribution are to be worked out. Structures and channels are planned to carry maximum runoff which can be expected in a specified recurrence interval and hence accurate estimation of runoff is very important. If the farmer can intelligently harvest the runoff from his field, store it in a pond and recycle it for life saving or supplemental irrigation to crops, it will be able to maximise the crop production and thus obtain good returns.

The Soil Conservation Service method was established to provide technical assistance to farmers, Ranchers and other rural residents through engineers located in each country. This method was developed by the United

States Department of Agriculture. Uniform recommended techniques have been established and promulgated through the Soil Conservation Service. National Engineering Handbook. This service has been very satisfactory for the purpose for which it was established. One of the techniques is the Soil Conservation Service curve number (SCS - CN) method for estimating runoff volume (Soil conservation service 1969). The fundamental hypothesis of the SCS-CN method are as follows:

1. Runoff starts after an initial abstraction (I_a) has been satisfied. This abstraction consists principally of interception, surface storage and infiltration.

2. The ratio of actual retention of rainfall to the potential maximum retention 'S' is equal to the ratio of direct runoff to rainfall minus initial abstraction.

This model has been selected for the following reasons.:

It uses daily rainfall data available in most of the meteorological stations in India. Basically this model has been developed for small agricultural watersheds. This model assumes initial rainfall abstraction which is a combination of interception storage, infiltration before the beginning of runoff and surface retention. This assumption of initial rainfall abstraction holds good for all practical purposes on small watersheds where type of soil vegetative cover, cultivation practices as well as rainfall can be taken as uniform throughout the watershed.

The SCS method makes use of curve numbers which were originally derived for the conditions existing in the United States. This curve number values may not agree with the conditions existing in Kerala. The present study was undertaken to ascertain the feasibility of SCS method of runoff estimation using the original curve numbers derived and tabulated by USDA, for the small sloping watersheds of Western Ghats of Kerala.

For the present study four small monoculture watersheds planted with cashew, rubber coffee and tea were selected. The rainfall and runoff data of these watersheds for 5 years have been collected by the Centre for Water Resources Development and Management, Calicut. The rainfall and runoff values were analysed on daily basis. Runoff values were also estimated by SCS method of runoff estimation using curve numbers suggested by USDA.

The objectives of the study were

1. To ascertain the feasibility of SCS method of runoff estimation using the curve numbers suggested by USDA for the small sloping watersheds of Western Ghats of Kerala.

2. To work out the variation, if any between the observed and predicted values of 'runoff'

3. To suggest suitable curve numbers for prediction of runoff from these small monoculture watersheds of Western Ghats.

REVIEW OF LITERATURE

A watershed is a natural integrator of all hydrologic phenomena pertaing to the boundaries and therfore may be considered as the logical physical unit for planning optimum development of soil and water. The amount of water moving out of a watershed depends upon the rainfall, vegetation and the depth and water holding capacity of soil. Intensive work on watershed hydrology has been done all around the world, and the amount of literature available on the subject is voluminous. This chapter gives a brief review of the works which are relevent for the present study.

Runoff comprises the rainwater which leaves the drainage basin by surface route, either as overland flow(water running down slops in the form of sheet wash, rills, rivulets) or channel flow (water concentrated into streams and rivers). Overland flow is the process which leads to soil erosion (both sheet and gully erosion) and is widely regarded as active in shaping of slops. It normally comprises a very thin layer of flowing water, rarely more than a few millimeters in depth and covering all or much of the slop surface. On the upper part of the slop it maintains its character as sheet flow otherwise sheet wash or concentrated wash. But on the lower part of the slop it may become concentrated washes. One to amount for overland flow is that proposed by R.E. Horton. Horton accepted that when rain falls at a low or even moderate intensity on a slope as in humid temperate regions experiencing frontal rainfall, the resultant surface water water sink readily into the ground. This is simply because the intensity, perhaps in the order of 1-2 mm/hr, will be below the infiltration capacity to absorb rainwater at a rate of 5-50 mm/hr. However, if rainfall intensity, sometimes abbreviated to 'i', is high as during tropical thunderstorms, or the soil infiltration capacity (f) is low, as in clay soils which have been baked by sun's heat, then surface water cannot penetrate the soil sufficiently rapidly. The excess water therefore accumulates on the soil surface, where initially it will occupy small irregularities giving rise to depression storage.

However, these will quickly fill them to form a continuous sheet of water flowing down the slop. This type of surface runoff is termed as infiltration excess flow or Hortonian Overland flow. At the slop base, overland flow enters the stream or river channel thus contributing to channel flow.

However the Horton model is now recognised as having limitations. The model works well in some situations such as semi arid environments in which rainfall intensity is high but, in the absence of an effective vegetative cover which aids infiltration and impedes surface flow, infiltration capacity is low. In other situations infiltration excess flow is rarely generated under natural conditions, that is where vegetation cover has not been seriously disturbed or destroyed or where the upper soil layers have not been manipulated to expose the less permeable subsoil.

2.1. Hydrologic Studies in Watersheds

The entire area of a river basin whose surface runoff due to storm drains into the river in the basin is considered as a hydrologic unit and is called a drainage basin. The hydrologic processes that are generally studied are : rainfall frequency analysis, estimation of potential evapotranspiration, runoff characteristics, derivation of unit hydrographs, determination of runoff coefficient, infiltration studies, water balance computations and water table fluctuations.

Hoover(1962) has shown how canopy intercepts a greater percentage of light showers and a smaller percentage for flood producing storms. For storms in excess of 2 inches this interception might well be less than 0.2 inches but the litter covering the floors of conifer stands could be expected to have field moisture capacity of upto twice this amount.

Helvey and Patric (1965) showed that litter interception losses could reach 5% of the annual percipituation and that it could be much more variable than canopy interception losses, particularly due to human intervention.

Klinge *et al.* (1978) estimated that about 50% of the water falling in a watershed is derived from water transpired by the forest, a figure confirmed by a study of water budget of tropical rainfalls.

Singh and Das (1985) have recommended a geomorphic approach to hydrograph synthesis with potential for application for ungaged watersheds. The nature of stream flow in a region is a function of the hydrologic input to that region and physical, vegetative, and climatic characteristics of that region.

2.2. Infiltration

Infiltration is defined as the the entry of water from the air side of the air soil interface into the soil profile. Cumulative infiltration is the total quantity of water that enters the soil in a given time and infiltration capacity is the maximum rate at which rain can be absorbed by a soil in a given condition.

Poeson (1984) reported that soil saturated on steep slops will absorb, especially at the begining of rainfall event, more rainwater compared to the soil saturated on a low slope. This is due to spatially varying matric potential induced by a gravitation potential.

Varadan and Ragunath (1985) reported that infiltration rates of latesols of Kerala are 12 to 20cm/hr after 6 hour of study. They also reported that infiltration rate increased towards higher elevation and such variation occured for latesols of Kerala even at an elevation difference of 3m.

2.3. Surface Runoff Generation

To clarify the basis of CN method we review here the process of surface runoff generation. Surface runoff is generated by a variety of surface and near surface flow processes, of which some of the most important are

1. Hortanian overland flow
2. Saturation overland flow

3. Through flow processes
4. Partial-area runoff
5. Direct channel interception
6. Surface phenomena, such as crust development, hydrologic soil layers and frozen ground

Kirkby and Chorley(1967) concluded that throughflow prevails in heavily vegetated area with thick soil covers containing less permeable layers, overlaying relatively inpermeable bed rock. The concept of partial-area runoff developed from recognition that runoff estimates where improved by assuming that only rainfall on a small and fairly constant part of each drainage basin in able to contribute to direct runoff.

Hawkins(1981) reported that partial-area runoff can be interpreted as a combination of through flow in the upper hill slops and saturation overlandflow in the lower hill slopes.

Le Bissonnais and Singer(1993) reported that large amounts of surface runoff may take place even though the underlying soil profile below a relatively thin veneer remains substantilly dry.

2.4. Small Watershed Studies

Considerable studies have been reported on large watersheds and river catchments in India, but, only a few studies have been reported with regards to small watersheds of the country. Detail watershed studies may reveal the type of conservation measures and how to manage these watersheds.

Russell(1980) reported that it is not necessary to use plantation forests for the protection of the watershed, for in suitable areas perennial crops such as coffee and tea can take the place of trees. A 750 ha estate cleared from high evergreen forest and planted with tea gave similar results as from evergreen forests.

Rambabu *et al.*(1974) have obseved for Dehradun that as a result of field bunding of small agricultural watersheds, there has been a 62% reduction in runoff and 40% reduction in peak runoff rate.

Krantz *et al.* (1978) has studied small agricultural watersheds as a part of ICRISAT's research programme on improved resourcs utilization, the central objective was to make best use of the rain that falls on a river area.

Abdul Hakkim(1993) reported that in case of small agricultural watersheds of Western Ghats, the infiltrated rain water meets the impermeable layer below and there it flows laterally through the soil. This lateral interflow reaches the valley portion of the watersheds where it saturates the soil. This saturated area acts like an impervious layer producing 100% surface runoff and it is responsible for sharp peak of hydrographs. Runoff is generated from these sources areas and Hortanian overland flow is a rare phenomenon in these watersheds.

2.5. Soil Conservation Service -Curve Number method

The origin of the curve number methodology can be traced back to the 1000 of infiltrometer tests carried out by SCS in the late 1930 and early 1940. The indent was to develope basic data to evaluate the effects of watershed treatment and soil conservation measures on the rainfall runoff process. A major catalyst for the development and implementation of runoff curve number methodology was the passage of United States watershed protection and flood prevention act of 1954.

Rallison and Cronshey (1969) reported that studies associated with small watershed project planning were expected to require a substantial improvement in hydrologic computation with SCS.

Hawkin (1975) came up with improved prediction of storm runoff from mountain watersheds and the importance of accurate curve number in estimation of runoff.

Aron *et al.*(1977) gave an infiltration formula based on SCS-Curve Number.

Chen (1982) evaluated the mathematical and physical significance of the SCS-CN procedure for estimating runoff volume.

Cazier and Hawkins came forward with regional applications of the curve number method.

Woodward (1992) published a progress report titled ARS-SCS-Runoff curve number work group.

Hawkins (1993) devised the asymptotic determination of curve numbers from runoff curve number data. He reported the background, general instructions and examples are given for determining runoff curve numbers from watershed event rainfall and direct runoff data sets. Inorder to preserve the return period matching between rainfall and runoff, the method matches rank order rainfall and runoff. Usually a secondary trend of CN with the storm rainfall itself emerges and 3 different patterns were observed; Complacent, Standard, and Violent. The standard and violent cases lead to a constant CN with increasing storm size. But complacent cuse does not lead to a stable determination of curve number.

Steenhuis *et al.* (1995) revisited the SCS-runoff equation for variable source runoff for two watersheds in Australia and three in the north eastern United States. By plotting the effective precipitation defined as the amount of precipitation minus the initial abstraction against the observed runoff for the above watersheds they found that the SCS-curve number equation in its elimentary from fitted the data well.

Bonta V. James (1997) concluded that a Monte-Carlo simulation showed the dervived distributions method gave a fewer variable estimates of CN for wide range of sample sizes than two other methods for CN estimation. CN estimated by the asymptotic method and dervived distribution where in agreement. The dervived distribution method has a potential for determining CN's when there are a limited P and Q data.

MATERIALS AND METHODS

The quantity of water that moves out of a watershed and the seasonal flow of the stream depends on the land use.The present study aims to assess the feasibility of SCS-Curve Number method of runoff estimation for the small sloping watersheds of Western Ghats of Kerala.The runoff Curve Number method for estimation of direct runoff from storm rainfall is well established in hydrological engineering and environmental impact analysis.Its popularity is rooted in its convenience ,its authoritative origin and its responsiveness to four readily grasped catchment properties - soil type ,land use / treatment, surface and antecedent conditions. The material used and the methodology adopted are described in this chapter.

3.1. Experimental Catchments

Four small watersheds planted with cashew,rubber,coffee,and tea were selected for the study.Surveying , stream gauging and the meterological data of the watersheds were already been carried out by CWRDM Kozhikode .The locational details of the selected watersheds are given in Table 1. The location map of the watersheds are shown in Figure 2. Fig. 3 to Fig. 6 gives the contour maps of the watersheds selected.

3.2. Instrumentation

Meterological stations were established for recording rainfall and stage level recorders along with masonary weirs and flumes were installed to measure the stream flow .

3.2.1. Rain gauges

The source of water available for runoff is the rain that falls on the watershed. The rainfall was measured with help of recording and non recording type raingauges for each watershed. The nonrecording type rain gauge was

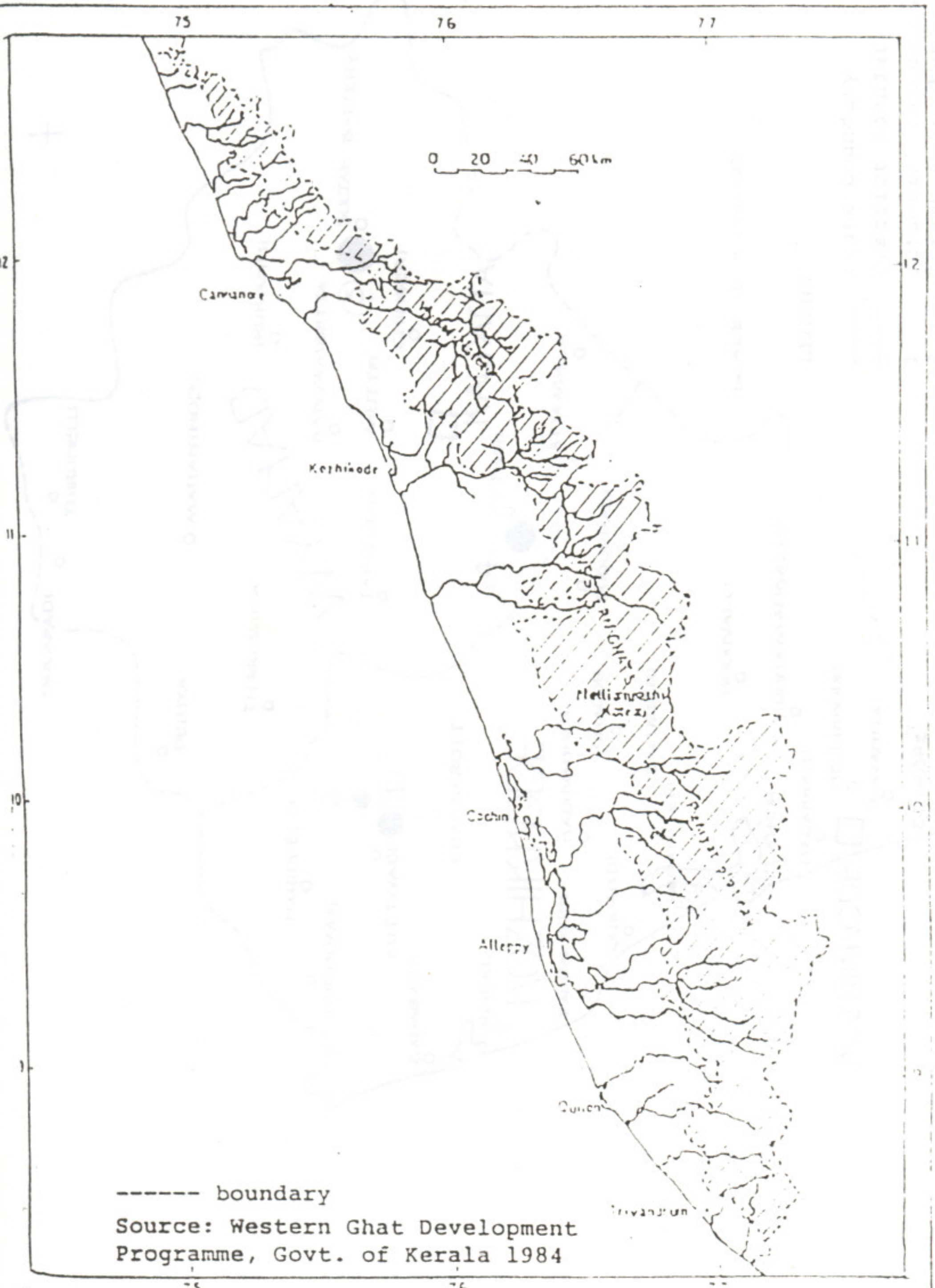

Fig.1 Western Ghats of Kerala

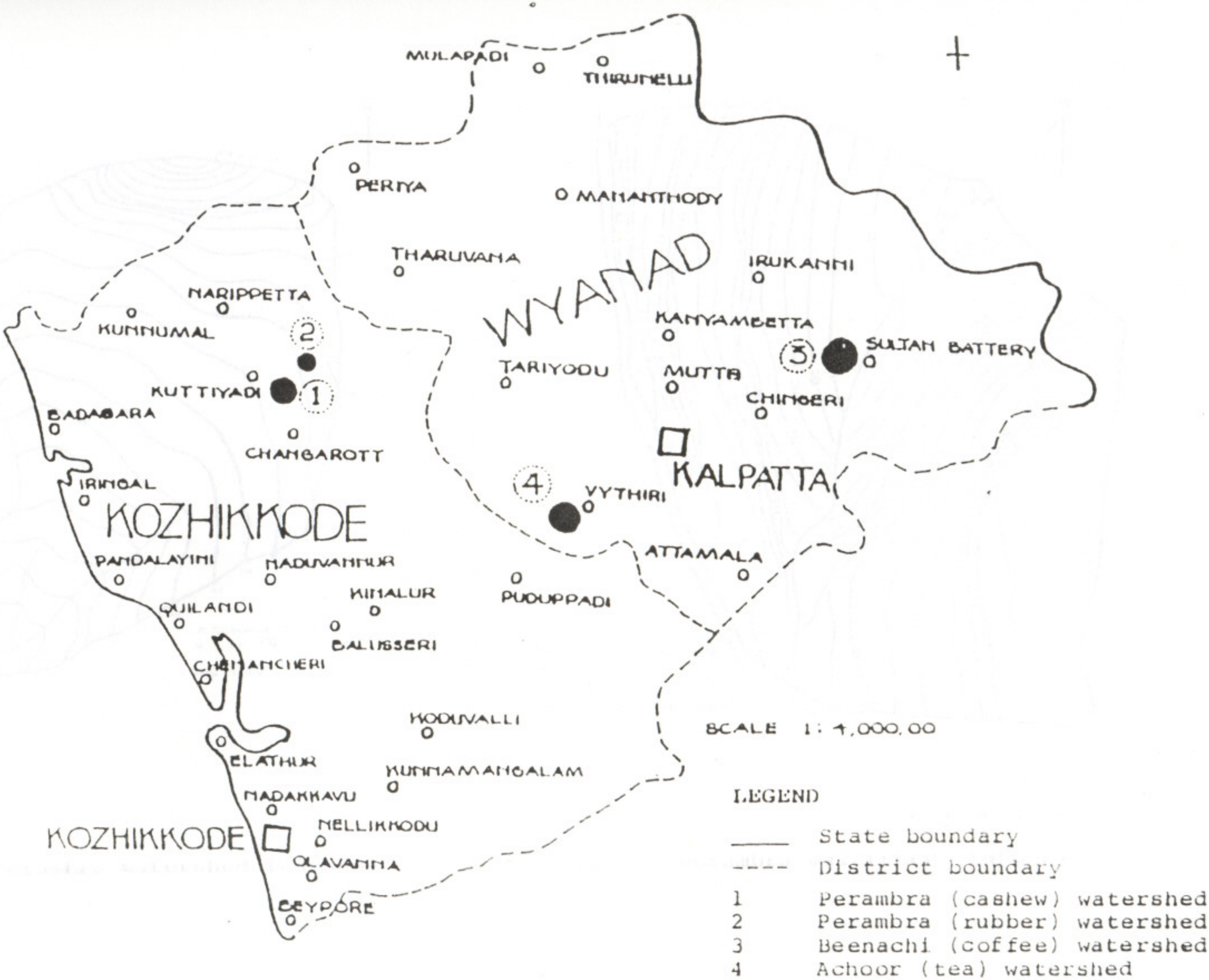

Fig.2 Location map of the selected watersheds

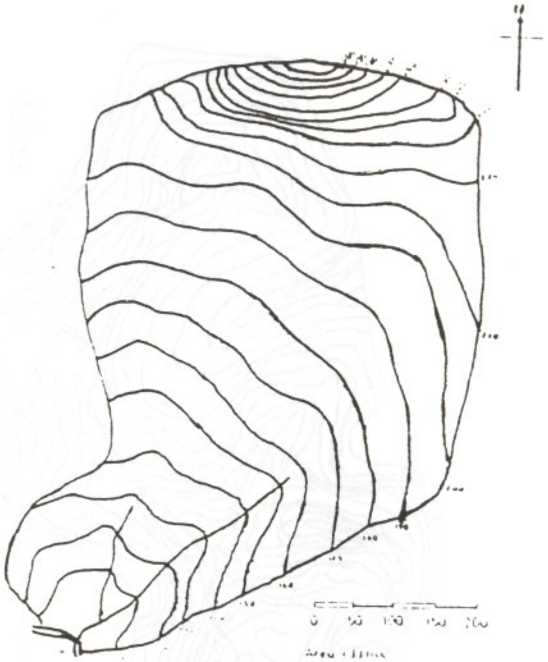

Fig.3 Perambra watershed (cashew)

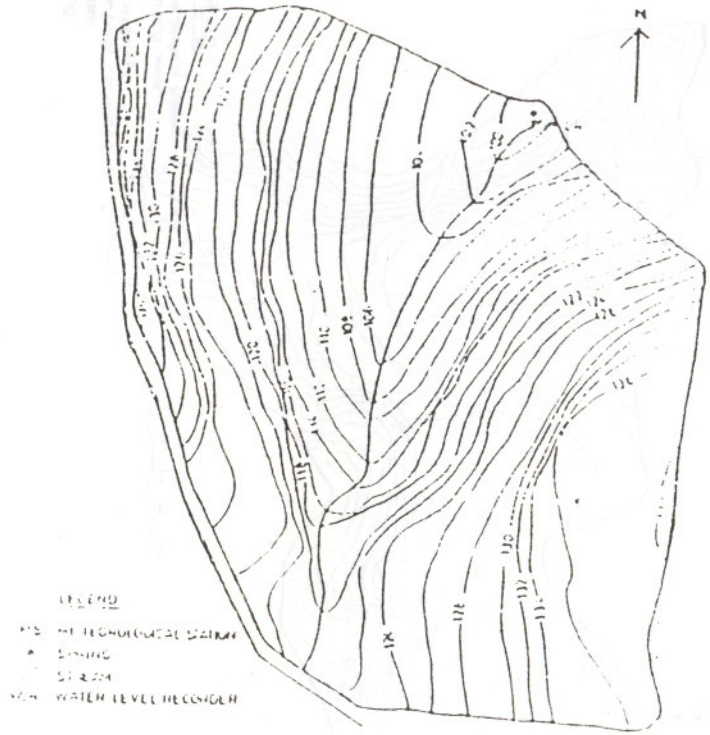

Fig.4 Perambra watershed (rubber)

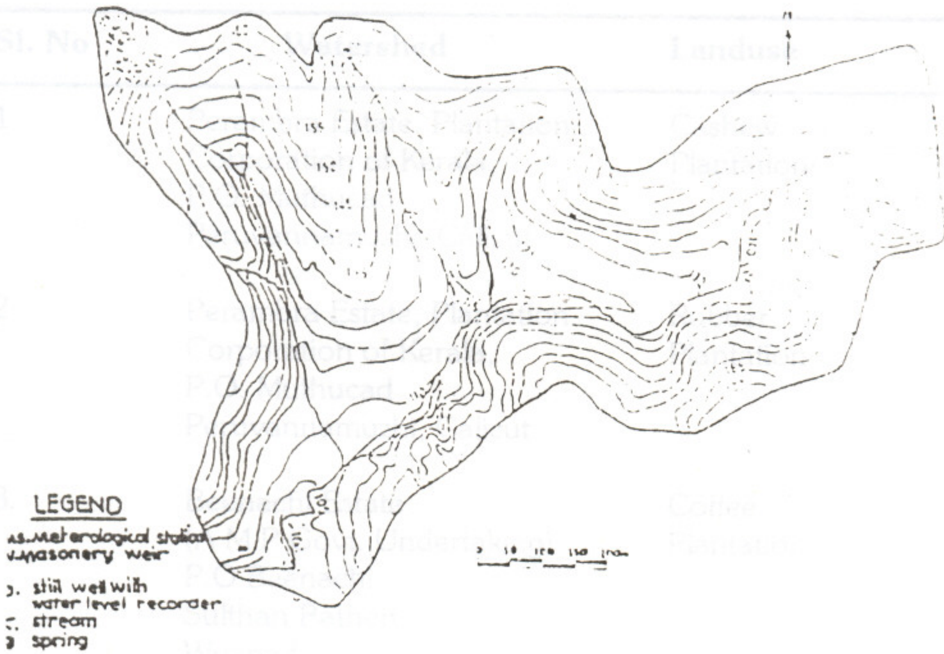

Fig.5 Beenachi watershed (coffee)

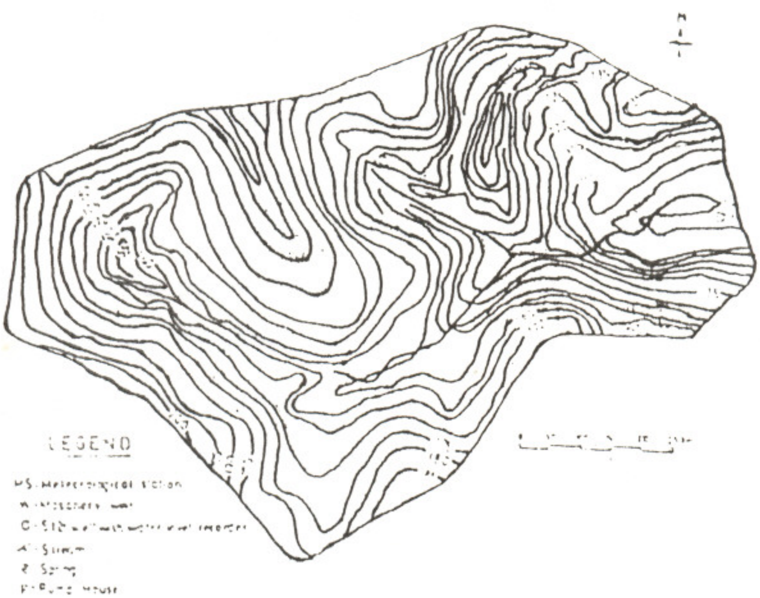

Fig.6 Achoor watershed (tea)

Table 1 Details of the selected watersheds

Sl. No	Watershed	Landuse	Area(ha)
1	Perambra Estate, Plantation Corporation of Kerala, P.O. Muthucad Peruvannamuzhi, Calicut	Cashew Plantation	29.5
2.	Perambra Estate, Plantation Corporation of Kerala, P.O. Muthucad Peruvannamuzhi, Calicut	Rubber Plantation	1.9
3.	Beenachi Estate (A M.P Govt. Undertaking) P.O.Beenachi Sulthan Bathery Wyanad	Coffee Plantation	74.87
4.	Achoor Estate Harrison Malayalam Ltd. Achooranam. P.O Pozhuthana South Wyanad	Tea Plantation	61.74

used along with recording type raingauges for cross checking .The total rainfall in a given period of time is measured by a non recording type raingauge.The rainwater reaches the brass funnel and is directed to suitable glass jar kept in an enclosed metallic cylindrical case.The rainfall characteristics such as intensity, frequency, duration and amount which influence the rate and amount of runoff are obtained by a recording (automatic) raingauge. The recording type raingauge consists of a galvanised iron cylinder 22.5 cm in diameter and 60 cm high with a funnel.The spout of the funnel leads into an inner circular tube of brass . The recording mechanism consists of a clock driven drum carrying the record sheet on which a pen traces the graph of rainfall against time. Fresh charts are set at fixed time after every 24 hours. The recording pen is fixed on a rod which is connected to a float in the inner cylinder. As water accumulates in the cylinder the float rises along with the inking pen which records the characteristics of the storm. When the cylinder is full, connection is established with the inner cylinders and siphon tube and the entire water in the cylinder is drained away and the float and the inking pen drops back to zero position.

3.2.2. Stage level recorder

Since it is difficult to make continuous direct measurements of the rate of flow in a stream , discharges were derived from stage level recorders .This approach is satisfactory only if there is an adequate correlation between stage and discharge. Stage level recorders were installed along with masonary weirs or flumes .The stage level recorders were housed to one side of the flume along a still well which is connected to the stream by a horizontal tapping pipe.The water level recorder consists of a time element and a water height element which operates together and produce on the chart the rise and fall of waterlevel with respect to time. The time element is a clock operating a recording pen . The water level is recorded with the help of a float and a counter weight operating in a stilling well. The float of the instrument is free to move up and down with variation of water level and its movements are transferred to the chart with the help of a recording pen .The river stage at any time can be converted into discharge using stage discharge rating curve .The stage discharge relationships were derived for each weir and flume .The discharge value in units of flow rate are converted into units of depth over the watershed by dividing it with area of the respective watershed. The rainfall and runoff data were collected for the years 1985, 1986 and 1987.

3.3. Hydrograph analysis

The basis of hydrograph analysis is that since a storm hydrograph reflects many of the physical characteristics of the basin , similar hydrographs will be produced by similar rainfall occuring with comparable antecedent conditions .

3.3.1. Runoff Hydrograph

It is also called storm hydrograph .It is a graph showing the flow rates as a function of time at a given location on the stream .To derive the storm hydrograph,the stage hydrograph recorded by the stage level recorder corresponding to the selected storm was obtained.The stage heights at regular time intervals were converted to corresponding flow rates using the stage discharge rating curve.The flow rates were plotted against the corresponding time to get the storm hydrograph. The correspondence between the hydrograph and its causitive rainfall was reflected. Runoff was calculated by finding area under the direct runoff hydrograph and dividing it by watershed area, in consistent units.

3.3.2. Baseflow separation

The slowly varying flow during rainless period is called baseflow.The variable slope method of baseflow separation (Chow.V.T) was used here.In this method the baseflow curve before the surface runoff began is extrapolated forward to the time of peak discharge and baseflow curve after surface runoff ceases is extrapolated backward to the point of inflection on the recession limb.A straight line is used to connect the end points of the extrapolated curves.This type of separation is preferred where ground water contributions are relatively large and the reach of the stream fairly rapid.

3.4. Infiltration studies

Infiltration studies were conducted in each watershed using double cylinder infiltrometers. The infiltration measurements were taken at two to three representative locations of each watershed and average values were taken. The lateral movement of water from the inner cylinder is minimized by ponding water in a guard cylinder or buffer area around the cylinder. The cylinders are 25 cm deep and are formed 2mm rolled steel. The inner cylinder from which infiltration measurement are taken, is 30 cm in diameter and the outer cylinder, which is used to form the buffer pond is 60 cm in diameter. The cylinders are installed about 10 cm deep in the soil. Care is taken to keep the installation depth of cylinders the same in all experiments . The cylinders are driven into the ground by falling weight type hammer striking on a wooden plank placed on the top of the cylinders. The water level in the inner cylinder is read with a hook gauge. The hook gauge is set at the desired level to which water is to be added. Water is added to the inner cylinder from a container of known volume and graduated jar. A stopwatch is used to note the instant the addition of water begins and the time the water reaches the desired level. The difference between the quantity of water added and the volume of water in the cylinder at the instant it reaches the desired point is taken as the quantity of water that infiltrated during the time interval between the start of filling and the first measurement . After the first reading , hook gauge readings are noted at different intervals to determine the amount of water that has infiltrated during the time interval. Water is added quickly after each measurements so that a constant average infiltration head could be maintained . The buffer pond is filled with water immediately after filling the inner cylinder . Water levels in the inner cylinder and the buffer pond are kept approximately the same .

3.5. Soil Conservation Service (SCS-CN) Method

The prediction of rain storm event runoff is a common task in applied hydrology . It is necessary for designing structures for peak flow , sediment storage accomodation and last but not the least in generating complex hydrographs.Also insofar as storm runoff is a reflection of land conditions the calculation of it is a statement of environmental impact and leads to erosion and sediment yield.The SCS-CN method is a simple equation .

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{.....................................(1)} \quad P \geq 0.2S$$

Given storm runoff depth (Q) for the storm rainfall depth (P) for a given value of S, where S is a site storage index. S is further related to land condition coefficient called Curve Number by the transformation .

$$CN = \frac{25400}{(254 + S)} \qquad \text{.............................(2)} \quad S \geq 0$$

while P,Q and S are in millimetres. CN is generally considered to be dimensionless and has value between 0 and 100.

3.5.1. Analysis

Analysis was carried out by considering these watersheds with landuse pattern as forest and initial abstraction as 20 % of the maximum retention potential (S). While values of CN are usually estimated from tables based on soils and vegetations , it is also possible to determine a de facto CN from rainfall and runoff data. This is possible through solution of equation (1) .For S to

$$S = 5(P + 2Q - \sqrt{(4Q^2 + 5PQ)}) \qquad \text{........................ (3)}$$

Thus defining a S value (and therefore a CN via equation 2) from any P-Q pair.

Steps involved in estimating runoff from the available rainfall data are:

1. Collect a reasonably good number of events of individual storms and corresponding hydrographs.
2. Make sure that the watershed data for the item 1 is well defined in terms of area , hydrologic soil cover, hydrologic soil group etc.
3. Find the direct runoff components by analysing the hydrographs.
4. Ascertain the most appropriate Curve Number (book value) and estimate the direct runoff for the individual storm.
5. Compare the results of 3 and 4

Steps involved in estimation of the curve number from rainfall and runoff data are :

1. Collect a reasonably good number of events of individual storms and their corresponding hydrograph.
2. Use eqn (3) and with the help of the individual storm rainfall and runoff data to find 'S'.
3. With value of 'S' from step 2 find the CN using equation (2).
4. Compare the CN (Book value) predicted with that of obseved CN.

The above steps were adopted again for prediction of Runoff and Curve Numbers for these watersheds considering them as Orchards without understory cover with initial abstaction as 30% of the maximum retention potential (S). Instead of equation (3) , to find S the following formula is adopted .

$$S = \frac{(6P + 7Q) + \sqrt{49Q^2 + 120PQ}}{1.8} \quad \text{.....................................(4)}$$

3.5.2. Antecedent Rainfall

Rainfall in antecedent periods of 5 to 30 or more days prior to a storm are commonly used as indexes of watershed wetness. An increase in the wetness means an increase in the runoff potential. Such indexes are only rough approximation because they do not include the effects of evaporation and infiltration on watershed wetness. It is not necessary to obtain great accuracy in computing the index decribed below.

3.5.2.1. Antecedent moisture condition:-

The index of watershed wetness used with runoff estimation method is antecedent moisture condition (A.M.C). Three levels of AMC are used.

AMC-1 Lowest runoff potential. The watershed soils are dry enough for satisfactory cultivation to take place.

AMC-2 The average condition.

AMC-3 Highest runoff potential. The watershed is practically saturated from antecedent rains.

Table 2 The AMC is estimated from the five day antecedent rainfall in the table given below.

AMC group	Total 5 day antecedent Rainfall	
	Dormant Season (mm)	Growing Season(mm)
I	less than 12.7	less than 35.6
II	12.7 to 27.9	35.6 to 53.3
III	Over 27.9	Over 53.3

3.5.3. Hydrologic Soil groups

There are four hydrologic soil groups. They are used in determing hydrologic soil cover complexes.

3.5.3.1. Hydrologic soil group A

Soil, having high infiltration rate even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravel where soils have a high rate of water transmission.

3.5.3.2. Hydrologic Soil group B

Soils have moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

3.5.3.3. Hydrologic soil group C

Soils have slow infiltration rate thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have moderate rate of water transmission.

3.5.3.4. Hydrologic soil group D

Soils having very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential. Soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils cover nearly impervious materials.

Table 3 Runoff curve numbers for hydrologic soil cover complexes:- for AMC-II conditions ($I_a=0.2S$)

Landuse	Treatment	Hydrologic Condition	A	B	C	D
Row Crop	Straight Row	-	77	86	91	94
	Straight Row	poor	72	81	88	91
	Straight Row	good	67	78	85	89
	Contoured	poor	70	79	84	88
	Contoured	good	65	75	82	86
	Terraced	poor	66	74	80	82
	Terraced	good	62	71	78	81
Small Grains	Straight Row	poor	65	76	84	88
	Straight Row	good	63	75	83	87
	Contoured	poor	63	74	82	85
	Contoured	good	61	73	81	84
	Terraced	poor	61	72	79	82
	Terraced	good	59	70	78	81
Close Seeded Legumes	Straight Row	poor	66	77	85	89
	Straight Row	good	58	72	81	85
	Contoured	poor	64	75	83	85
	Contoured	good	55	69	78	83
	Terraced	poor	63	73	80	83
	Terraced	good	51	67	76	80
Pasture/Graze	Straight Row	poor	68	79	86	89
	Straight Row	fair	49	69	79	84
	Straight Row	good	39	61	74	80
	Contoured	poor	47	67	81	88
	Contoured	fair	25	59	75	83
	Contoured	good	6	35	70	79
Meadow	-	good	30	58	71	78
Woods(Forested)	-	poor	45	66	77	83
		fair	36	60	73	79
		good	25	55	70	77
(Ia = 0.3 S)						
Orchards(without understory cover)			41	55	69	73

Table 4 **Antecedent Rainfall Conditions andCurve Number (Ia =0.2S)**

Curve No. For Condition II	Conversion factor for Condition II to I	III
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

Table 5 **Watershed description summary**

Land type	No.of Watersheds	Watershed	Land use	Area (ha)	Storms/watershed
Forest	1	Perambra	Cashew	29.5	13
Forest	1	Perambra	Rubber	1.9	12
Forest	1	Beenachi	Coffee	74.87	11
Forest	1	Achoor	Tea	61.74	9

3.6. Data

A number of data for the four watersheds mentioned were collected and analysed as per the procedure mentioned. That is, Curve Numbers were estimated from both the soils and vegetation data, and from hydrologic data analysis. The four watersheds selected can be treated as forested watersheds from the hydrologic point of view.

RESULTS AND DISCUSSION

Western Ghats,being the main water contributor for all the forty four rivers of Kerala the information regarding all the runoff from Western ghat watersheds are important .The SCS-CN method is a model to calculate the runoff . The method involves selection of suitable Curve Numbers for each watershed and then estimation of the runoff. Thus the correct predicted Curve Number derived and tabulated by USDA may not be in agreement with the conditions existing in small sloping watersheds of Western Ghats. The results obtained from the study are discussed in this chapter.

4.1. Hydrograph analysis

From the stage and discharge hydrograph runoff hydrographs are prepared for selected storms The baseflow was separated to obtain actual runoff.The runoff hydrographs are shown in fig 7 to 14 . Two hydrographs for each watershed are provided as representative samples with date of occurence.

From the runoff hydrographs it was observed that the baseflow component was comparatively high for Cashew,Coffee and Tea watersheds. For the Rubber watershed the baseflow was found to be nil. The hydrograph attains a sharp peak immediately as the rain falls , indicating steep sloping terrains having a low channel storage. The recession limbs are also found to be somewhat steep for all these watersheds.

From the hydrograph analyses it was observed that as the direct runoff starts it attains a sharp peak and recedes with a steep limb.This indicates that the channel storage for these watersheds are very low.From the hydrographs it was observed that there was a baseflow which is flowing through the three watersheds, except for rubber.

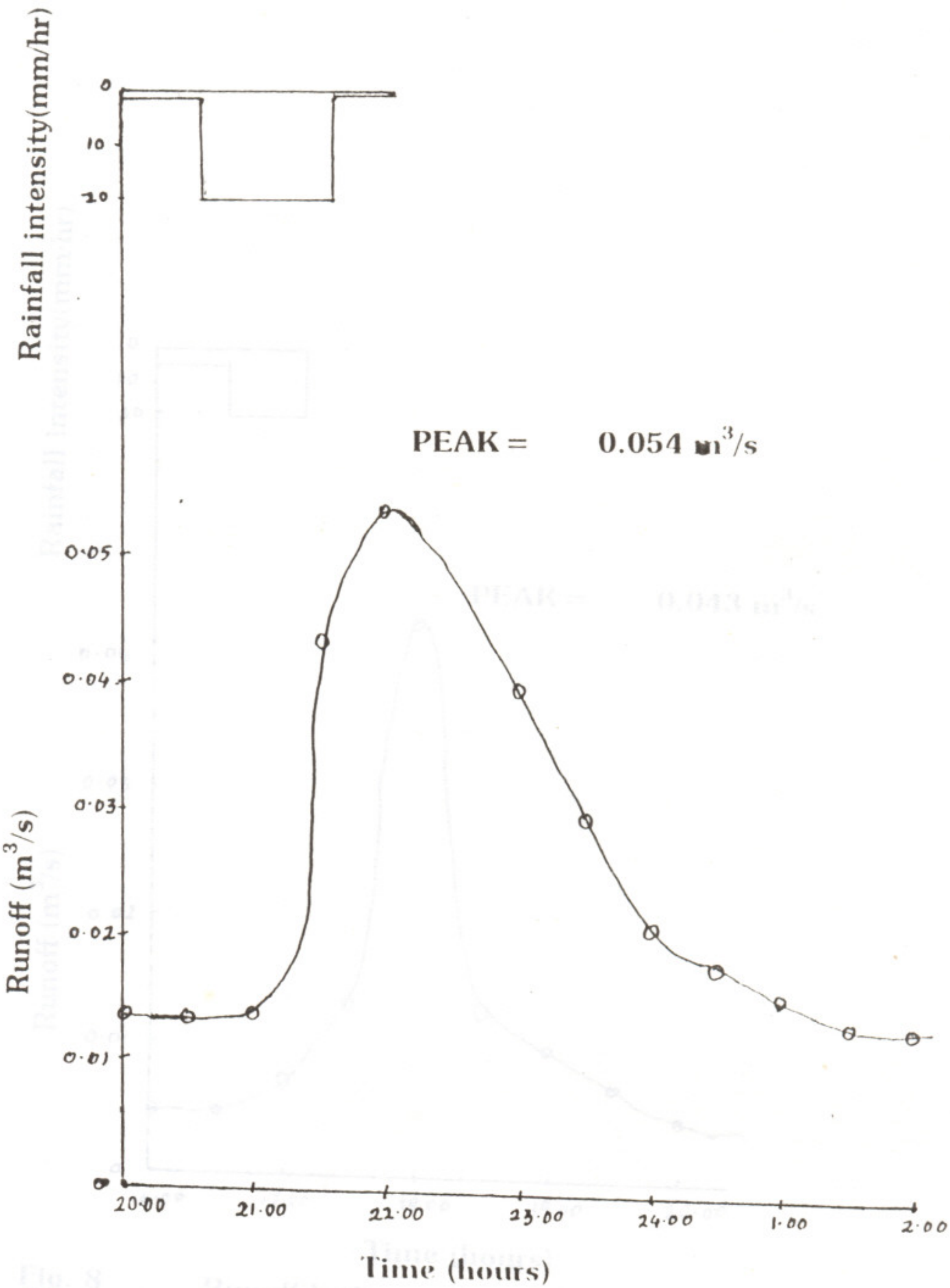

Fig. 7 Runoff hydrograph of tea watershed on 10-08-1985

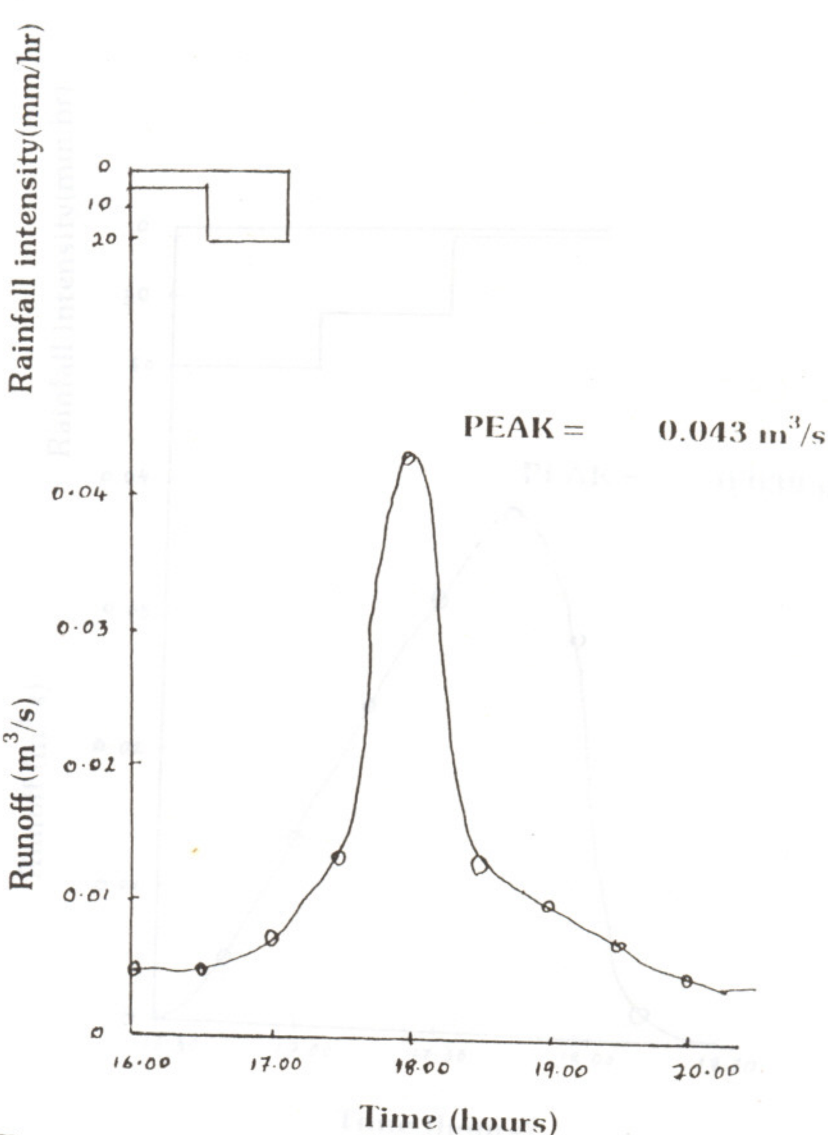

Fig. 8 **Runoff hydrograph of tea watershed on 04-11-1985**

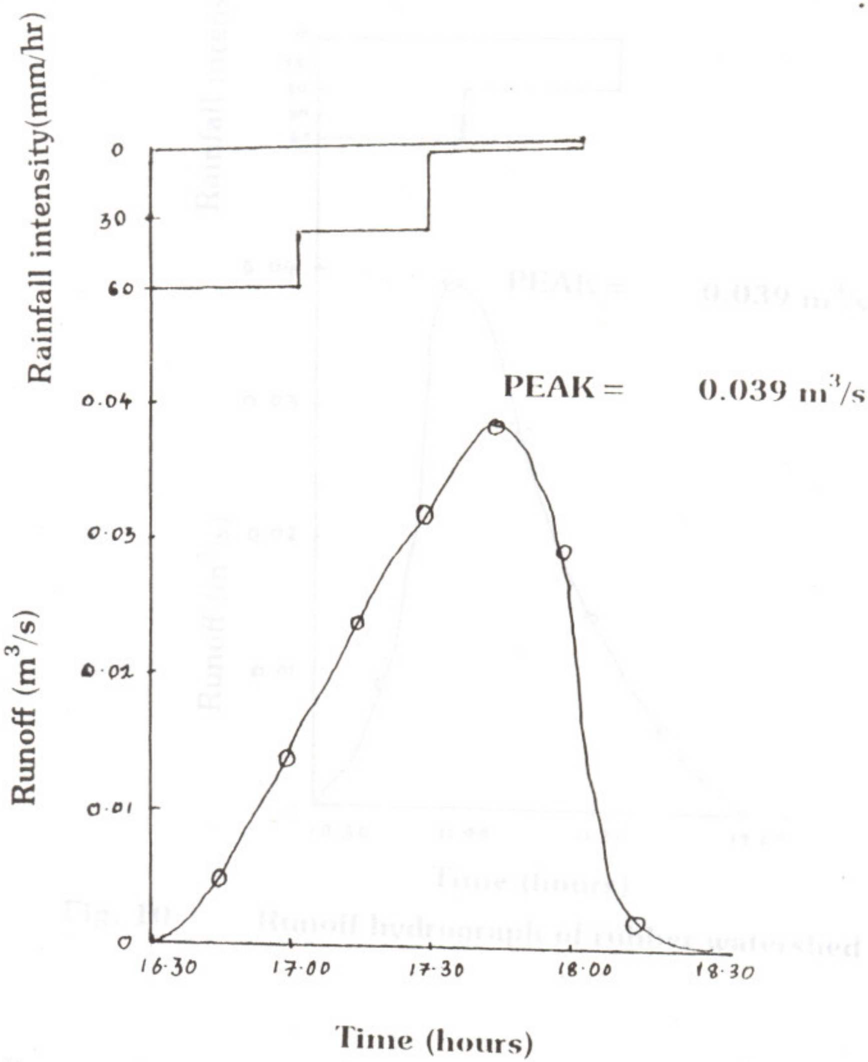

Fig. 9 Runoff hydrograph of rubber watershed on 21-09-1986

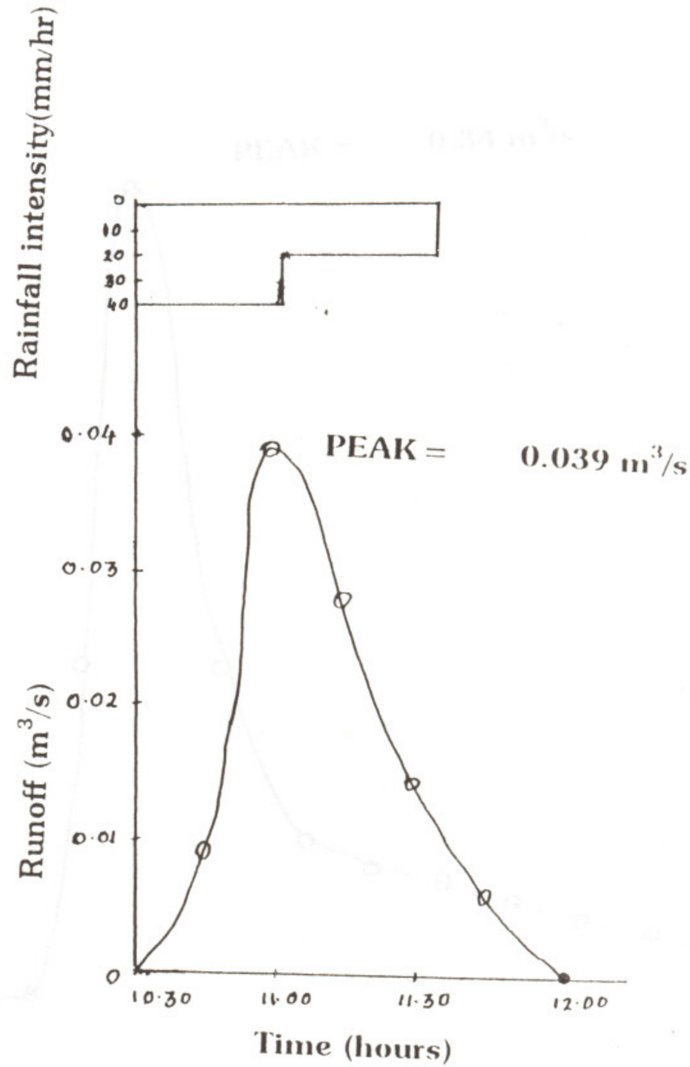

Fig. 10 Runoff hydrograph of rubber watershed on 20-08-1987

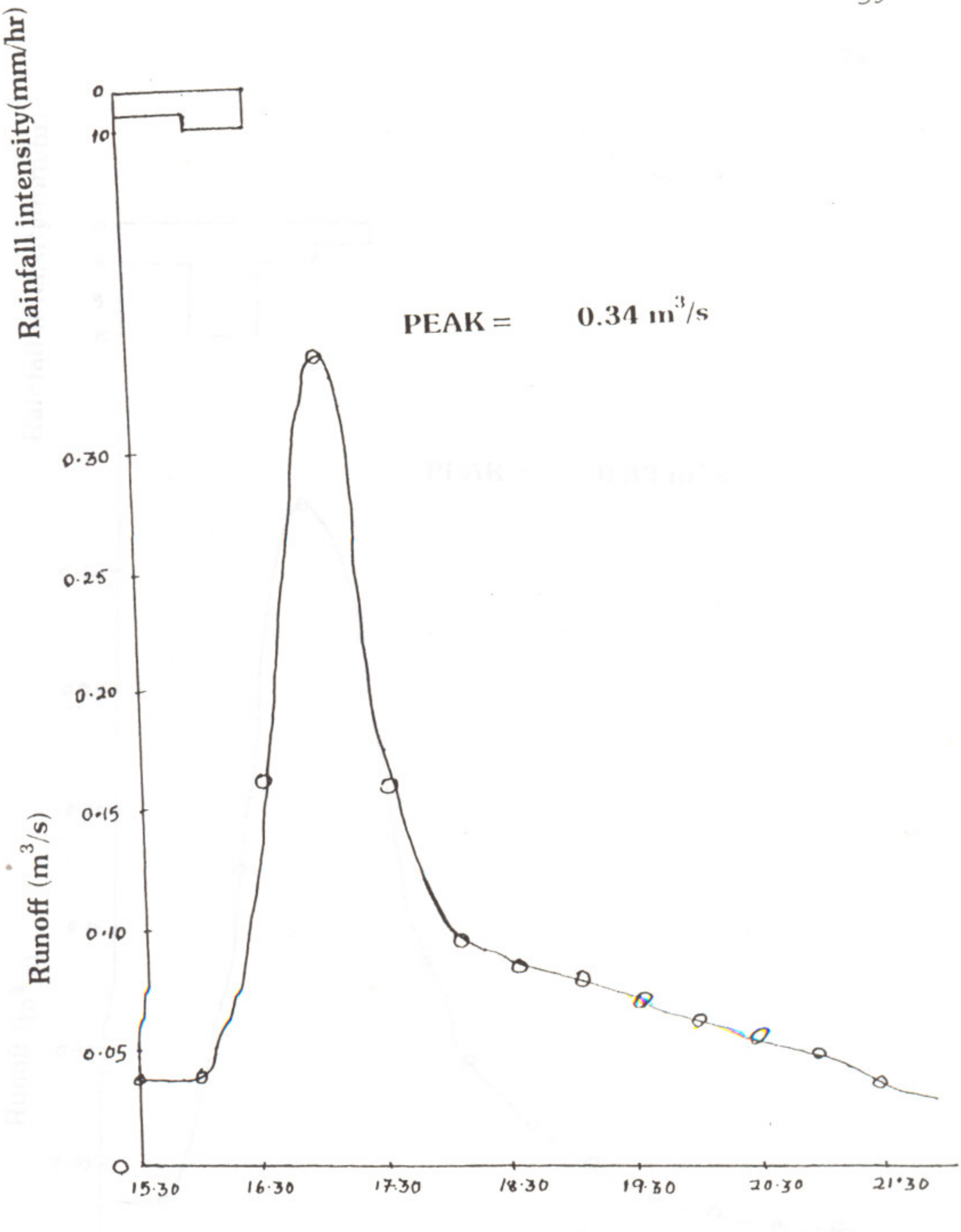

Fig. 11 Runoff hydrograph of coffee watershed on 19-06-1986

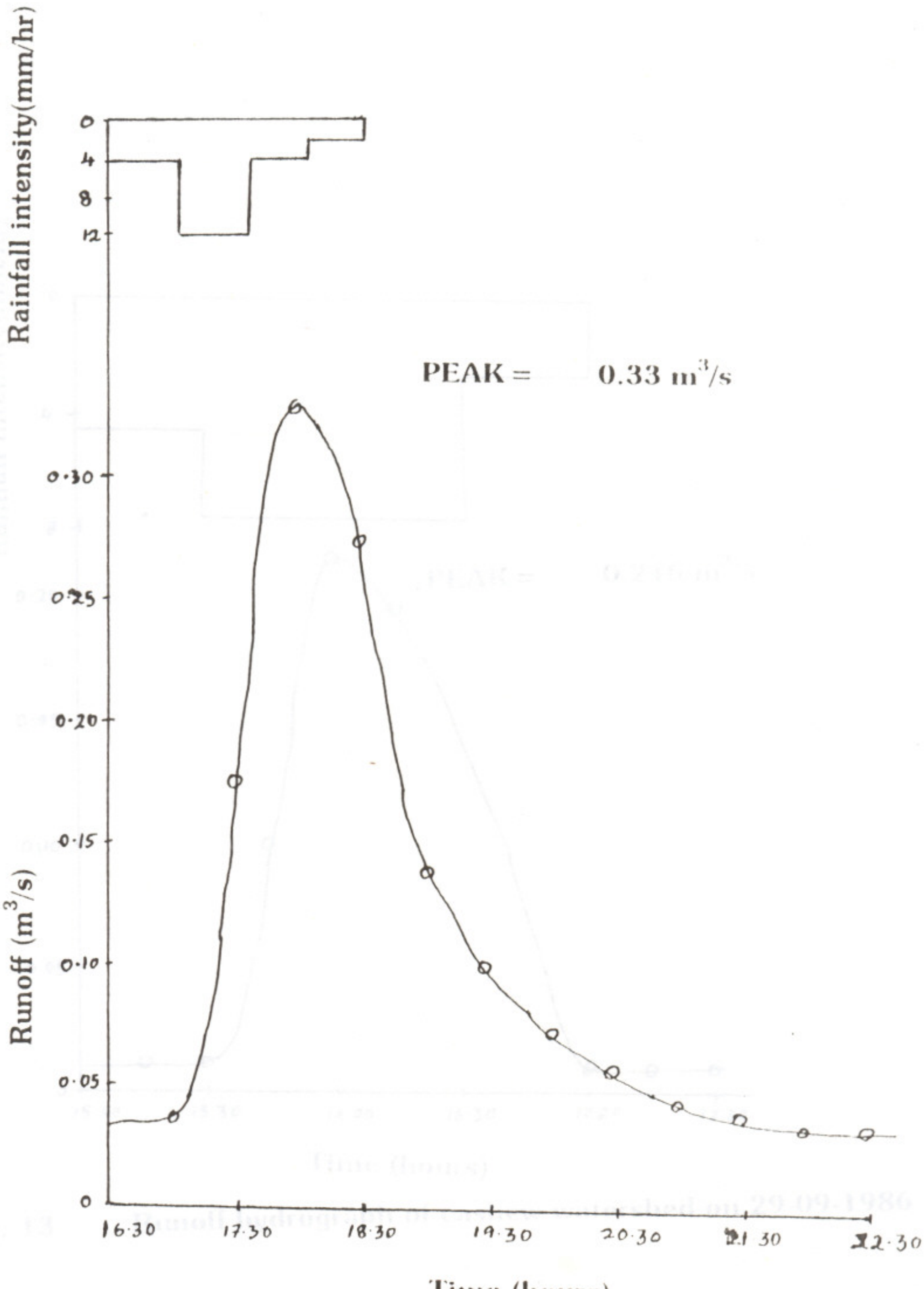

Fig. 12 Runoff hydrograph of coffee watershed on 5-11-1986

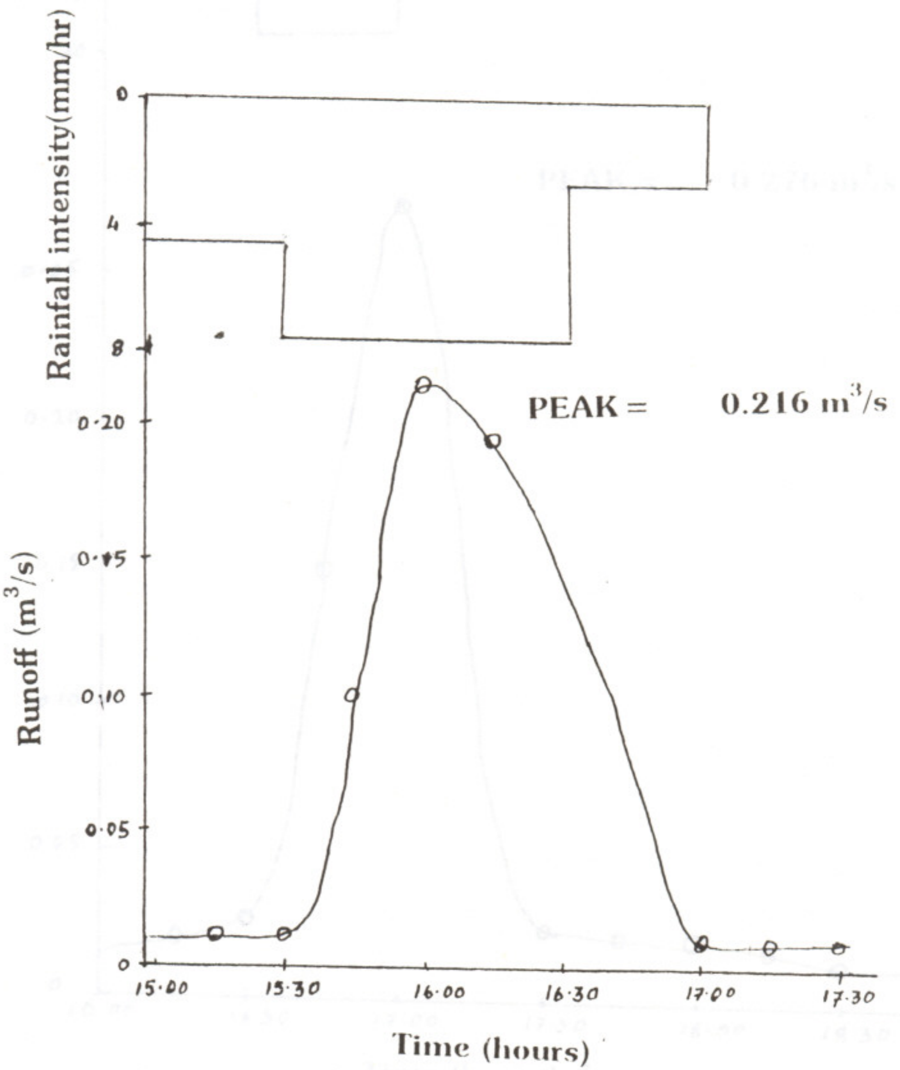

Fig. 13 Runoff hydrograph of cashew watershed on 29-09-1986

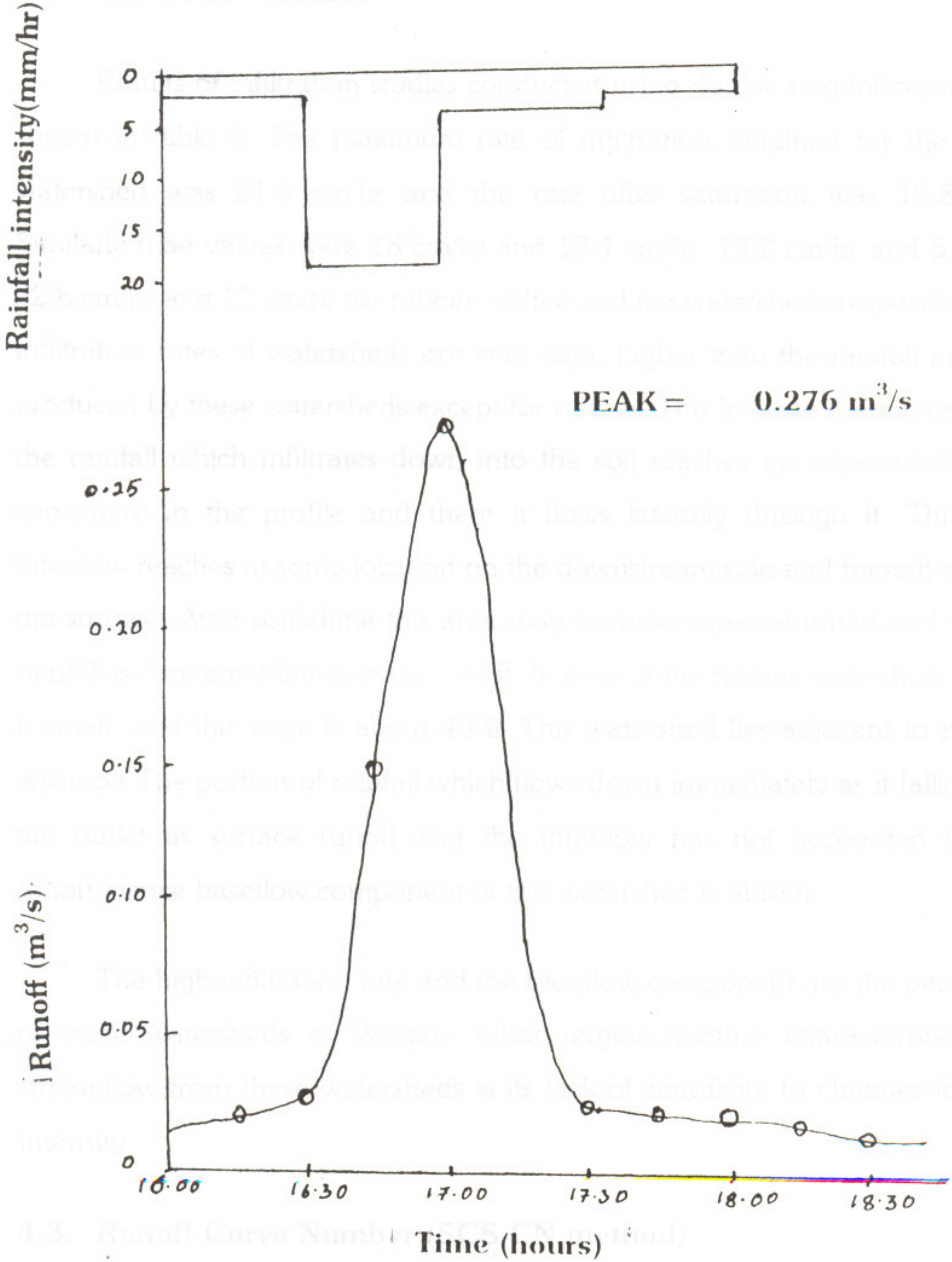

Fig. 14 Runoff hydrograph of cashew watershed on 7-11-1986

4.2. Infiltration studies

Results of infiltration studies conducted using double ring infiltrometer are shown in table 6. The maximum rate of infiltration obtained for the cashew watershed was 21.6 cm/hr and the rate after saturation was 12.8 cm/hr. Similarly thae values were 18 cm/hr and 12.4 cm/hr, 19.2 cm/hr and 5.6 cm/hr 22.8 cm/hr and 12 cm/hr for rubber, coffee and tea watersheds respectively. The infiltration rates of watersheds are very high, higher than the rainfall intensities produced by these watersheds except for rubber. This leads to the inference that the rainfall which infiltrates down into the soil reaches an impermeable layer somwhere in the profile and there it flows laterally through it .This lateral interflow reaches at some location on the downstream side and there it saturates the surfaces.After sometime this area may become supersaturated and the total rainfall is converted into surface runoff. In case of the rubber watershed the area is small and the slope is about 40% .This watershed lies adjacent to Kuttiyadi reservoir.The portion of rainfall which flows down immediately as it falls reaches the outlet as surface runoff and the interflow has not accounted for total runoff.Hence baseflow component of this watershed is absent.

The high infiltration rate and the baseflow component are the peculiarities of these watersheds of Western Ghat rergion.Another characteristic of the streamflow from these watersheds is its lack of sensitivity to changes in rainfall intensity.

4.3. Runoff Curve Number (SCS-CN method)

The details like name of watershed , serial number of storm, storm amount , predicted Curve Number, runoff estimated by CN method, runoff obtained by hydrograph method and the observed CN are given in Table respectively. Altogether 45 storm events have been selected.

The data set is presented in graphical form in fig. 15 to fig.18 and in condensed statistical form in Table 8 . As it can be seen from fig. 15 to fig. 18

Table 6 Infiltration rates of watersheds

Elapsed Time (minutes)	Average Infiltration Rate (cm/hr) for			
	Cashew	Rubber	Coffee	Tea
5	21.60	18.00	19.20	22.80
10	20.40	18.00	16.80	20.40
15	20.40	18.00	14.40	19.20
20	19.20	18.00	14.40	18.00
25	19.20	18.00	12.00	16.80
30	18.60	18.00	12.00	16.80
40	17.10	16.80	8.40	15.60
50	16.20	15.80	8.40	15.00
60	15.00	15.60	6.80	13.80
70	14.40	14.40	6.40	13.20
80	13.80	14.40	6.40	13.50
90	13.20	13.60	6.00	13.20
105	13.20	13.20	6.00	12.80
120	12.80	12.40	5.60	12.00

Table 7 Runoff values estimated using CN method and by Hydrograph analysis for the selected watersheds. (Assuming land use to be Forest)

1	2	3	4	5	6	7
Name. of Watershed	Sl. No.	Storm Amount (mm)	CN. Predicted value	Runoff by CN Method (mm)	Runoff by Hydrograph (mm)	CN. Observed value
Beenachi (Coffee)	1	43	43	1.87	1.56	64
	2	64	25	11.60	7.23	64
	3	26	43	5.76	0.10	69
	4	6	43	13.63	0.77	80
	5	19	43	8.07	1.42	60
	6	11	43	11.28	1.22	70
	7	8	43	12.66	1.94	70
	8	8	43	12.66	1.36	73
	9	23	43	6.70	0.73	60
	10	9	43	12.20	1.10	73
	11	13	43	10.42	1.65	65
Achoor (Tea)	12	45	43	1.59	1.79	64
	13	49	43	1.04	2.50	63
	14	23	43	6.69	0.15	65
	15	20.5	25	7.54	1.13	60
	16	35.5	43	3.30	1.58	70
	17	19	43	8.07	1.42	60
	18	16.5	43	9.04	1.49	62
	19	12.5	43	10.66	0.46	75
	20	16.5	43	9.04	2.48	58
Perambara (Cashew)	21	13	43	10.42	1.27	67
	22	119.5	43	7.04	19.21	53
	23	30	43	4.63	2.10	50
	24	23.5	43	6.53	3.65	49
	25	8.5	43	12.43	1.80	70
	26	9.5	43	11.96	0.98	73
	27	16.5	43	9.00	2.48	58
	28	11.5	43	11.06	1.42	68
	29	14	25	10.00	2.62	60
	30	18.5	43	8.25	2.84	55
	31	11	25	11.28	1.36	69
	32	52	25	15.24	8.98	73
	33	33	43	3.87	2.99	45
Perambara (Rubber)	34	16.5	43	9.00	0.83	83
	35	10	43	11.74	0.75	90
	36	58.5	25	13.20	5.22	64

1	2	3	4	5	6	7
	37	48	43	1.17	3.22	66
	38	51.5	25	15.39	4.55	67
	39	47	43	1.29	3.01	66
	40	37	43	2.98	2.63	72
	41	6.5	43	13.38	0.23	92
	42	14.5	43	9.80	0.70	85
	43	14	43	10.00	0.81	86
	44	61	25	12.46	6.92	63
	45	13	43	10.42	1.00	88

Table 8 REGRESSION STATISTICS (Assuming land use to be Forest)

	Achoor (Tea)	Beenachi (Coffee)	Perambara (Cashew)	Perambara (Rubber)
Title of X variable	CN pv	CN pv	CN pv	CN pv
Title of Y variable	CN ov	CN ov	CN ov	CN ov
Number of data points	9	11	13	12
Mean of X variable	41.00	41.36	38.85	38.50
Mean of Y variable	64.11	68.00	60.77	76.83
Coefficent of correlation	0.287	0.218	-0.383	0.644
Regression line intercept	53.576	57.889	79.185	42.136
Regression line slope	0.257	0.244	-0.474	0.901

there is only a faint suggestion of a trend and thus of any reasonable association between predicted and observed Curve Numbers.

From Table 8 (Cashew) the correlation was extremely poor and came to about -0.383. The slope of the regression line came to about -0.474 which reveals a bad correlation.

The result for rubber watershed was better when compared to the other watersheds , relatively high correlation coefficient of 0.644 has been observed.The regression line slope is 0.901which is nearly equal to unity.

For the coffee watershed a low correlation coefficient of 0.218 was obtained and a regression line of 0.244 was observed , which fails to reveal any sensible relationship between observed and estimated CN values.

Lastly, the tea watershed has a similar result as obtained for the coffee watershed. The correlation coefficient was 0.287 and the slope of the regression line being 0.257.

As the Curve Number values observed by assuming the watersheds as forested watersheds with initial abstraction equal to 20% of the maximum retention potential have shown significant variation from the predicted values analysis was repeated assuming the watersheds as Orchards without understory cover and initial abstraction equal to 30% of the maximum retention potential. The results are shown in Table 9.

When these watersheds were considered as having landuse similar to Orchards without understory cover comparatively good correlation was established for Coffee and Rubber watersheds and was found to be 0.79 and 0.70 respectively. The other two watersheds Tea and Cashew showed a bad correlation and was -0.12 and 0.10 respectively. The Curve Number suggested for the Coffee watershed is 40 and for Rubber watersheds is 44 for AMC-II condition.

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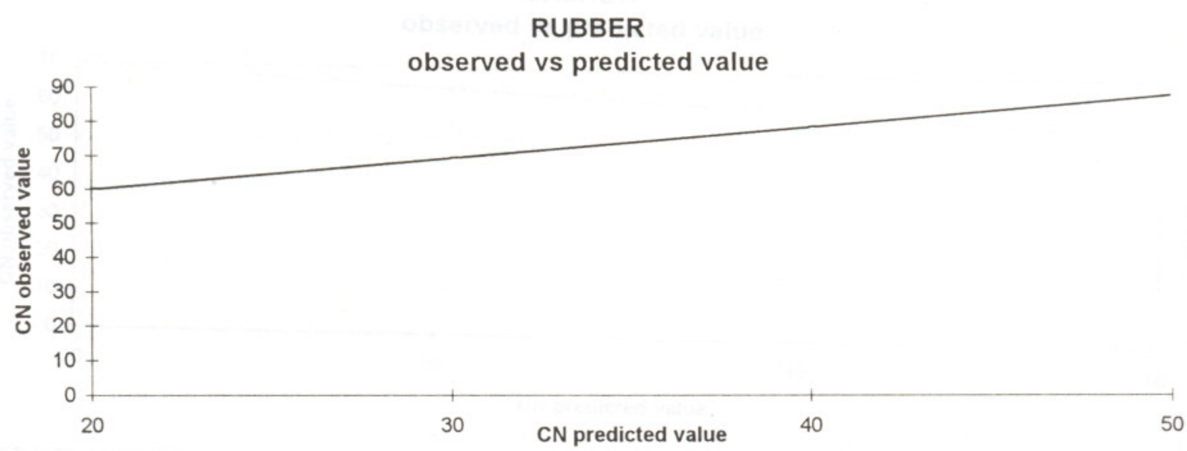

Fig. 15 Relations between observed and predicted Curve Number values for Rubber watershed (landuse forest)

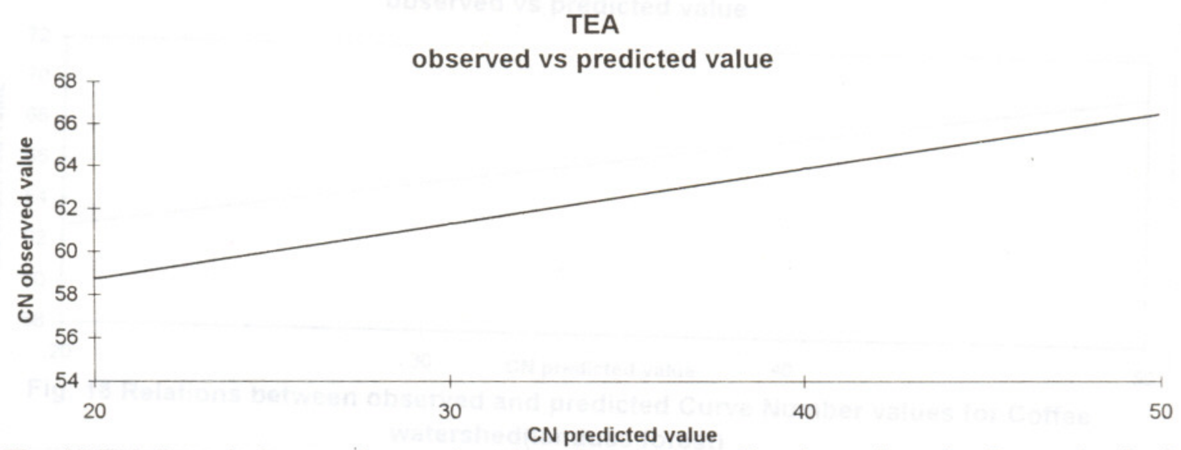

Fig. 16 Relations between observed and predicted Curve Number values for Tea watershed (landuse forest)

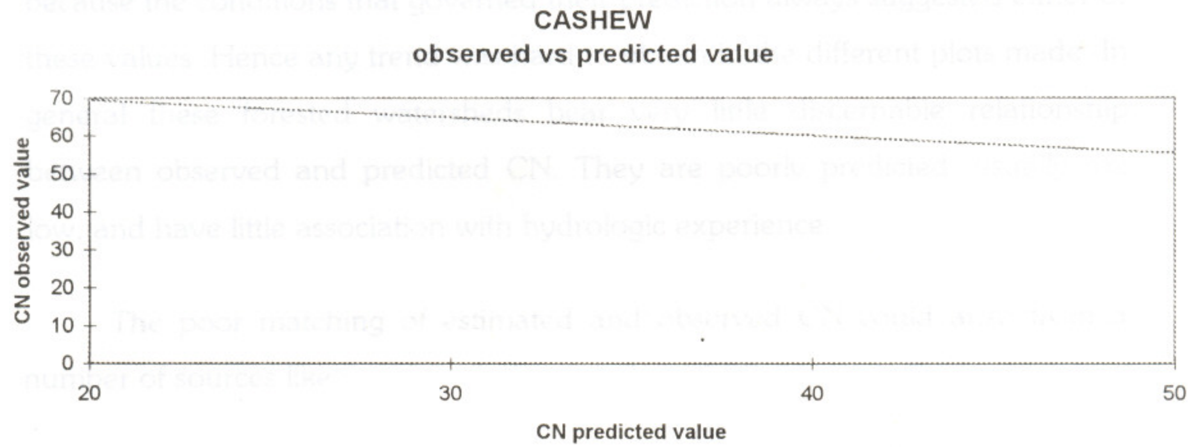

Fig. 17 Relations between observed and predicted Curve Number values for Cashew watershed (landuse forest)

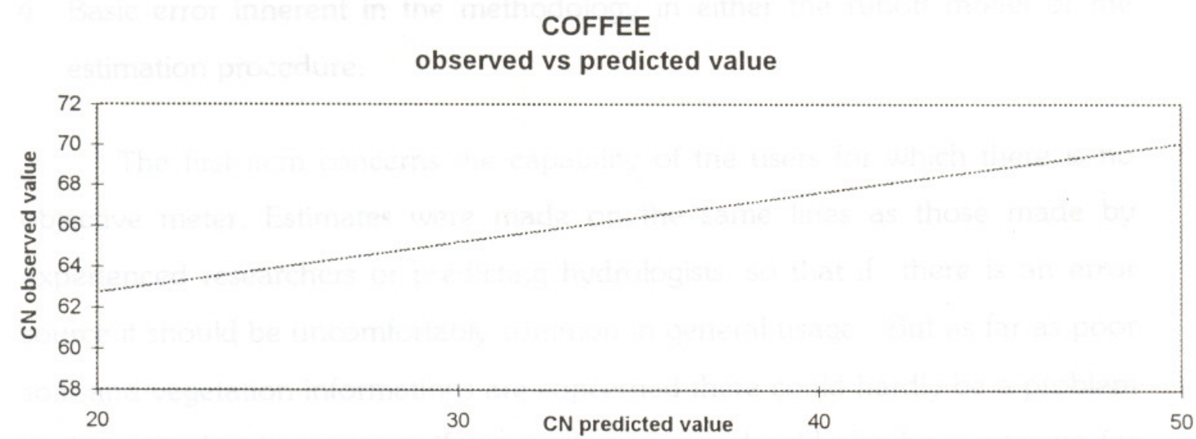

Fig. 18 Relations between observed and predicted Curve Number values for Coffee watershed(landuse forest)

Nevertheless a relationship between the observed and predicted CN for all the watersheds and each individual watershed has been obtained separately. One reason behind the bad correlation could be that the predicted CN turned out either to be 25 and 43 when considering all the watersheds as forested and 41 and 61 when considering them as Orchards without understory cover, because the conditions that governed their prediction always suggested either of these values .Hence any trend was hard to obtain in the different plots made. In general these forested watersheds bear very little discernable relationship between observed and predicted CN. They are poorly predicted, usually too low, and have little association with hydrologic experience.

The poor matching of estimated and observed CN could arise from a number of sources like :

1. Inability of the user to apply the estimation technique correctly.
2. Poor input of soil and vegetation data.
3. Incorrect hydrological analysis of field data to calculate CN.
4. Basic error inherent in the methodology in either the runoff model or the estimation procedure.

The first item concerns the capability of the users for which there is no objective meter. Estimates were made on the same lines as those made by experienced researchers or predicting hydrologists, so that if there is an error source it should be uncomfortably common in general usage . But as far as poor soils and vegetation informations are concerned there could hardly be a problem in data sets, but its presence if any in these cases should also be a warning for general new research settings. Thus, the first two error sources might be seen as omnipresent in most situations and thus a background hazard in CN method.

The right techniques of computing watershed CN by hydrological analysis are subject to some continued discussion.The recommended algorithm or procedure as given by Rallison and Cronshey and Hjelmfelt requires long records on stationary watersheds to build a stable series of annual floods and storm

Table 9 **Runoff values estimated using CN method and by Hydrograph analysis for the selected watersheds. (Assuming land use to be Orchards without understory cover)**

1	2	3	4	5	6	7
Name. of Watershed	Sl. No.	Storm Amount (mm)	CN. Predicted value	Runoff by CN Method (mm)	Runoff by Hydrograph (mm)	CN. Observed value
Beenachi (Coffee)	1	43	61	0.208	1.56	56
	2	64	41	6.51	7.23	40
	3	26	61	3.69	0.10	72
	4	6	61	15.24	0.77	87
	5	19	61	6.65	1.42	72
	6	11	61	11.41	1.22	80
	7	8	61	13.62	1.94	81
	8	8	61	13.62	1.36	83
	9	23	61	4.83	0.73	71
	10	9	61	12.85	1.10	82
	11	13	61	10.07	1.65	76
Achoor (Tea)	12	45	61	0.087	1.79	55
	13	49	61	4.92	2.50	51
	14	23	61	4.83	0.15	74
	15	20.5	41	28.76	1.13	71
	16	35.5	61	1.17	1.58	60
	17	19	61	6.65	1.42	72
	18	16.5	61	7.97	1.49	74
	19	12.5	61	10.39	0.46	81
	20	16.5	61	7.97	2.48	71
Perambara (Cashew)	21	13	61	10.07	1.27	78
	22	119.5	61	21.48	19.21	25
	23	30	61	2.43	2.10	62
	24	23.5	61	4.63	3.65	83
	25	8.5	61	13.23	1.80	81
	26	9.5	61	12.48	0.98	82
	27	16.5	61	7.97	2.48	71
	28	11.5	61	11.06	1.42	79
	29	14	41	33.90	2.62	73
	30	18.5	61	6.90	2.84	68
	31	11	41	36.47	1.36	79
	32	52	41	10.79	8.98	42
	33	33	61	1.68	2.99	58
Pera (Rubber)	34	16.5	61	7.97	0.83	76
	35	10	61	12.12	0.75	83
	36	58.5	41	8.32	5.22	44

1	2	3	4	5	6	7
	37	48	61	3.17	3.22	50
	38	51.5	41	11.00	4.55	47
	39	47	61	0.02	3.01	51
	40	37	61	0.92	2.63	57
	41	6.5	61	14.00	0.23	89
	42	14.5	61	9.13	0.70	78
	43	14	61	9.44	0.81	78
	44	61	41	7.47	6.92	41
	45	13	61	10.07	1.00	79

Table 10 REGRESSION STATISTICS

(Assuming land use to be Orchards without understory cover)

	Achoor (Tea)	Beenachi (Coffee)	Perambara (Cashew)	Perambara (Rubber)
Title of X variable	CN pv	CN pv	CN pv	CN pv
Title of Y variable	CN ov	CN ov	CN ov	CN ov
Number of data points	9	11	13	12
Mean of X variable	58.778	59.182	56.385	56.000
Mean of Y variable	67.667	72.727	67.769	64.417
Coefficent of correlation	-0.125	0.791	0.102	0.703
Regression line intercept	78.688	-33.8	56.398	-11.806
Regression line slope	-0.188	1.80	0.202	1.361

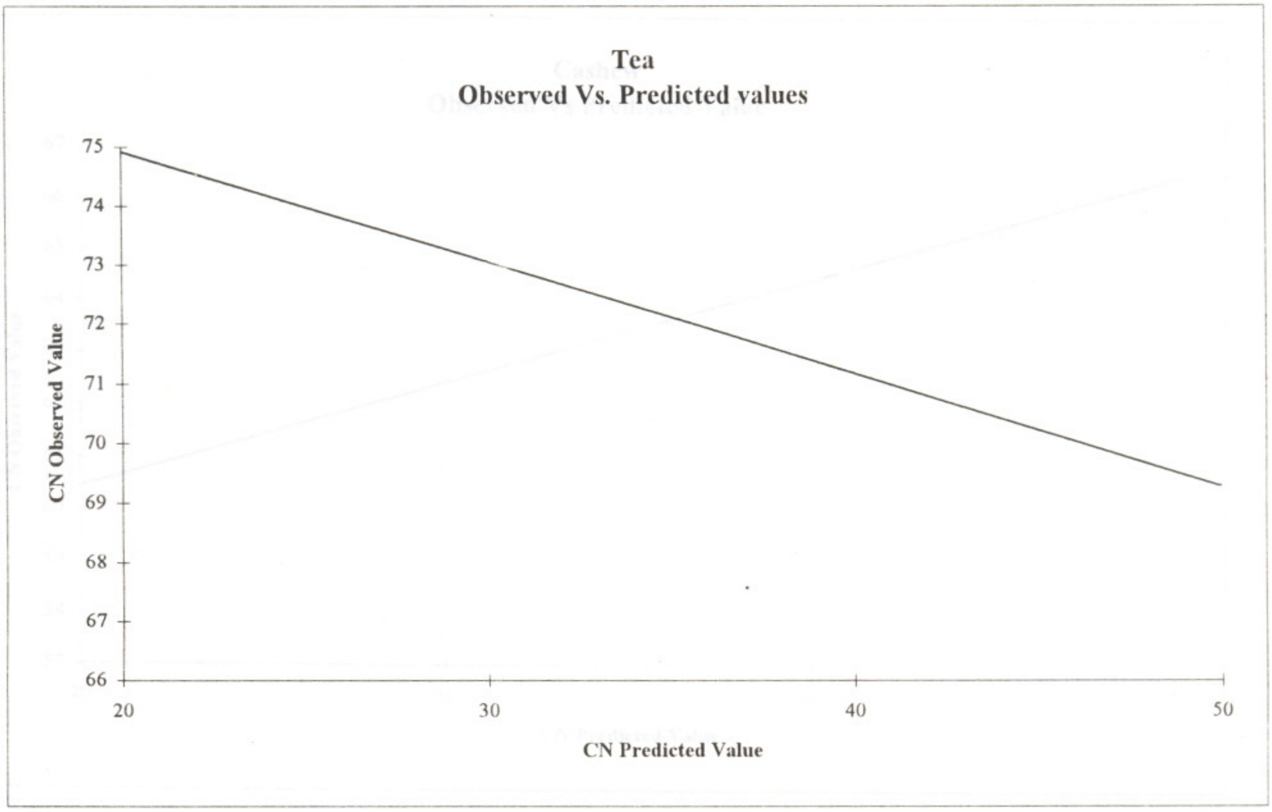

Fig. 19 Relations Between Observed and Predicted Curve Number Value for Tea Watershed (landuse orchard)

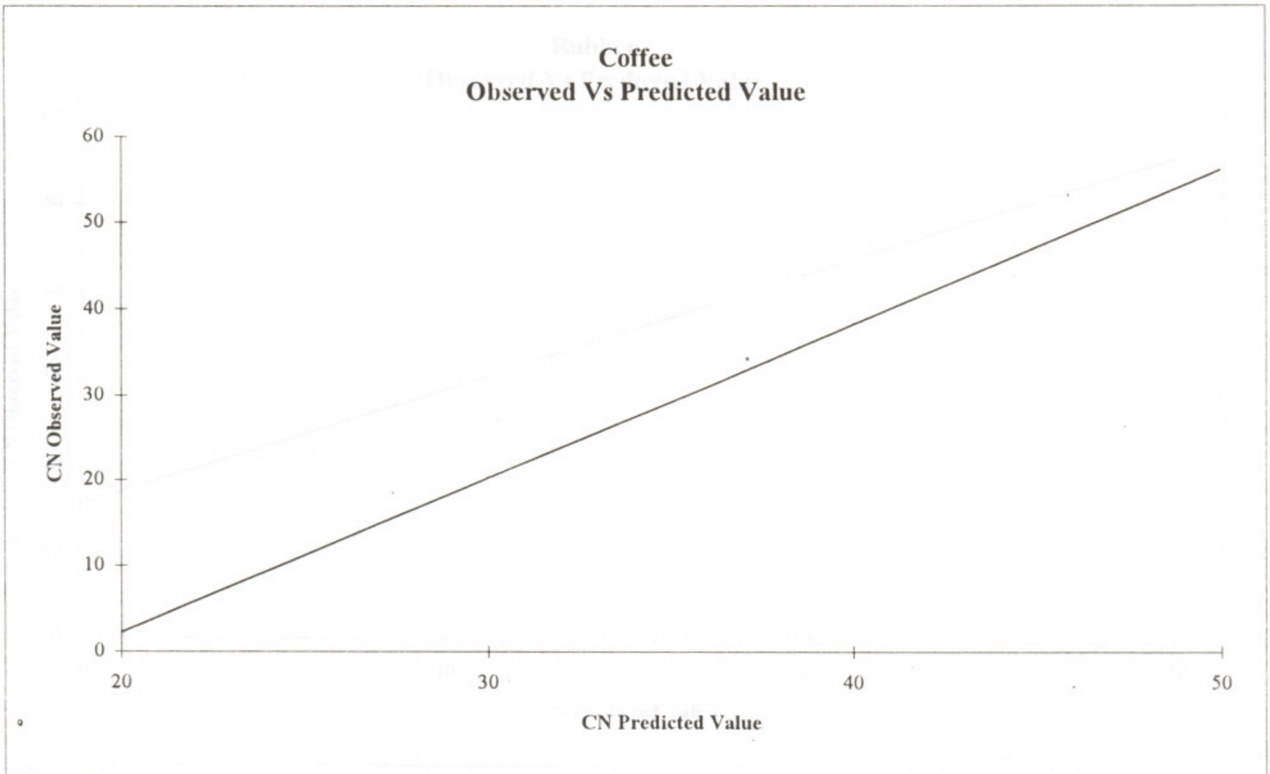

Fig. 20 Relations Between Observed and Predicted Curve Number Value for Coffee Watershed (landuse orchard)

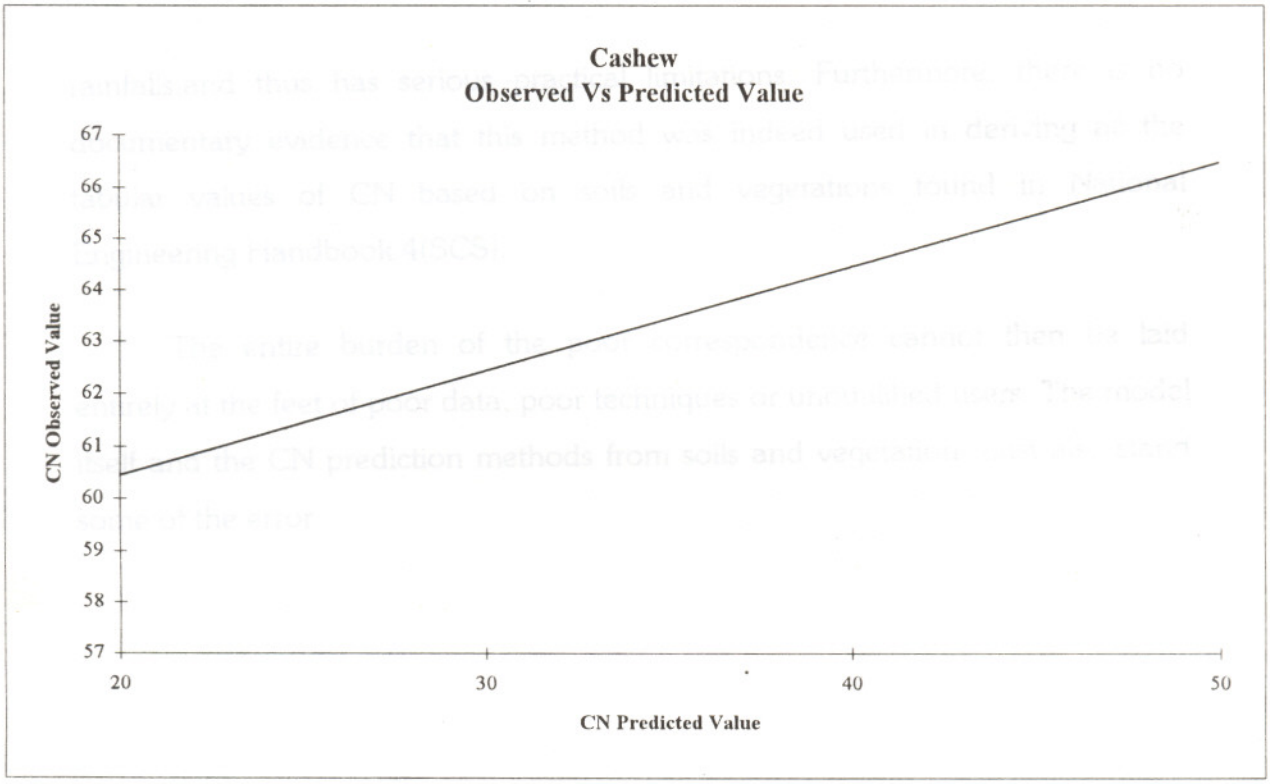

Fig. 21 Relations Between Observed and Predicted Curve Number Value for Cashew Watershed (landuse orchard)

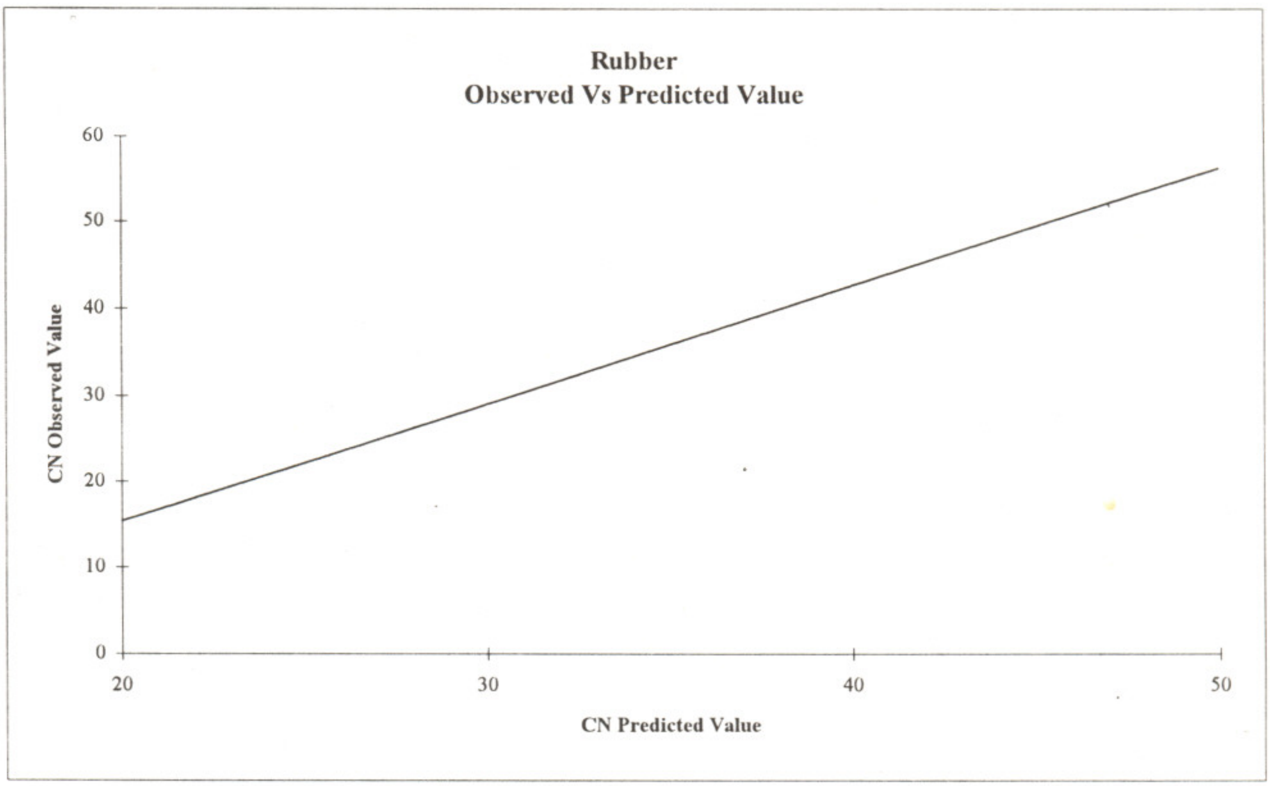

Fig. 22 Relations Between Observed and Predicted Curve Number Value for Rubber Watershed (landuse orchard)

rainfalls,and thus has serious practical limitations. Furthermore, there is no documentary evidence that this method was indeed used in deriving all the tabular values of CN based on soils and vegetations found in National Engineering Handbook.4(SCS).

The entire burden of the poor correspondence cannot then be laid entirely at the feet of poor data, poor techniques or unqualified users. The model itself and the CN prediction methods from soils and vegetation must also stand some of the error.

CONCLUSION

Analysis of the data from the selected watersheds considering them as forested watersheds indicate that the runoff estimate using CN selected for each wateshed show poor matching with the direct runoff obtined from hydrograph analyses. The curve numbers estimated for the four Western Ghat watersheds with land use pattern coming under the category of forest where almost entirely unrelated to observed reality. Considering them as Orchards only two watersheds Coffee and Rubber showed relatively good correlation. In general CN are underestimated are inconsistent. The findings suggest that routine application of the CN parameter may lead to variable, inconsistent, or invalid results. Further work might be dedicated to more precise and consistent estimation Curve Numbers from soil and vegetation data to refining estimates especially for forested watershed, and to developing credible methods of determing of Curve Numbers from soil and vegetation data to refined estimation procedure for small sloping watersheds.

From the analysis it was found that for watersheds planted with Coffe and Rubber coming under the hydrologic soil group A , the Curve Numbers of 40 and 44 can give a reasonably good estimate of direct runoff. This was for the AMC-II conditions with an initial abstraction of 30% of the maximum retention potential . Hence Curve Numbers suggested for Coffee and Rubber are 40 and 44 respectively for the above conditions. These Curve Numbers may be used for prediction of runoff from other similar watersheds. The variation may be due to the fact that the catchment properties like soil type, land use / treatment, suface and antecedent conditons are different from those used for deriving the Curve Numbers by USDA. Furthermore the method gives reliable results in case of large, flat watersheds. But in case of small sloping watersheds (the peculiarity of watershed of Kerala) this is not in good agreement as indicated by the results of this study.

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Appendix- I

Ordinates of storm hydrographs

Tea Watershed, Date 10-08-1985

Time (hours) (1)	Discharge (m^3/sec) (2)	Baseflow (m^3/sec) (3)	Direct runoff ordinate (m^3/sec) (4) (2)-(3)
16.00	0.0048	0.0048	0.00
16.30	0.0048	0.0048	0.00
17.00	0.0075	0.0048	0.0027
17.30	0.0136	0.0048	0.0088
18.00	0.0435	0.0048	0.0387
18.30	0.0136	0.0120	0.0016
19.00	0.0105	0.0105	0.00
19.30	0.0075	0.0075	0.00
20.00	0.0048	0.0048	0.00
			0.0518 m^3/sec

Direct runoff = 0.0518 m^3/sec

= 0.0518 x 30 x 60 m^3 = 93.24m^3

Area = 61.72 ha

Runoff depth = $\frac{93.24 \times 100}{61.72 \times 10000}$ cm = 0.150mm

Appendix

Tea Watershed, Date 04-11-1985

Time (hours) (1)	Discharge (m^3/sec) (2)	Baseflow (m^3/sec) (3)	Direct runoff ordinate (m^3/sec) (4) (2)-(3)
20.00	0.0136	0.0136	0.000
20.30	0.0136	0.0136	0.000
21.00	0.0136	0.0136	0.000
21.30	0.0435	0.0136	0.0299
22.00	0.0540	0.0136	0.0404
22.30	0.0435	0.0136	0.0299
23.00	0.040	0.0136	0.0264
23.30	0.030	0.0136	0.0164
24.00	0.021	0.0136	0.0074
00.30	0.018	0.0136	0.0044
1.00	0.0162	0.0136	0.0026
1.30	0.0136	0.0136	0.000
2.00	0.0136	0.0136	0.000
			0.1574 m^3/sec

Direct runoff = 0.1574 m^3/sec

= $0.1574 \times 30 \times 60\ m^3$ = 283.32m^3

Area = 61.72 ha

Runoff depth = $\frac{283.32 \times 100}{61.72 \times 10000}$ cm = 0.46mm

Appendix

Rubber Watershed, Date 20-08-1987

Time (hours) (1)	Discharge (m^3/sec) (2)	Baseflow (m^3/sec) (3)	Direct runoff ordinate (m^3/sec) (4) (2)-(3)
16.30	0.000	0.000	0.000
16.45	0.005	0.000	0.005
17.00	0.014	0.000	0.014
17.15	0.024	0.000	0.024
17.30	0.032	0.000	0.032
17.45	0.039	0.000	0.039
18.00	0.030	0.000	0.030
18.15	0.002	0.000	0.002
18.30	0.000	0.000	0.000
			0.146 m^3/sec

Direct runoff = 0.146 m^3/sec

= $0.146 \times 15 \times 60$ m^3 = 131.4 m^3

Area = 1.9 ha

Runoff depth = $\frac{131.4 \times 100}{1.9 \times 10000}$ cm = 6.92 mm

Appendix

Rubber Watershed, Date 21-09-1986

Time (hours) (1)	Discharge (m^3/sec) (2)	Baseflow (m^3/sec) (3)	Direct runoff ordinate (m^3/sec) (4) (2)-(3)
10.30	0.000	0.000	0.000
10.45	0.009	0.000	0.009
11.00	0.039	0.000	0.039
11.15	0.028	0.000	0.028
11.30	0.014	0.000	0.014
11.45	0.006	0.000	0.006
12.00	0.000	0.000	0.000
			0.096 m^3/sec

Direct runoff = 0.096 m^3/sec

= 0.096 x 15 x 60 m^3 = 86.4 m^3

Area = 1.9 ha

Runoff depth = $\frac{86.4 \times 100}{1.9 \times 10000}$ cm = 4.55 mm

Appendix

Coffee Watershed, Date 05-11-1986

Time (hours) (1)	Discharge (m^3/sec) (2)	Baseflow (m^3/sec) (3)	Direct runoff ordinate (m^3/sec) (4) (2)-(3)
15.30	0.0362	0.0362	0.000
16.00	0.0362	0.0362	0.000
16.30	0.1638	0.0362	0.1276
17.00	0.3429	0.0362	0.3067
17.30	0.1638	0.0950	0.069
18.00	0.0922	0.0875	0.0047
18.30	0.0832	0.0832	0.000
19.00	0.0794	0.0794	0.000
19.30	0.0711	0.0711	0.000
20.00	0.0619	0.0619	0.000
20.30	0.0579	0.0579	0.000
21.00	0.0502	0.0502	0.000
21.30	0.0362	0.0362	0.000
			0.508 m^3/sec

Direct runoff = 0.508 m^3/sec

= $0.508 \times 30 \times 60\ m^3$ = 914.4 m^3

Area = 74.87 ha

Runoff depth = $\frac{914.4 \times 100}{74.87 \times 10000}$ cm = 1.22 mm

Appendix

Coffee Watershed, Date 19-06-1986

Time (hours) (1)	Discharge (m^3/sec) (2)	Baseflow (m^3/sec) (3)	Direct runoff ordinate (m^3/sec) (4) (2)-(3)
16.30	0.036	0.036	0.000
17.00	0.036	0.036	0.000
17.30	0.1752	0.036	0.1392
18.00	0.3287	0.036	0.2927
18.30	0.274	0.0625	0.2115
19.00	0.01419	0.060	0.0819
19.30	0.1016	0.055	0.0466
20.00	0.0744	0.050	0.0244
20.30	0.0589	0.0475	0.0114
21.00	0.0465	0.0465	0.000
21.30	0.0429	0.429	0.000
22.00	0.0390	0.0390	0.000
22.30	0.0360	0.0360	0.000
			0.8077 m^3/sec

Direct runoff = 0.8077 m^3/sec

= 0.8077 x 30 x 60 m^3 = 1453.86 m^3

Area = 74.87 ha

Runoff depth = $\frac{1453.86 \times 100}{74.87 \times 10000}$ cm = 1.94 mm

Appendix

Cashew Watershed, Date 29-09-1986

Time (hours) (1)	Discharge (m^3/sec) (2)	Baseflow (m^3/sec) (3)	Direct runoff ordinate (m^3/sec) (4) (2)-(3)
15.00	0.009	0.009	0.000
15.15	0.009	0.009	0.000
15.30	0.009	0.009	0.000
15.45	0.100	0.009	0.091
16.00	0.216	0.009	0.207
16.15	0.193	0.009	0.184
16.30	0.145	0.009	0.136
16.45	0.075	0.009	0.066
17.00	0.009	0.009	0.000
17.15	0.009	0.009	0.000
17.30	0.009	0.009	0.000
			0.684 m^3/sec

Direct runoff = 0.684 m^3/sec

= 0.684 x 15 x 60 m^3 = 615.6 m^3

Area = 29.5 ha

Runoff depth = $\frac{615.6 \times 100}{29.5 \times 10000}$ cm = 2.10 mm

Appendix

Cashew Watershed, Date 07-11-1986

Time (hours) (1)	Discharge (m^3/sec) (2)	Baseflow (m^3/sec) (3)	Direct runoff ordinate (m^3/sec) (4) (2)-(3)
16.00	0.0165	0.0165	0.000
16.15	0.020	0.020	0.000
16.30	0.026	0.026	0.000
16.45	0.150	0.026	0.124
17.00	0.276	0.033	0.243
17.15	0.125	0.028	0.097
17.30	0.026	0.026	0.000
17.45	0.026	0.026	0.000
18.00	0.026	0.026	0.000
18.15	0.020	0.020	0.000
18.30	0.0165	0.0165	0.000
			0.464 m^3/sec

Direct runoff = 0.464 m^3/sec

= $0.464 \times 15 \times 60$ m^3 = 417.6 m^3

Area = 29.5 ha

Runoff depth = $\frac{417.6 \times 100}{29.5 \times 10000}$ cm = 1.42 mm

FEASIBILITY OF SCS-CURVE NUMBER METHOD OF RUNOFF ESTIMATION FOR SMALL SLOPING WATERSHEDS OF WESTERN GHATS

By

Minil Kumar K.X.
Narayan Nair
Rajesh Kutty

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree.

BACHELOR OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING

Faculty of Agricultural Engineering and Technology
KERALA AGRICULTURAL UNIVERSITY

Department of Irrigation and Drainage Engineering.
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
Tavanur-679 573
MALAPPURAM- KERALA

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ABSTRACT

The runoff curve number method for the estimation of direct runoff from storm rainfall is well established in hydrology engineering and environmental impact analyses. Its popularity is rooted in its convenience, simplicity, authoritative origins and responsiveness to soil type, land use and surface conditions. In order to ascertain the feasibility of the method for small sloping watersheds of Western Ghats of Kerala four small watersheds planted with Cashew, Rubber, Coffee and Tea were selected for the study. The rainfall and runoff data for different storm events were estimated and used for the analysis. When used for design or environmental impact purpose on ungaged basins, the method draws on the selection of a curve number (CN) from published tables, charts or graphs, based on site conditons. The calculation was found to be sensitive to this choice, which required professional judgement of the user. However as storm rainfall and runoff data were available, observed curve numbers were calculated by accepted procedures and a consensus value established for the watersheds. The study presents the results of the analyses for testing the feasibility of the SCS method of runoff estimation from small sloping watersheds of Western Ghats. From the rainfall and runoff data observed Curve Numbers were assessed. The summarised results of the study for which both Predicted and Observed Curve Numbers are available highlights the most error prone prediction situations. A regression equation was established between the Predicted and Observed Curve Numbers for these watersheds. In general there is a discouraging lack of correspondence between the handbook Predicted and hydrologic data Observed Curve Numbers of the four selected small watersheds of Western Ghats of Kerala.