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QUANTIFICATION OF SOIL AND WATER LOSS FROM TEAK AND EUCALYPT PLANTATIONS

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ABSTRACT

Soil and water loss through surface run-off from a three year old teak **(Tectona grandis)** plantation at Nilambur and a two year old eucalypt **(Eucalyptus tereticornis)** plantation at Thrissur have been quantified through a 3 year study. Both the sites have humid tropical climate with intense and high energy bimodal monsoonal rains. Loss of water through run-off depended mainly on amount of rainfall and its distribution. Run-off water loss from the teak plantation on lateritic soil with 8-12% slope was found to be 25- 26%of the rainfall. It was estimated to vary from 5220 to 8310 m^3/ha The corresponding loss of soil was 4-15 metric tons per hectare. Loss of nitrogen varied from 5-17 kg/ha while that of potassium, 0.4-2.3 kg per hectare. The eucalypts plantation on lateritic soil with 15-20% slope was found to lose 19-20% rain water through surface run-off; 4460-5675 m^3/ha water ran off the site which carried 31-46 metric tons of soil along with it. Nitrogen loss through sediment was found to be 30-52 kg per hectare and potassium loss 8-10 kg/ha during the study period.

Key words: Soil loss, run-off, teak. eucalypt.

1. INTRODUCTION

Water, one of the most important natural resources, is indispensable to life on earth. The hydrologic cycle makes water available to land, plant and animals alike. Evaporation from the land surface and transpiration by plants convert water to water vapour leading to formation of clouds which on cooling pours down as rain. The rain drops while speeding down attain great energies. These raindrops splash the surface soil particles and the effect is worse on barren soil. When precipitation exceeds infiltration, water flows down the slopes carrying the splashed soil particles along with. Channelization follows this 'sheet erosion' creating 'rills'or microchannels and if left uncontrolled may lead to the formation of bigger channels called 'gullies'. Soil erosion by water denudes the upland of its rich top soil, pollutes the fresh water streams and rivers and sediments the reservoirs, ponds, ports and navigation channels.

An understanding of the processes involved in soil erosion and finding out ways to combat them are very important for conserving soil and water. First and foremost step in this direction is the quantification of soil and water that runs off from the land. The present study was taken up with this objective, ie.. to quantify the loss of soil and water from teak (*Tectona grandis*) and eucalyptus (*Eucalyptus tereticornis*). the two most important species in plantation forestry.

2. REVIEW OF LITERATURE

2.1. HISTORICAL BACKGROUND

It was Wollny who began rainfall erosion research in Germany in the latter half of the nineteenth century. Plots to study the effect of soil, slope and cover on run-off were established in the United States by Professor M.F. Miller in 1917. Similar studies were also undertaken by H.H. Bennet and L.A. Jones of United States Department of Agriculture between 1929 and 1933. Fundamental studies like mechanics of rainfall erosion, raindrop characteristics, erosivity of flowing water, soil erodibility, effect of slope and influence of vegetation were also conducted by Miller (1936), Little (1940). Lutz and Hargrove (1944), Mihara (1952). Baver (1956), Wischmeier *et al.* (1958), Wischmeier (1959), Hudson (1961a, b), Wischmeier and Smith (1965), Spomer *et a1.* (1973) and others.

In India the Central Soil and Water Conservation Research and Training Centre at Dehra Dun with its 8 regional centres spread over the country made several notable field observations on soil erosion and soil and water conservation in different parts of the country (Tejwani, *et al*, 1975). Some of them are Basu (1952), Basu and Puranik (1952), Chinnamani *et al.* (1955), Agarwal and Rege (1960). Dabral *et al.* (1963), Chinnamani and Gupta (1965), Chinnamani *et al.* (1969). Das *et al.* (1970), Raghunath *et al* . (1970), Wasi Ullah et al., (l970), Wasi Ullah and Ram Babu (1970), Erasmus *et al.* (1971), Raghunath and Erasmus (1971), Wasi Ullah *et al.* (1972), Sahi *et al.* (1976) and Samraj *et al.* (1977).

2.2. FACTORS INFLUENCING SOIL EROSION

Many factors influence the type and magnitude of soil erosion in a region. Rainfall characteristics, land and soil features, type of vegetation and its management are the main factors (Smith and Wischmeier, 1957).

2.2.1. Rainfall characteristics

Run-off and erosion from a badly eroded area were highly correlated with the magnitude of rainfall (Mookerjea, 1950). The energy of raindrops rather than the intensity was more important in causing soil erosion on a loam, silt loam and sandy loam. It was found that reducing the raindrop impact energy by 89% without reducing the rainfall intensity decreased soil loss by over 90 per cent. Most of the soil lost (80-85%) from between the rills passed along a rill before leaving the plot (Young and Wiersma, 1973). Lal (1976a) found that the correlation coefficients of per cent run-off from individual rainstorms with various indices such as kinetic energy (E), EI 30, KE > 1, rainfall amount (A), maximum intensity (Im) and AIm were generally low. The correlation coefficients of all these indices with soil loss per storm were high and did not differ significantly from one another. The kinetic energy of tropical rainstorms may be significantly influenced by other factors such as wind velocity, drop size distribution and high rainfall intensity. The index AIm has the advantage of simplicity of computation and it incorporates one of the most important factors, peak intensity (Im).

2.2.2. Land features

Length and steepness of slope influences soil erosion to a great extent (Culling, 1965; Battawar and Rao, 1971). Soil loss increased with plot length from 11 m to 67 m on 9% slope while on 5% slope loss decreased from 11 m to 67 m length (Gard and Van-Doren, 1950). Soil loss is directly proportional to the run-off velocity. Thus a slight increase in gradient results in increased erosion (Suarez De Castro, 1951). Studies in Japan revealed that soil erosion occurred mainly on slopes of more than 10% and on concave'rather than convex slopes (Suyama *et al.* 1973).

2.2.3. Soil properties

Finer soil particles are carried away over long distances as suspended sediment in running water. Laflen *et al.* (1972) reported that most of the soil lost by wafer erosion consisted of particles and aggregates with diameters less than 0.016 mm. The study of Mookerjea (1950) showed that the percentage of clay particles <0.002 mm in diameter in the eroded soil tended to decrease while the percentage of sand particles >0.6mm tended to increase with increasing intensity of rainfall.

Properties making a soil resist erosion included a high organic matter content and the presence of large quantities of >0.25 mm aggregates. The heavier the soil, the smaller were the dispersion ratio and erosion ratio (Tyan and Hwang, 1964). Studies on erodibility of soils in south western Jawa by Schmidt *et al.* (1964) showed that organic carbon decreased significantly in surface soil with increasing slope in both virgin and cultivated lands.

Density, cation exchange capacity and soluble potassium increased with the degree of erosion while soluble phosphorus and nitrogen and humus contents decreased. In Chernozems and podzolized dark gray and gray soils erosion is accompanied by a change in the composition of organic phosphorus. The amount of fulvic acid P decreases in some soils and remains unchanged in others. The amount of P in humic acid remains virtually unchanged.

2.3. SOIL LOSS

The type of erosion decides to a certain extent the quantity of soil lost. Olson (1949) concluded that with slight sheet erosion, 25% top soil gets lost, and with moderate erosion, 25-75% of top soil may be carried away. In the case of severe erosion, more than 75 percent of top soil gets lost. On slopes of length 10 m, annual loss of soil were 327 and 199 tons/ha for gradients of 43% and 21% respectively(Suarez De Castro, 1951). Clean cultivated land of moderate slope in Columbia lost about 200 tons/ha annually. Corresponding loss of soil under a dense crop varied from 1-20 tons/ha depending upon the cultural practices and the age of the plantation while ungrazed grassland lost only 2 tons/ha. Total annual loss of soil in Columbia was estimated at 426 million tons, of which clean cultivation is responsible for as much as 80% even though only 2% of the agricultural land is subject to this treatment (Suarez De Castro, 1952). On a red sandy loam soil in Central Tanganyka with 6.6% slope, the average run-off due to storms for eight seasons decreased from 19.31% on plots cultivated with Sorghum to 15.52% when the top half was cultivated and grass was allowed to cover the lower half. The run-off losses further got reduced to 4.94% under full grass. Perennial grasses used were *Cynodon plectostachyum* and *Cenchrus ciliaris.* On cultivated plots, more than 30 cm of soil were eroded on the top and middle slopes and deposited at the bottom (Van Rensburg, 1955). Gopinath (1986) reported a soil loss of 353 t/ha/yr from cultivated fallow in Kerala.

2.4. NUTRIENT LOSS

Selectiveness of the erosive process in removing nutrients was found to increase in the order organic matter, ammoniacal nitrogen, available phosphorus and exchangeable potassium. The change in the group composition of phosphates and some forms of potassium in soil subjected to water erosion depends on the properties of the underlying genetic horizons. The total annual loss of nutrient elements in run-off were 55 kg/ha for bare fallow, 17 kg/ha for maize-maize (plowed), 12 kg/ha for cow pea-maize (plowed), 2.3 kg/ha for maize-maize (plowed and mulched) and 4.3 kg/ha for maize-cow peas (no till). Plowed treatments lost lot of O.M and total N (Lal, 1976b).

2.5. SOIL CONSERVATION

Reducing the steepness of slope as well as providing cover to the land helps in reducing soil erosion. On a moderately eroded silt loam soil with 11% slope and planted with wheat, run-off was reduced by 24 and 50% by 1 and 2 tons straw /ha. Soil losses were 35,8.8 and 4.1 tons/ha/year with 0.1 and 2 tons straw/ha respectively (Pena Mac-Caskill, 1978). Losses from a slope of 20 m length were reduced from 259 to 199 and 117 tons/ha by dividing the length into two and four parts respectively by means of ditches (Suarez De Castro, 1951). Terracing reduced N losses by about ten times as compared to contour cultivation and also reduced the run-off and sediment yield. With contour cultivation, 92% of the N loss was associated with the sediment. Schuman *et al.*, (1973) found that terracing could reduce soil erosion from 63.5 metric tons/hectare/year to 2.5 metric ton/hectare/year and surface run-off by 95 per cent. Under a tropical monsoon climate, the establishment of vegetation on seriously eroded slopes over a period of 10 years has resulted in a decrease in the annual amount of soil eroded by water from 15,000 to 2945-4400 m^3/km^2 (Xiaoling Experimental and Extension Station of Soil Conservation, 1977). Different conservation practices suitable for managing soil erosion in forest plantations of Kerala were reviewed by Alexander and Thomas (1982).

3. MATERIALS AND METHODS

3.1. EXPERIMENTAL AREA

3.1.1. Teak Plantation

The teak plantation selected for the study was a replanted area, at Nilambur and situated in the KFRI subcentre campus. Teak was planted in 1991 at a spacing of 2 x 2 m. The area is undulating with slight slope of 8-12% and with all aspects.

Ground cover

The ground is covered by several species of shrubs, herbs, grasses and climbers. The teak saplings alongwith the ground flora and its litter almost covered the ground fully and offered good protection to the soil from the beating action of raindrops and the velocity of flowing water.

The Soil

The soil is a ferralsol developed from granitic gneiss type parent material. The surface itself contains much lateritic gravel indicating that the site has suffered over exploitation and consequent degradation in the distant past. The soil properties are shown in tables 1 and 2. The soil is yellowish red,

Table 1. Soil Physical Properties in Nilambur Teak Plantation

Depth (cm)	Colour	Gravel	Sand	Silt	Clay	BD	PD	Porosity (%)
		g/kg				gcm^{-3}		
00-20	5YR4/3 Reddish brown	300 (140)	572 (134)	76 (22)	52 (18)	1.25 (0.03)	2.38 (0.04)	47.5 (5.8)
20-40	5YR5/6 Yellowish red	284 (130)	564 (146)	78 (20)	74 (24)	1.35 (0.05)	2.42 (0.03)	44.0 (4.4)
40-60	5YR5/8 Yellowish red	268 (153)	550 (167)	75 (19)	87 (21)	1.50 (0.05)	2.40 (0.04)	37.5 (3.7)

Plates 1 & 2. Run-off plots in a 3 yr old Teak plantation slightly darker in the surface, acidic in reaction and poor in primary nutrients. The surface soil has 14g/kg organic carbon and is endowed with loose (bulk density 1.25 gcm^{-3}) granular structure. This structure is the product of organic matter and plant roots mainly because there is not much finer soil separates to impart necessary binding. The properties show that the soil can promote infiltration and resist splashing by raindrops to some extent; it is not easily erodable.

Table 2. Soil Chemical Properties in Nilambur Teak Plantation

Depth (cm)	p^H	OC g/kg	EA	EB	N	P	K
			me/kg		mg/kg		
00-20	5.2 (0.3)	14.0 (4.50)	70 (17)	76.5 (28)	247 (53)	4.5 (0.5)	196 (47)
20-40	5.3 (0.2)	10.0 (3.4)	63.2 (24)	62 (24)	106 (34)	2.7 (0.3)	97 (40)
40-60	5.2 (0.2)	4.2 (2.4)	46.2 (18)	41.4 (20)	60 (31)	1.3 (0.1)	73 (34)

n = 4, Figures in parentheses indicate standard deviation. BD = Bulk Density: PD = Particle Density: OC = Organic Carbon: EA = Exchange Acidity: EB = Exchangeable Bases: N = Nitrogen: P = Phosphorus: K = Potassium.

Climate

Nilambur generally receives 2000-3500 mm annual rainfall on an average and the temperature regime varies from a minimum of 18^{0}C to a maximum of 40^{0}C. The South West monsoon falling in the months of June, July, August and September contribute maximum and the North East monsoon of succeeding four months the rest. Summer rains contribute very little. The South West monsoon of 1994 accounted for 74.47% of the total rains, while that of 1995, 69.7 per cent. North East monsoon did not vary in the two years. It was 17.5 per cent. Summer rains contributed 8% and 13% respectively in the two years. Rainfall occurs in 130-140 days and intense rain in more than 60 days. Details of rainfall received in the years 1994 and 1995 are shown in table 3.

Table 3. Rainfall Data at Nilambur

Month	No. of rainy days		Rainfall (mm)			
			Total		Maximum in a day	
	1994	1995	1994	1995	1994	1995
January	1	—	40.2	—	40.2	—
February	—	1	—	15.0	—	15.0
March	3	1	21.8	15.0	10.8	15.0
April	7	5	97.6	72.6	47.2	31.2
May	8	10	144.6	151.5	59.0	63.4
June	27	22	734.4	380.2	102.8	121.3
July	30	28	1244.0	591.1	210.8	140.1
August	22	21	347.3	221.2	124.2	56.5
September	10	14	110.8	193.7	24.0	108.4
October	19	20	392.8	164.8	104.4	45.0
November	9	12	136.9	183.7	85.8	74.3
December	1	—	1.2	—	1.2	—
Total	137	134	3271.6	1988.8		

		1994	1995
Days when rainfall exceeded 10 mm	:	76	64
Summer rain contribution	:	8.07%	12.78%
South West monsoon contribution	:	74.47%	69.7%
North East monsoon contribution	:	17.45%	17.52%

3.1.2. Eucalyptus plantation

Palakathadom. Machad Range, Thrissur Forest Division was a degraded forest area with habitations all around where forest plantations were raised during the past. Teak and cashew were tried without much success and of late *Eucalyptus tereticornis* was raised. Replanting was done in 1992 with the same species at a spacing of 2 x 2 m. Few coppice shoots were left to grow at random. The land is moderately sloping (15-20%) and undulating with all aspects.

Ground Cover

The ground is feebly protected by the species planted. Some ground cover was offered by weeds like grasses and shrubs. Litter practically provided no

Plates 3 & 4. Run-off plots in a 2 yr old Eucalypt plantation

such cover. Grasses offered about25-40% cover of the ground, but not thick enough to absorb the energy of intense raindrops. Stones, pebbles and gravel which were present on the surface helped in retarding the velocity of flowing water to some extent.

The Soil

The soil is a ferralsol derived from gneissic parent material. The land has been denuded of its rich top soil as evidenced by the soil properties. It is reddish yellow, acidic, sandy loam with high bulk density, massive structure and poor in bases and primary nutrients. The content of finer soil fractions, namely silt and clay, and organic carbon which can initiate and maintain stable aggregates are also less in this soil. Thus the soil has a highly erodable nature. Physical and chemical properties of the soil are given in tables 4 and 5.

Table 4. Soil Physical Properties in Palakathadom Eucalyptus Plantation

Depth (cm)	Colour	Gravel	Sand	Silt	Clay	B D	PD	Porosity (%)
		g/kg				g/cm^3		
00-20	5YR 5/4 Reddish brown	267 (124)	584 (140)	71 (15)	78 (21)	1.35 (0.04)	2.42 (0.06)	44 (3.4)
20-40	5YR 6/6 Reddish yellow	345 (186)	516 (194)	68 (20)	72 (22)	1.44 (0.04)	2.46 (0.05)	41 (3.6)
40-60	5YR 6/8 Reddish Yellow	334 (194)	503 (187)	78 (24)	85 (23)	1.50 (0.5)	2.43 (0.05)	38 (3.7)

Table 5. Soil Chemical Properties in Palakathadom Eucalyptus Plantations

Depth (cm)	pH	OC g/kg	EA	EB	N	P	K
			me/kg		me/kg		
00-20	4.9 (0.2)	10.2 (4.3)	60.0 (18)	49.8 (30)	104 (42)	2.1 (0.8)	122 (55)
20-40	5.0 (0.2)	6.8 (3.3)	51.3 (21)	54.3 (28)	87 (36)	1.4 (0.5)	84 (62)
40-60	5.0 (0.1)	4.3 (2.0)	40.4 (22)	42.0 (27)	62 (41)	0.8 (0.4)	80 (36)

n = 4, Figures in parentheses indicate standard deviation; B D = Bulk Density; P D = Particle Density; OC = Organic Carbon: EA = Exchange Acidity: EB = Exchangeable Bases; N Nitrogen: P = Phosphorus K = Potassium.

Climate

Palakathadom receives an average annual rainfall of 2000-3000 mm and the temperature varies from a minimum of 18^{0}C to a maximum of 40^{0}C. Most of the rain is contributed by the South West and North East monsoons during June to November. The plantation site generally receives around 120 rainy days and rainfall exceeds 10 mm in more than 60 days a year. Details of rainfall received during 1994 and 1995 are given in table 6.

Table 6. Rainfall Data at Palakathadom

Month	No. of rainy days		Rainfall (mm)			
			Total		Max. in a day	
	1994	1995	1994	1995	1994	1995
January	—	—	—	—	—	—
February	—	—	—	—	—	
March	1	—	7.5	—	7.5	—
April	9	2	176.8	21.4	42.0	16.5
May	3	13	18.0	257.3	9.0	42.5
June	29	21	838.1	439.1	84.5	122.5
July	30	29	757.7	717.6	78.0	196.5
August	17	21	378.5	303.1	83.0	46.5
September	7	18	211.7	221.4	56.0	43.0
October	20	9	492.3	80.2	91.5	21.5
November	4	7	78.0	106.2	31.7	28.5
December	—	—	—	—	—	—
Total	120	120	2958.6	2146.3		

		1994	1995
Days when rainfall exceeded 10 mm	:	82	68
Summer rainfall proportion	:	6.23%	0.91%
South West monsoon proportion	:	74.50%	90.41%
North East monsoon proportion	:	19.27%	8.68%

3.2. LAY OUT OF RUN-OFF PLOTS AND MEASUREMENTS

Run off plots of size 50 x 8 m along the slope were established in the field by making brick masonry partition walls to a height of 15cm and depth of 15cm from the ground surface along the boundary. Towards the bottom boundary the walls were made to converge to the centre from where water could flow into a rectangular cistern of size 180 x 90 x 90 cm. This cistern was divided into three compartments with the help of slotted frames to reduce the turbulence of water. A stilling well with a platform and cover to accommodate the stage level recorder assembly and its smooth functioning in still water was constructed along the side of the first cistern. The stage level recorders were of the Steven's F-type with stage graphs of 8-day duration. A cut is made on the common wall of the stilling well and the cistern to the exact depth as that of the V-notch so that still water in the cistern keeps level with the overflowing water through the V-notch. The float and counter weight of the stage level recorder operates in the stilling well. The rise of water in the stilling well is proportionately transmitted to the drum with the help of float, counter weight, float pulley and float cable. The pen moves at a uniform speed along the horizontal axis where as the drum moves in the vertical axis. The relative movements of the chart and the pen produce a curve called stage-graph which is analysed to determine the amount of run-off.

Water flowing over from the first cistern was led into a second circular cistern of 120 cm diameter and 70 cm height through a 90^0 V-notch. This cistern had multiple slots along the upper portion through which water could flow out. Water overflowing through one of the slots was led into a third circular cistern of the same size. This multi-slot divisor system was necessary to obtain the' quantity of run-off if the stage level recorder goes out of order once in a while. It is calculated by adding the amount of water in the first and second cistern with the quantity obtained by multiplying the amount of water in the third cistern by the number of slots in the second cistern.

Water samples (5L) collected from the cisterns were mixed with alum solution (5ml per litre) and kept for a day. The supernatant clear solution was decanted and the sediment collected, oven dried and weighed. This value was used to derive the quantity of soil lost through surface run-off taking into consideration the quantity of run-off water. Rainfall was measured using self recording as well as manual raingauges. Manual raingauge was found essential because the self recording raingauge malfunctions occassionally. The stage level recorder was found to be sturdy and functional except for the quartz movement.

Run-off plots (3 each) were established at two sites, one in teak and another in eucalyptus plantation. Part of Valluvasseri plantation of Nilambur Forest Division located within the KFRI Sub Centre Campus was selected to study soil and water loss through surface run-off from young teak. Palakathadom

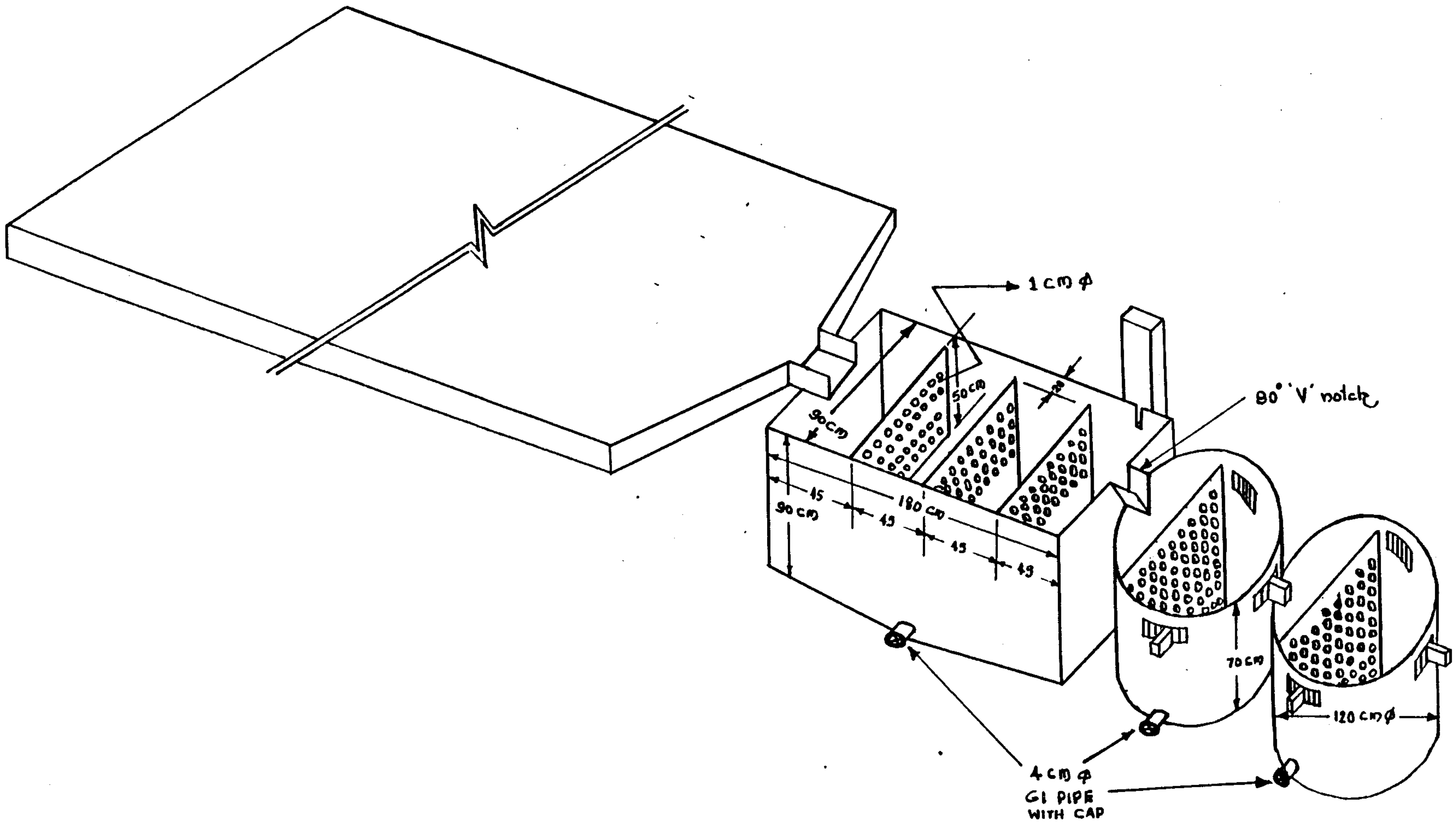


Fig. 1. Schematic representation of run-off collection cisterns in the field

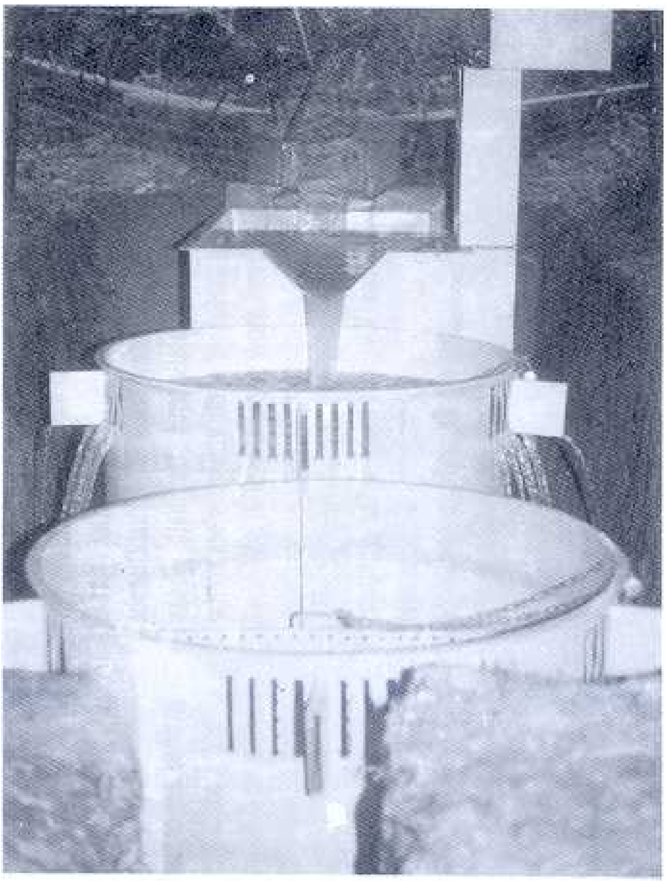


Plate 5. Run-off collection cisterns in the field

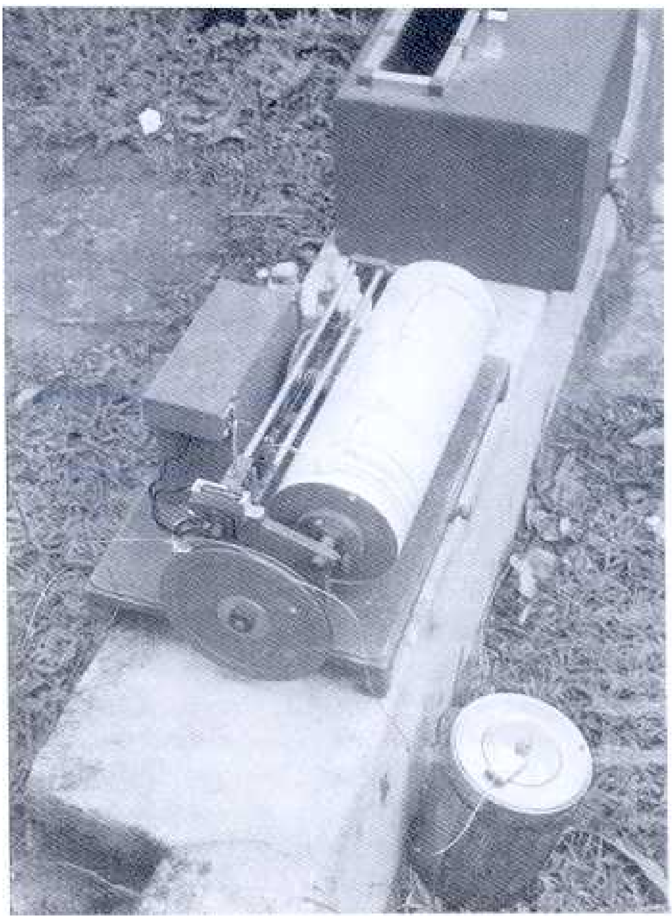


Plate 6. The water level recorder used in the study

in Thrissur Forest Division was selected to study soil and water loss from young plantation of eucalyptus. Since the factors that influence soil erosion are different in these two sites, they are discussed separately in the report.

Soil sampling and analyses

Four soil pits each were taken in both sites and soil samples collected from 00-20, 20-40, 40-60 cm layers. Core samples were taken separately for bulk density estimation. The samples were air dried, sieved through 2 mm sieve and analysed following standard procedures. Soil textural fractions were determined using hydrometer, particle density (PD) using standard flask and bulk density (BD) gravimetrically. Organic carbon (OC) was estimated by potassium dichromate - sulphuric acid wet digestion, pH in 20:40 soi1:water suspension, exchange acidity (EA)by 0.5 N barium acetate and exchangeable bases (EB)by 0.1 N hydrochloric acid. Available nitrogen (N) was determined by alkaline permanganate method, extractable phosphorus (P) by vanado molybdo phosphoric acid blue colour method and exchangeable potassium (K) by colorimeter.

4. RESULTS

4.1. SOIL AND WATER LOSS FROM TEAK PLANTATION

4.1.1. Water loss through surface run-off

Water loss through surface run-off from the experimental plots of teak at Nilambur during the years 1994 and 1995 are depicted in tables 7 and 8. The site received 3272 mm rain spread over 137 days in 1994. This corresponds to 1308.4 m^3 rain water in the experimental plot. The amount

Table 7. Rainfall - Surface Run-off Relationship in Teak Plot

Month	Rain water in plot m^3		Surface Runoff from plot m^3		(Percentage)	
	1994	1995	1994	1995	1994	1995
January	16.08	—	—	—	—	—
February	—	06.00	—	—	—	—
March	08.72	06.00	—	—	—	—
April	39.00	29.04	00.50 (0.05)	01.45 (0.21)	01.28	04.99
May	57.80	60.06	01.69 (0.15)	07.27 (1.03)	02.92	11.99
June	293.76	152.08	71.98 (16.43)	53.23 (9.84)	24.50	35.00
July	497.60	236.44	199.22 (34.16)	96.94 (14.36)	40.03	40.99
August	138.90	88.48	32.70 (7.22)	19.47 (3.25)	23.54	22.00
September	44.30	77.48	04.49 (1.02)	11.62 (1.91)	10.13	14.99
October	157.00	65.92	11.93 (2.66)	08.57 (1.50)	07.59	13.00
November	54.76	73.48	09.79 (1.80)	10.27 (2.04)	17.88	13.97
December	00.50	—	—	—	—	—
Total	**1308.42**	**795.52**	**332.3**	**208.82**	**25.39**	**26.25**

Figures in parentheses indicate standard deviation.

of water which ran away from the plot was quantified to be 332.3 m^3 in the year which means that 25.4 per cent of the incoming water was lost by run-off over the surface immediately. A peak day with 84.3 m^3 rainfall in the plot lost as high as 56.5 m^3 of water through surface run-off (67%). Maximum rainfall in the plot (974.56 m^3) and run-off from the plot (308.4 m^3) occurred during South West monsoon of 1994.

Table 8. Rainfall and Surface Run-off Seasonal Distribution

Season	Rain water in plot (m^3)		Surface run-off from plot (m^3)		(Percentage)	
	1994	1995	1994	1995	1994	1995
Summer Rain	105.52	101.64	2.19	8.72	2.07	8.58
S.W. Monsoon	974.56	554.48	308.39	191.26	31.64	32.49
N.E. Monsoon	228.34	139.40	21.72	18.84	9.51	13.51
Total	1308.42	795.50	332.30	208.80	25.39	26.25

Rainfall was much less in 1995 (1988.8mm) compared to the previous year though the number of rainy days (134) remained more or less the same. Thus the plot received 795.5 m^3 rainwater of which 208.8 m^3 ran off as surface run-off. The loss of water by surface run-off was 26.25 per cent. Maximum run-off of 191.26 m^3 (32.49%) occurred during the South West monsoon though the rain was spread over both monsoons and summer. During the summer, 101.64 m^3 rain was received in the plot while 554.48 m^3 in South West monsoon and 139.40 m^3 during North East monsoon. A peak day received 72.4 m^3 rain and the loss through surface run-off on the same day was 37.6 m^3 water. About $1/4^{th}$ of the rain water was lost through surface run-off in both the years studied, though there was appreciable difference in rainfall and its distribution in the two years. The year 1994 experienced heavy rainfall with 76 days getting more than 10mm rainfall while in 1995 there were only 64 such days.

4.1.2. Soil loss through surface run-off

Soil loss through surface run-off from the experimental plots of teak is shown in tables 9 and 10. It can be seen that most of the loss occurred during the South West monsoon. The losses during summer and North East rains were negligible. During 1994. the plots on an average lost 594 kg of soil (98%) during the South West monsoon, 6 kg (0.98%) during the Summer rains and 5 kg (0.79%) during the North East monsoon. The total loss was 605 kg. In the year 1995, soil loss from the plots were 154.8. 3.76 and 2 kg during the South West monsoon, North East monsoon and Summer rains, respectively.

The total loss in the year was 161 kg. The South West monsoon accounted for 96% of soil loss, North East monsoon 2.3% and Summer rains 1.3 per cent. The total loss of soil through surface run-off was 15.13 metric tons and 4 metric tons per hectare in 1994 and 1995 respectively.

Table 9. Soil Loss Through Surface Run-off from Teak Plot

Month	Sediment in .005m^3(kg)		Runoff (m^3)		Soil loss (kg)	
	1994	**1995**	**1994**	**1995**	**1994**	**1995**
January	—	—	—	—	—	—
February	—	—	—	—	—	—
March	—	—	—	—	—	—
April	0.0044 (0.001)	—	00.50	01.45	00.44	—
May	0.0164 (0.003)	0.0014 (0.0002)	01.69	07.27	05.50	02.04
June	0.0127 (0.004)	0.0082 (0.0013)	71.98	53.23	182.80	87.20
July	0.0092 (0.002)	0.0027 (0.0005)	199.22	96.94	366.56	52.35
August	0.0067 (0.0015)	0.0027 (0.0004)	32.70	19.47	43.80	10.51
September	0.0014 (0.0003)	0.0020 (0.0002)	04.49	11.62	01.26	04.65
October,	0.0012 (0.00021	0.0010 (0.0002)	11.93	08.57	02.86	01.71
	0.0010 (0.0002)	0.0010 (0.0002)	09.79	10.27	01.96	02.05
December	—	—	—	—	—	—
Total			332.3	208.82	605.18	160.61

Figures in parentheses indicate standard deviation.

Rain was well spread over the months in both the years in Nilambur. The summer rains were only enough to wet the soil. Very little loss of soil occurred during this season. The South West monsoon brought intense rains which splashed the surface soil particles. Since precipitation exceeded infiltration during most of these rain events, water flowed over the surface and carried these splashed particles also alongwith. Similar rains were present during the North East monsoon also, but to a lesser extent. Thus the loss of soil was much less in the North East monsoon than that during the South West monsoon.

Table 10. Soil Loss Through Surface Run-off -- Seasonal Differences

Season	Soil loss from plot (kg)		(Percentage)	
	1994	**1995**	**1994**	**1995**
Summer Rain	**05.94**	**02.04**	**00.98**	**01.27**
S.W. Monsoon	**594.42**	**154.81**	**98.20**	**96.39**
N.E. Monsoon	**04.82**	**03.76**	**00.80**	**02.34**

4.1.3. Nutrient loss through sediment in run-off

Nitrogen and potassium losses through the sediments carried in run-off water were quantified (Table 11). Maximum loss occurred during the South West monsoon, especially in June and July. The difference between the two years is also due to the variation in rainfall and its pattern. The plots lost about 4.92 kg and 0.197 kg N on an average in 1994 and 1995. This is equivalent to a loss of 17.11 and 4.92 kg/ha, respectively. Loss of potassium amounted to 0.096^Oand 0.023 kg per plot. On a per hectare basis, it was 2.313 and 0.385^0kg/ha during the two consecutive years.

Table 11. Nutrient Loss Through Sediment in Runoff

Month	Nitrogen kg/plot		Nitrogen kg/ha		Potassium kg/plot		Potassium kg/ha	
	1994	1995	1994	1995	1994	1995	1994	1995
January	—	—	—	—	—	—	—	—
February	—	—	—	—	—	—	—	—
March	—	—	—	—	—	—	—	—
April	0.001	0.001	0.020	0.035	—	—	—	—
May	0.002	0.007	0.038	0.180	—	.001	—	0.013
June	0.249	0.081	6.220	2.030	0.029	0.006	0.733	0.138
July	0.342	0.062	8.540	1.550	0.057	0.006	1.410	0.148
August	0.085	0.016	2.120	0.410	0.006	0.002	0.160	0.053
September	0.001	0.008	0.035	0.187	—	0.007	—	0.018
October	0.004	0.008	0.008	0.190	0.004	0.001	0.010	0.015
November	0.002	0.014	0.048	0.340	—	—	—	—
December	—	—	—	—	—	—	—	
Total	**0.686**	**0.197**	**17.109**	**4.922**	**0.096**	**0.023**	**2.313**	**0.385**

4.2. SOIL AND WATER LOSS FROM EUCALYPT PLANTATION

4.2.1. Water loss through surface run-off

Rain falling in summer is mostly absorbed by the soil with only slight amount of run-off as surface flow. Most of the surface run-off occurs during the monsoons. The South West monsoon in June and July is so intense that the plot of 80 m x 5 m contributes about 70 m^3 run-off water in each of these two months amounting to about 23% of the rainwater falling in the plot. Amount of water running off the surface during August, September and October is also considerable, eventhough less when compared to the South West monsoon. Surface run-off from the experimental plots during 1994 and 1995 are shown in tables 12 and 13.

Table 12. Rainfall-- Surface Run off Relationship in Eucalypt Plot

Month	Rainwater in plot (m^3)		Surface Runoff from plot (m^3)		Surface Runoff from plot (Percentage)	
	1994	1995	1994	1995	1994	1995
January	—	—	—	—	—	—
February	—	—	—	—	—	—
March	03.00	—	—	—	—	—
April	70.72	08.56	0.910 (0.216)	—	01.29	—
May	07.20	102.92	0.084 (0.004)	13.278 (2.934)	00.12	12.90
June	335.20	175.64	75.884 (15.321)	43.158 (7.62)	22.64	24.57
July	302.80	287.04	71.180 (22.57)	100.325 (21.375)	23.51	34.95
August	151.40	121.24	30.574 (8.362)	9.074 (1.893)	20.19	07.48
September	84.68	88.56	22.625 (4.496)	9.060 (2.014)	26.72	10.23
October	196.92	32.08	23.349 (5.560)	0.750 (0.182)	11.86	02.34
November	31.20	42.48	2.902 (0.464)	2.606 (0.317)	09.30	06.13
December	—	—	—	—	—	
Total	1183.12	898.52	227.43	178.25	19.22	19.64

In 1994, the plot received on an average 1183 m^3 rain water of which 227 m^3 was lost through surface run-off (19%). The highest value recorded on a particular day was 33.8 m^3 rainwater and 8.45m^3 run-off water (25%). In 1995,898.5 m^3 rain was received in the plot ofwhich 178.25 (20%) ran away from the plot. A peak day received 78.6 m^3 rain and lost 42 m^3 (54%) through surface run-off. Run-off water loss during the South West monsoon of 1994 was 200 m^3, while in 1995 it was 162 m^3 . North East monsoon contributed about 26 m^3 run-off water in 1994 and 3 m^3 in 1995. Summer rain contribution in 1994 was only 0.92 m3 and during 1995, it was 13.28 m^3.

Table 13. Rainfall and Surface Run-off -- Seasonal Distribution

Season	Rain water in plot (m^3)		Surface Run-off from plot (m^3)		Surface Run-off from plot (Percentage)	
	1994	1995	1994	1995	1994	1995
Summer Rain	80.92	111.48	0.92	13.28	1.14	11.91
S.W. Monsoon	874.08	672.48	200.26	161.62	22.91	24.03
N.E. Monsoon	228.12	74.56	26.25	3.36	11.51	4.50
Total	1183.12	858.52	227.43	178.25	19.22	20.76

Eighty eight percent of the total run-off in 1994 occurred during the South West monsoon while in 1995, 90 per cent was lost during this monsoon. The water loss was 11.54% of the total run-off during North East monsoon of 1994. The loss during the summer rains was negligible. In the year 1995, summer rain could cause 7.45% of the total run-off while the North East monsoon did not contribute any appreciable quantity.

4.2.2. Soil loss through surface run-off

Soil loss through surface run-off from the *eucalyptus* plot is depicted in tables 14 and 15. The plot lost on an average about 1836 kg of soil in 1994. ofwhich 1765 kg was lost during the South West monsoon. Most of the soil loss through surface run-off occurred during the South West monsoon. Almost 96% of the soil loss was recorded during this period. North East monsoon could erode 68.4 kg soil from the plot while the soil lost during summer rains was hardly 2 kg. Contribution of North East monsoon towards total was 3.72% while that of summer rains was negligible. In 1995, the total soil loss was 1230 of which the loss in South West monsoon was 1181 kg. This accounted for 96% of the total loss. North East monsoon caused only

1.48% (18kg) and summer rains 2.44% (30 kg) of the total soil loss. The loss of soil through surface run-off was 45.9 metric tons per hectare in 1994 and 30.75 metric tons per hectare in 1995 from the experimental plots of eucalyptus.

Table 14. Soil Loss hrough Surface Run-off from Eucalypt Plot

Month	Sediment in .005m^3 (kg)		Run-off (m^3)		Soil loss (kg)	
	1994	**1995**	**1994**	**1995**	**1994**	**1995**
January	—	—	—	—	—	—
February	—	—	—	—	—	—
March	—	—	—	—	—	—
April	0.011 (0.0016)	0.035 (0.003)	00.91	—	02.00	—
May	0.009 (0.0013)	0.011 (0.001)	00.01	13.28	00.02	30.01
June	0.028 (0.062)	0.058 (0.013)	75.88	43.16	424.95	500.63
July	0.087 (0.017)	0.030 (0.006)	71.18	100.33	1238.53	601.95
August	0.013 (0.0014)	0.018 (0.001)	30.57	09.07	79.49	32.67
September	0.005 (0.0004)	0.026 (0.003)	22.63	09.06	22.63	46.21
October	0.014 (0.0009)	0.014 (0.002)	23.35	00.75	65.38	02.10
November	0.005 (0.0003)	0.031 (0.002)	02.90	02.61	03.02	16.16
December	—	—	—	—	—	—
Total					11836.02	1229.73

Figures in parantheses indicate standard deviation.

During the summer rains, the antecedent soil moisture might not have been at a saturation level to cause run-off over the surface. Most of the water could have infiltrated into the soil. During the North East monsoon of 1994 there was appreciable run-off and soil loss only in the month of October. In 1995, the North East monsoon was very weak and there was not much soil loss. Summer rains also were weak and the little loss occurred was only in May, 1995.

Table 15. Soil Loss Through Surface Run-off -- Seasonal Difference

Season	Soil loss from plot			
	kg		(Percentage)	
	1994	1995	1994	1995
Summer rain	2.02	30.01	0.11	2.44
S.W. Monsoon	1765.6	1181.46	96.16	96.07
N.E. Monsoon	68.4	18.26	3.72	1.48
Total	1836.02	1229.73		

4.2.3. Nutrient loss through sediment in run-off

The sediment samples collected were analysed to determine the loss of nitrogen and potassium. They are given in table 16. The loss was maximum

Table 16. Nutrient Loss Through Sediment in Run-off

Month	Nitrogen				Potassium			
	kg/plot		kg/ha		kg/plot		kg/ha	
	1994	1995	1994	1995	1994	1995	1994	1995
January	—	—	—	—	—	—	—	—
February	—	—	—	—	—	—	—	—
March	—	—	—	—	—	—	—	—
April	0.002	0.012	0.043	0.308	—	0.005	—	0.131
May	—	0.019	—	0.479	—	0.010	—	0.260
June	0.459	0.401	11.473	10.037	0.072	0.139	1.795	3.468
July	1.375	0.683	34.369	17.065	0.216	0.210	5.387	5.238
August	0.092	0.018	2.305	0.452	0.020	0.009	0.508	0.215
September	0.029	0.041	0.724	1.019	0.005	0.012	0.122	0.309
October	0.129	0.002	3.220	0.039	0.015	0.001	0.385	0.02
November	0.004	0.010	0.092	0.255	0.001	0.006	0.013	0.138
December	—		—	—	—	—	—	—
Total	2.090	1.186	52.226	29.695	0.329	0.392	8.210	9.779

during June and July and least during the summer rains. The run-off plots on an average lost 2.09 and 1.19 kg nitrogen in 1994 and 1995, respectively. This corresponds to 52.23 and 29.70 kg nitrogen per hectare. The reduction in 1995 is probably related to the rainfall because there occurred no notable changes in other factors. Sediments could carry 0.32 and 0.392 kg potassium irom the plots, which amounts to a loss of 8.21 and 9.78 on a per hectare basis.

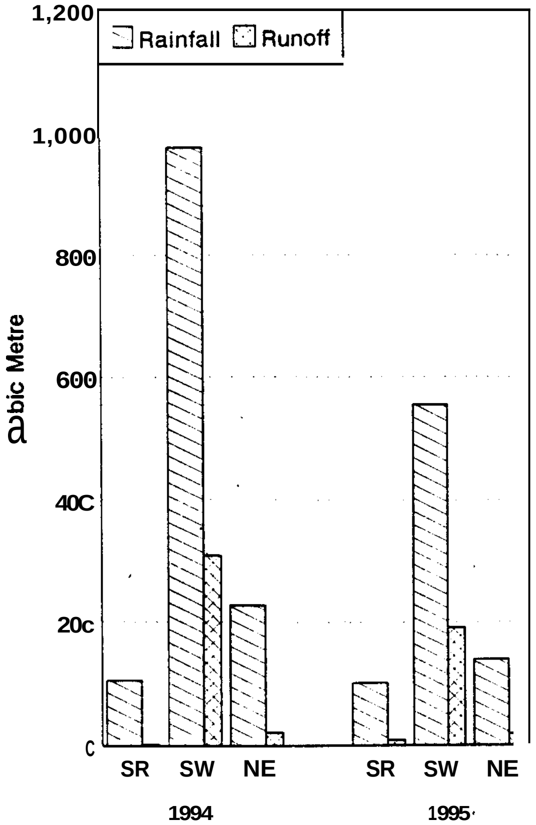
5. DISCUSSION

Loss of water from the experimental plots in young teak at Nilambur with 8-12% slope was found to be proportional to the quantity of rainfall. In 1994, 332.3m^3 water ran off from the plot of 400m^2 area out of the 1308.4m^3 water received as rainfall. The loss of water from a rainfall of 795.5m^3 in 1995 was 208.8m^3 from the same plot. The run-off loss in both the years is approximately 25% of the rain water. Soil loss through surface run-off from these plots were 605 kg and 161 kg in 1994 and 1995respectively. Maximum losses of water and soil occurred during the South West monsoon in both the years studied. Nutrient loss was related to the the soil loss, since the loss through the sediment alone was studied.

Run-off water, soil and nutrient losses from the eucalyptus plantation at Palakathadom with 15-20% slope was also seen to be influenced most by the amount of rainfall. Loss of water from the plot of 400m^2 area in 1994 was quantified to be 227 m3 corresponding to a rainfall of 1183 m^3. In 1995, 898.5^3 rain fell in the plot and 178.25m^3 ran away from the plot. The loss in both the years was approximately 20% of the rainfall. The experimental plots lost 1836 kg of soil in 1994 and 1230 kg soil in 1995. Most of the loss of water, soil and nutrients occurred during the South West monsoon season and nutrient losses through sediments were directly related to the amount of sediment in run-off water.

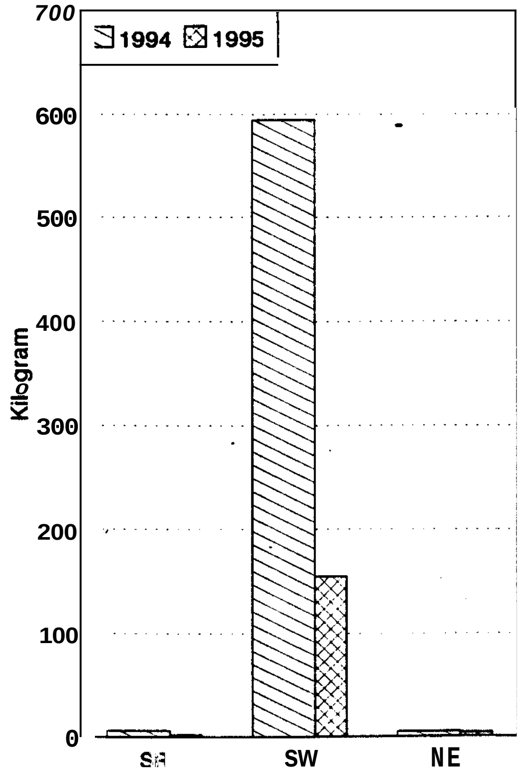
Water starts running off over the land surface when precipitation exceeds infiltration and the soil gets saturated. Thus, continuous and intense down-pour favours water run-off while intermittent showers of low intensity contribute mostly towards sub-surface flow and ground water recharge. Though various indices related to intensity and kinetic energy of rainfall have been attempted by many workers, Lal (1976a) found that the correlation coefficients of percent run-off from individual rainstorms with various indices such as kinetic energy, rainfall amount, maximum intensity etc. were generally low. He concluded that the kinetic energy of tropical rainstorms may be significantly influenced by other factors such as wind velocity, drop size distribution and high rainfall intensity. Smith and Wischmeier (1957) was also of similar opinion. They stated that many factors such as rainfall characteristics, land and soil features, type ofvegetation and its management influence the type and magnitude of soil erosion in a region.

Since most of the factors influencing soil erosion are different in the two sites studied, the results are not comparable with one another. Also the present study was intended only to quantify the loss of soil and water as a first step.



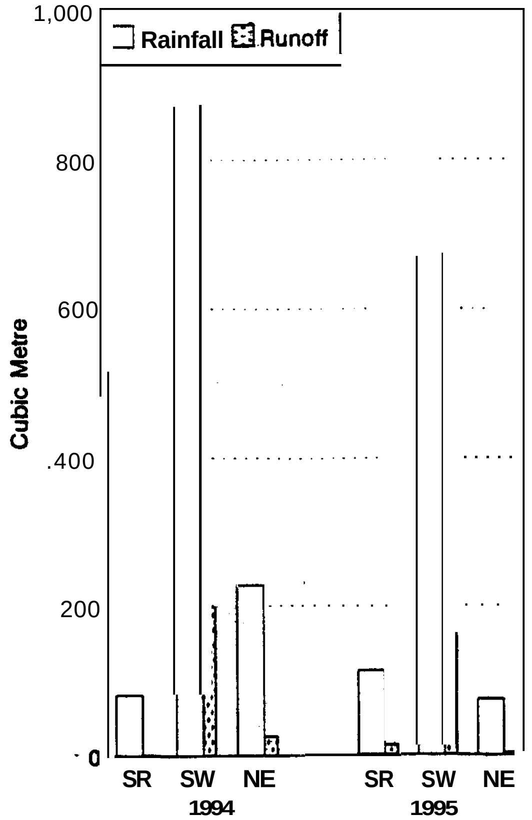
SR= Summer Rain SW= SW Monsoon NE = NE Monsoon

Fig. 2. Distribution of Rainfall and Run-off in 1994 and 1995 in Teak Plantation



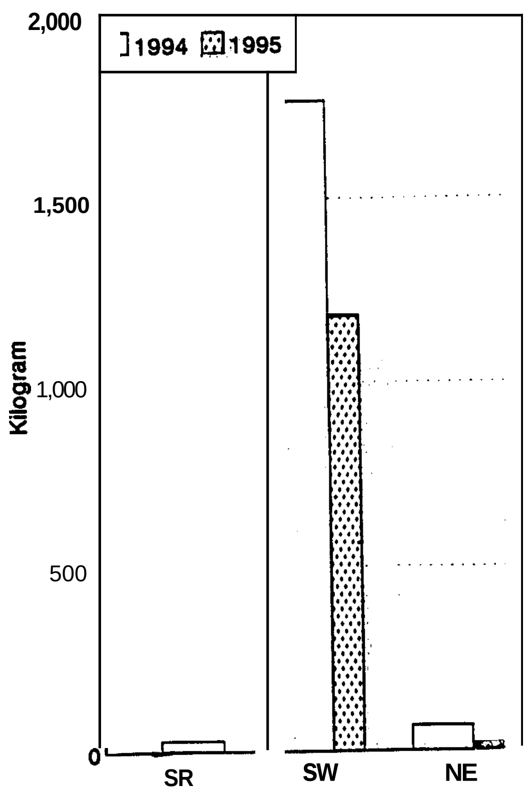
SR = Summer Rain SW = SW Monsoon = NE Monsoon

Fig. 3. Distribution of Soil Loss in 1994 and 1995 in Teak Plantation



SR = Summer Rain SW = SW Monsoon NE = NE Monsoon

Fig. 4. Distribution of Rainfalland Run-off in 1994 and 1995 in Eucalypt Plantation



SR = Summer Rain SW = SW Monsoon NE = NE Monsoon

Fig. 5. Distribution of Soil Loss 1994 and 1995 Eucalypt Plantation

Influence of different factors controlling the losses was not intended. Moreover it is extremely difficult, if not impossible, to single out causes which are intertwined in complex relations. Haan (1950) from his observations concluded that run- off plot studies give results that have a comparative value only. Due to the small size and the variable character of the experimental plots, 2-5 fold differences were found in adjacent and seemingly identical plots, and erosion figures obtained in one area are not applicable to another situated in the same river basin.

Still, inferences can be drawn from the available data to some extent. It is seen that the loss of water from both the sites followed a similar pattern though the sites were different in almost all aspects. It was about 25% of the rainfall received from the teak plantation at Nilambur and about 20% from the eucalyptus plantation at Palakathadom. The teak plot lost 605 kg soil in 1994 and 161 kg soil in 1995. The loss of soil from the eucalyptus plot was 1836 kg and 1230 kg in the respective two years. The steeper slope, the degraded land and soil and the poor vegetation cover might have caused this increase in soil loss at Palakathadom compared to Nilambur.

6. SUMMARY

Soil and water loss through surface run-off from young plantations of teak and eucalyptus at two sites in Kerala have been quantified by laying out field plots of size 50 x 8 m. The teak plantation at Nilambur with 8-12% slope and lateritic soil lost 8310 m^3/ha water through surface run-off from the rainfall of 32710 m^3/ha received in the year 1994. The loss in 1995 was 5220 m^3/ha when 19890 m^3/ha rainfall was recorded. The soil loss was found to be 15 metric tons and 4 metric tons per hectare: nitrogen loss through sediment in run-off was found to be 17 kg/ha and 5 kg/ha and potassium loss was found to be 2.3 and 0.4 kg/ha in the respective years.

The eucalyptus plantation at Palakathadom with 15-20% slope and lateritic soil lost 5675m^3/ha water as surface run-off when 29575 m^3/ha water was received as rainfall in the area in 1994. In the next year, 22460 m^3/ha rain fell in the site out of which 4460m^3/ha ran off. The soil loss in the corresponding years were 46 metric tons and 31 metric tons per hectare respectively. Nitrogen loss through sediment was quantified to be 52 kg/ha in 1994 and 30 kg/ha in 1995. Loss of potassium was 8 kg and 10 kg per hectare in these two years.

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