AGROTECHNIQUES FOR SOIL CONSERVATION IN TAUNGYA SYSTEMS

By

R. GOPINATHAN

THESIS

Submitted in partial fulfilment of the requirement for the degree

Doctor of Philosophy in Agronomy

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
Kerala - India

1986

DEDICATED TO:

THE HILL-SLOPE FARMERS

DECLARATION

I hereby declare that this thesis, entitled 'Agrotechniques for soil conservation in taungya systems' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

Vellanikkara,
8-12-1986.

R. Gopinathan

C E R T I F I C A T E

Certified that this thesis, entitled 'Agrotechniques for soil conservation in taungya systems' is a record of research work done independently by Sri. R. Gopinathan (82-21-03) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

Vellanikkara,
8-12-1986.

Dr. C. Sreedharan
(Chairman, Advisory Committee),
Professor & Head,
Department of Agronomy,
College of Horticulture,
Vellanikkara.

C E R T I F I C A T E

We, the undersigned, members of the Advisory Committee of Mr. R. Gopinathan (82-21-03), a candidate for the degree of Doctor of Philosophy in Agronomy, agree that the thesis entitled 'Agrotechniques for soil conservation in taungya systems' may be submitted by Mr. R. Gopinathan in partial fulfilment of the requirement for the degree.

C. Sreedharan,
Professor of Agronomy
(Chairman)

T.P. George,
Professor,
Agricultural Engineering
(Member)

P. Balakrishna Pillai,
Professor,
Agrometeorology
(Member)

R. Vikraman Nair,
Professor,
K.A.D.P.
(Member)

V.K. Venugopal,
Associate Professor,
Agricultural Chemistry
(Member)

ACKNOWLEDGEMENT

I am immensely indebted to Dr. C. Sreedharan, Professor & Head, Department of Agronomy, College of Horticulture, Vellanikkara, the Chairman of my advisory committee, at whose behest the present task was undertaken and completed. The constant encouragement, guidance and constructive criticism received from him during the entire period of the investigation are gratefully acknowledged.

I am also obliged to Prof. T.P. George, Dr. P. Balakrishna Pillai, Dr. R. Vikraman Nair and Dr. V.K. Venugopal, members of my advisory committee, for their encouragements, generous investment of time and numerous suggestions for the successful completion of this project and preparation of the thesis. The pain taken by Dr. V.K. Venugopal in scrutinising the manuscript is specially acknowledged.

The interest of Dr. P.K. Gopalakrishnan, Associate Dean, College of Horticulture, Vellanikkara in this project has been really instigative. My indebtedness to him is unexplainable.

Sri. T. Madhava Menon, IAS, Hon'ble Vice-Chancellor of Kerala Agricultural University had inspired me by visiting the experimental plot and sharing his views and valuable suggestions in the conduct of this experiment, quite a few times. Dr. M. Aravindakshan, Director of Research i/c., Dr. N. Sadanandan, Director, Post-Graduate Studies, Dr. C.C. Abraham, Associate Director, Dr. V.K. Sasidhar, Professor of Agronomy and Mr. V.R. Krishnan Nair, Special Officer (Agroforestry) were also visited the plot and encouraged me many times. I place my deep felt gratitude to all of them.

I also had the benefit of exchanging views with Dr. P.K.R. Nair, Principal Scientist, ICRAF, Nairobi, Kenya. His frequent, elaborative and informative replies were of immense utility to me. I am very much thankful to Dr. Nair.

It is my great pleasure to acknowledge the counsel and encouragement received from Dr. M. Achuthan Nair, Dr. J. Thomas, Dr. P.V. Balachandran, Mr. P.K. Ashokan, Mrs. P. Sreedevi and Mrs. E.K. Lalithabai, my department colleagues, throughout the period of investigation. The strain taken by Dr. C.T. Abraham to edit the entire manuscript is sincerely appreciated.

I am thankful to Dr. Jayaram, Scientist, KFRI, Peechi, Dr. K.C. George, Professor of Agricultural Statistics, KAU, and Mr. V.K.G. Unnithan, Associate Professor, Department of Agricultural Statistics, Horticultural College, Vellanikkara for their helps to analyse and interpret the data. The helps rendered by Dr. P.A. Vahid, Professor, Radiotracer Laboratory and Mr. K. Madhavan Nair, Associate Professor, Instrumentation in undertaking the chemical analysis are also gratefully acknowledged.

I express my appreciation to Mr. P. Gopinathan Nair, Chief Artist, KAU and Mr. Pradeep Varma, M.Sc.(Ag) student for their help in preparing the required illustrations and photographs. The assistance rendered by Mr. Lonan, K.J., in typing the manuscript is gratefully acknowledged.

I am indebted to ICAR for awarding the senior fellowship which, infact, helped me forget the financial burdens during the investigation period. The three years of study leave, sanctioned by KAU enabled me finish the work in time.

Last but by no means the least, I gratefully memmorise the dedication, persuation and encouragement of my wife Smt. P.K. Sushama and my parents, which sustained me when my resolve might have flattered.

R. Gopinathan

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

19. Total nutrient loss (soil + run-off) in kg/ha and run-off loss as % to total - 1985

20. Micro, macro and total porosity

21. Total canopy cover index during rainy months

22. Rate of increase in growth parameters of eucalyptus

23. Growth of eucalyptus at the end of experiment

24. Canopy height of eucalyptus and intercrops at monthly intervals

25. Net income and % contribution of eucalyptus to total income in each treatment

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

Soil erosion is almost universally recognized as a serious threat to man's well being and an alarming majority of tropical farmers suffer from the consequent self generating cycle of poverty, erosion and low crop productivity. The severity of this problem is so great that the very existence of man itself will be in danger, if the present rate of erosion continues unabated. It is observed that 5 - 7 million ha of good quality land is being lost every year from all over the world (Kovda, 1974). In India, out of the total geographical area of 328 million ha, about 175 million ha are subjected to varying degrees and forms of soil erosion (Kanwar, 1982). Characterised by its undulating topography, acute pressure on available land and very high intense seasonal rainfall, Kerala has severe erosion problems in more than 50 per cent of its cultivable area necessitating urgent soil conservation measures.

Conventional soil conservation efforts in the form of contour embankments, check dams, retaining walls and terraces are characterised by their inherent drawbacks such as high cost and incompatability with the existing farming situations, which inevitably prevent the hill slope farmers from adopting them to any measurable extent. Agroforestry has been widely accepted as an economically and ecologically viable land management system suited to the fragile and brittle ecosystems of tropical developing world, where soil erosion is a major problem. Most of the research results now available are from temperate zones and knowledge of the mechanisms of erosion in tropical climate, soil and ecosystem is rather inadequate. Moreover, local environmental conditions and farming system need also to be taken into account while transfering technology from one country to another. Therefore, soil conservation planning and implementation must necessarily be country-specific and some times region-specific or even economic-sector-specific. In Kerala, the research on this line is at an infant stage (Nair, 1984).

Good crop management, can be upto ten times more effective in reducing the amount of erosion than any improved conservation practice like terracing or contouring. This is mainly because of the importance of crop cover in reducing the effects of raindrop impact on the soil. Shaxson (1981) argues that the effects of vegetation are so enormous that more effort should be made to integrate crop cover with other soil conservation works. Unfortunately, the research on crop cover is inadequate as a basis for conservation planning.

Taungya, originated from Burmese language, means hill (Taung) cultivation (Ya) and commonly denotes the practice of growing agricultural crops during the initial two-three years of forest plantation. Conventionally, cassava taungya has been a time honoured practice in Kerala for raising usually, teak and eucalyptus. Soil erosion hazard is the most severe problem in many of the taungya plantations. Also, there are reports of soil physico-chemical changes in forest plantations consequent to taungya cultivation. Though indirect projections on soil loss are available (Alexander et al. 1980), correct quantifications of soil, run-off and nutrient losses in various taungya systems practiced in Kerala based on clearly laid field studies are practically absent. This still remains a lacuna in conservation planning and sediment control operations.

Judged from the literal meaning of taungya, an awareness on the severity of soil degradation in hill slopes is of immense importance to Kerala conditions. About 50 per cent of cultivation in Kerala is carried out on slopes, which according to land capability classification, can be considered unsuitable for cultivation. Irrespective of the severe criticism of growing cassava, a highly erosion permitting crop, large and growing numbers of small and marginal farmers in the foot-hills of Kerala are extensively practicing cassava cultivation in an environment highly vulnerable to erosion. This will inevitably result in the degradation of majority of farm lands apart from the possible threat of silting up of costly irrigation reservoirs, rivers and lakes and non-point source of environmental pollution. Since, cassava will continue as an inevitable crop component of subsistence agriculture, the need of the hour is to develop conservation techniques compatible with the current farming systems.

Considering the highly erosive edapho-climatological conditions of Kerala, soil conservation strategies developed through better recognition of the rainfall erosive characteristics and erosion processes for each location are very much essential. Hence, the present study was taken up, with the following objectives.

1) To understand and establish the exact relationship between the rainfall erosivity characteristics vis-a-vis run-off and soil loss under the existing edapho-climatological conditions.

2) To quantify the run-off, soil and nutrient losses as influenced by the major taungya systems practiced in Kerala.

3) To monitor the major physico-chemical changes of soil under different taungya systems.

4) To study the overtopping and adverse competition (if any) of the crop component on the tree during the initial two years of taungya.

5) To work out the economics of each system.

6) To identify economically and ecologically viable agroforestry measures for minimising run-off, soil and nutrient losses in steep hill-slopes.

Review of Literature

REVIEW OF LITERATURE

1. What is soil erosion?

Erosion always has taken place, and always will. Although this is clearly evident throughout 7000 years of history, an awareness of the problem developed very slowly and was almost unknown 80 years ago. The vastly accelerated process of soil removal brought about by human interference with the change in equilibrium between soil building and soil removal is designated as soil erosion. As against soil formation, it is essentially a destructive process. It can be best described as the theft of soil by the natural elements and is the removal of soil particles either singly or in mass. Hudson (1971) viewed erosion as essentially a smoothing or levelling process with soil and rock particles being carried, rolled or washed down, by the force of gravity. The main agents which loosen and break down the soil particles are wind and water. Man's activities seldom slow down or halt the process of soil erosion but frequently speed it up. When the erosion results only from the forces of nature, it is referred as 'geological erosion' or 'normal erosion' or 'natural erosion' and 'accelerated erosion' when the process is influenced by Man (Hudson, 1984).

2. Tolerable limits of soil erosion:

Tolerable soil loss is the maximum rate of erosion that will permit sustained crop productivity economically and indefinitely. This can be achieved when the rate of soil loss is no greater than the rate of formation of soil. The rate of formation cannot be precisely measured. According to the best estimate of soil scientists, under undisturbed conditions, it will take about 300 to 1000 years to form 25 mm of soil but when the disturbances, aeration and leaching actions are speeded up by tilling the land, this will be reduced to something like 100 years. Soil loss limits, most commonly used in selecting appropriate land uses and soil and crop management practices, range from 2.5 to 12.5 t/ha/yr (Lal, 1984).

Naturally, the acceptable soil loss will depend on the soil conditions. Hence different values are in use in different countries, though many doubts are expressed about them. All the soils in USA have been assigned values ranging from 4.5 to 11.2 t/ha/yr (Hudson, 1971). Bertoni et al. (1975) estimated soil loss tolerance of some central Brezilian soils to be as low as 4.5 t/ha/yr. Assessing the world soil degradation, Requier (1982) proposed supporting conservation practices for tropical soils to reduce soil loss below 10 t/ha/yr. Krishnarajah

(1983) used a soil loss tolerance of 9 t/ha/yr for soils in the wet zone of Srilanka. Lal (1984) indicated that for soils with gravel and concretionary horizon at shallow depth beneath the soil surface, the amount of acceptable soil loss ranges from a low value of 0.05 t/ha/yr to a maximum of 2.00 t/ha/yr for South Western Nigeria. It seems from this analysis that the currently used rates of 12.50 t/ha/yr are far too high for fragile tropical soils with low inherent fertility. More research information are needed to substitute the presently used values (Hudson, 1984).

3. Soil erosion by water:

In humid tropics where problems from wind erosion are few, major attention is given only to water erosion. The fundamental cause of soil erosion by water is the action of rain on soil (Hudson, 1977). The amount of erosion, therefore, depends upon a combination of the power of the rain to cause erosion and the ability of the soil to withstand the rain. Mathematically, erosion is a function of the erosivity (of the rain) and the erodibility (of the soil) or

$$\text{Erosion} = f\ (\text{Erosivity})\ (\text{Erodibility}).$$

4. Erosivity of rain:

Erosivity can be defined as the potential ability of the rain to cause erosion which is specifically and solely a property of the rainfall (Hudson, 1977). The aggressivity or erosivity of rainfall is a function of its physical characteristics. The amount of rainfall and soil erosion obviously show positive relation. It is also an established fact that the same total quantity of rain because of inherent variation in erosivity, can on different occasions, result in widely different amounts of erosion.

4.1 Amount and intensity of rainfall:

Tropical rains are more erosive than temperate ones, because of the high intensity. A majority of the tropical rain storms fall in the category of 'erosion' storms while only 5 - 10 per cent of the temperate storms are erosive.

The mean rainfall intensity in tropical regions may be two to four times greater than in the northern latitudes. Roose (1971) observed in Abidjan, Ivory Coast, that it is common for 150 - 200 mm of rain to be received in 24 hours with a sustained intensity of 40 mm/hr. Lal (1976 c) reported peak rainfall intensities of upto 200 mm/hr in south western Nigeria. Ramaiah and Sreenivas (1975) reported intensities of 85-100 mm/hr sustained for 30 minutes in south India. Both amount and intensity influence the kinetic energy and erosivity of rainfall (Wischmeier and Smith, 1958; Hudson, 1971; Hudson, 1984 and Verma, 1984).

4.2 Terminal velocity:

The kinetic energy of a rainstorm is related to the velocity of the raindrops at the time of impact with the soil. The distance through which a raindrop must fall before attaining its terminal velocity is a function of drop size distribution (Wischmeier and Smith, 1960). When the rain is accompanied by wind there is an added sideway component of velocity and resultant terminal velocity may be greater than the still air velocity (Kowal and Kassam, 1977 and Hudson, 1984).

4.3 Momentum and kinetic energy:

Experimental evidences are numerous to prove that erosive power of rainfall is related to compound parameters derived from combinations of more than one physical property (Free, 1960). Yadav (1961) calculated the total energy of rain drops is being equal to roughly 100 hp on an acre during a rainfall of 0.1 inch/hr and 250 hp at a rainfall rate of 2 inches/hr. Rose (1960) argues that momentum is more related with erosivity of rainfall than the kinetic energy. However it has been shown that for natural rainfall, the relationship between intensity and either momentum or kinetic energy are of similar form (Lal, 1984 and Hudson, 1984).

4.4 Erosivity indices:

Experiments by various researchers have indicated that neither the rainfall amount nor the intensity is very highly correlated, with soil loss and run-off. Various attempts have been made to determine a combination of different rainfall parameters which would be a better index of erosivity than either the amount or intensity. Various indices have so far been developed and are mainly situation specific. The most widely used index is the R factor (EI_{30}) of the USLE (Wischmeier and Smith, 1958). It is the product of one hundreth of the kinetic energy of the storm in mt/ha cm and maximum 30 minutes rainfall intensity in cm/hr. Similarly EI_5 and EI_{15} are also in use. Hudson (1971) developed KE>1 index for Zimbabwe. It is the accumulative kinetic energy of storm with intensity greater than 2.5 cm/hr. He pointed out that storms with intensity of less than 2.5 cm/hr were not erosive. Lal (1976 a, b) reported a better correlation with the product of total rainfall amount (A) and peak storm intensity (I_m) than either EI_{30} or KE>1 for Nigeria. However, though the most widely used rainfall erosivity value, EI_{30}, be appropriate for many temperate regions, it may not be suitable for tropical regions, which have large number of thunderstorms and/or cyclones (Hudson, 1984 and Turner et al. 1984).

4.5 Erosivity and splash erosion:

When raindrops hit the soil they have a dispersive action. The detachment of soil particles by the raindrops splash was effectively demonstrated by Hudson (1957). When splash erosion was eliminated, he could reduce soil erosion to one hundredth of the soil loss from the unprotected plot. Mutchler and Young (1975) reported that raindrop splash was the primary agent in soil detachment and transport from interrill areas (Monke et al. 1977; Singer et al. 1981; and Luk, 1983). Several experimental evidences suggest that soil splash and intensity and hence erosivity are strongly correlated (Meyer, 1981 and Quanasa, 1981).

4.6 Erosivity and run-off:

The detached particles lead to sealing of the soil surface, plugging the soil pores, lowering infiltration and increasing surface run-off. With each successive rainfall on bare soil, the infiltration rate is reduced due to the increasing blockage of the macropores by the translocated particles. Then the run-off point occurs at a lower time and/or intensity interval leading to erosion (Yadav, 1961; and Uriyo, 1979). Better correlations were observed between run-off and various erosion indices by many workers. Lal (1976 c) reported highest correlation (r = 0.91) for AI_m with run-off in Nigeria. Correlation coefficients with other indices were 0.81 and 0.85, respectively, for KE>1 and EI_{30}. Viswambharan (1980) got good correlation for run-off with AI_m (r = 0.960) and total rain (r = 0.859) for Kerala. Teje and Agu (1982) in Ife area of south western Nigeria got consistently higher run-off from bare plot which was highly correlated with rainfall peak intensity, rainfall amount, El_{30}, El_{15}, KE>1 and AI_{15} indices in that order.

4.7 Erosivity and soil erosion:

Confirmation on the relation of rainfall erosivity and erosion came from the work of Wischmeier (1955) in the United States. The result summarised by Wischmeier and Smith (1958) showed that the factor most closely related to erosion was the kinetic energy of the rain. However, there was still considerable unexplained variation and on trying multiple regression, the best estimates of soil loss was found to be EI_{30}. Wischmeier's EI_{30} index had subsequently been extensively used in predicting soil loss (Wischmeier and Smith, 1978; Teje and Agu, 1982; Ulasker and Onstad, 1984 and Verma, 1984). Adequate research evidences are also there to support the inadequacy of EI_{30} index in explaining soil loss. Barnet (1958) found that maximum 60 minutes intensity was clearly correlated with soil loss. Das et al. (1967) recommended the use of EI_{15} for Nilgiris. In Dehra Dun, though daily and monthly EI_{30} values were better correlated with soil loss, annual values failed to show significant correlation (Rambabu et al. 1969). Viswambharan (1980) also reported EI_5 ($r = 0.95$) and EI_{15} ($r = 0.977$) as best indices in explaining soil loss, for Kerala condition.

In several studies of the tropics, erosivity index has been found to be less effective as a measure of erosivity than might be expected from Wischmeier's study in America (Hudson 1971 and 1984 and Turner et al. 1984). This has lead to the search for alternative methods. One such index is KE>1 developed by Hudson (1971) in Rhodesia. Excellent correlation for this index in laboratory splash cup studies ($r = 0.960$) are reported (Hudson, 1984). In

Nigeria, Lal (1976 b) found Al_m as the best to explain soil loss from small plots. He got a r value of 0.80 for Al_m, 0.65 for El_{30} and 0.64 for KE>1. Similar results were also reported by Teje and Agu (1982) and Ulasker and Onstad (1984).

5. Soil erodibility:

The erodibility of a soil (K) is its vulnerability or susceptability to erosion; that is the reciprocal of its resistance to erosion. It is a function of both physical characteristics of the soil and management of the soil (Hudson, 1984). Soils vary grately in their origin and manner of formation as well as in their management. Hence all indirect and empirical methods of estimating erodibility should be regarded only as second substitutes for direct measurement from undisturbed soil (Hamilton, 1977; Egashira et al. 1983 and Vanelslandae et al. 1983).

5.1 Topography:

Both steepness and length of slope contribute to erosion and run-off. Experimental evidences are exhaustive to support this. Increased soil loss and run-off with increase in steepness of slope were reported by many workers in many countries (Bhola et al. 1975; Balasubramanian and Sivanappan, 1981; Subhashchandra and Rao, 1984 a).

Length of slope has a similar effect on soil loss as degree of slope. On a long slope there will be a bigger build up of the amount of surface run-off and its velocity and depth. So for the longer slope there will be a greater total soil loss just because it is longer. Though it is widely accepted, there are reports of decreasing soil loss with increase in length on gentle slope beyond a limit (Subhashchandra and Rao, 1984 b).

5.2 Crop Management:

Crop cover is widely recognized as being of major importance in reducing the effects of raindrop impact on the soil. By minimizing splash erosion, rates of soil detachment are reduced, soil aggregates do not break down so readily, aggregate structure is retained, there is less surface crusting or sealing, infiltration rates remain high and surface run-off is reduced (Morgan, 1985 a).

5.2.1 Crop cover - its protective role:

Ellison (1944) was the first to recognize the protective role of crop cover in robbing the falling raindrops of its kinetic energy. With increase in crop cover/ground cover increased rainfall interception and dissipation of energy are reported by many workers

(Meyer et al. 1975 and Singh, 1984). When rainfall is intercepted, drops that directly penetrate the crop canopy accounts much of the throughfall kinetic energy and drops that are splashed from leaves are quite small and contain little kinetic energy (Quinn and Laflen, 1983 and Turner et al. 1984).

Multi-storey canopy structure offers an effective mechanism for cushioning raindrop impact. As rain water drips off the leaves, it is intercepted by the lower canopy layer so that when rain drop reach soil surface, it is no longer erosive (Celestinó, 1984). Increased crop canopy is hence invariably associated with lesser run-off (Lang 1979; Costin, 1980 and Lang and Mallett, 1984) and soil loss (Megahan, 1978; Singer et al. 1980; Singh, 1984 and Krishnarajah, 1985). Among various crops, a vegetative cover as complete as the artificial cover of wire gauze is only obtained from grass and forage crops (Hudson, 1984).

Unfortunately, research on crop cover effects is inadequate as a basis for conservation planning. Wischmeier (1975) argues that soil erosion decreases with increasing crop canopy cover in a linear relationship whereas Shaxson (1981) clearly states that the relationship is exponential. Experimental evidences exist for both relationships. Foster

(1982) favours an exponential form for mulches and crops in close proximity to the ground surface but a linear relationship for taller crops. Hussein and Laflen (1982) obtained a linear relationship for interrill erosion and an exponential relationship for rill erosion, in their work with crop residues. Further there are also reports on instances where soil detachment unexpectedly increase with crop cover (Noble and Morgan, 1983 and Finney, 1984). More fundamental work on crop cover effects is clearly warranted, so that crops can be correctly classified according to their protection effectiveness.

5.2.2 Crops and soil structural improvement:

Apart from the energy dissipating function, crops improve the soil physical structure so that there is increased porosity, infiltrability and aggregate stability and consequent reduction in run-off and soil loss. Uriyo (1979) observed that under permanent vegetative cover, infiltration rate was normally greater or equal to the hydraulic conductivity of the soil. In the work reported from Namalongae, Uganda, ten times more run-off occurred from bare plots than from grass covered plots and a grass mulch cover was twice as effective than a stone mulch, interms of run-off control (Uriyo, 1979). Increased moisture storage capacity of the soil provided by the transpiratory withdrawal of growing crops results in high infiltration rate (Venktaraman, 1978). Zein et al. (1980) reported high hydrolic conductivity values in the vicinity of the roots of shallow rooted crops. Low bulk density, high porosity and increased soil aggregation were also reported by other workers in grass covered plots (Williams, 1963 and Colbrone and Staines, 1985). Following tuber development, decrease in soil bulk density and lower run-off for cassava than for maize was seen in Nigeria (IITA, 1980). Lately (1985) argues that the effect of crops on important soil physical properties is indirect rather than direct. No correlation between plant growth and soil physical properties such as texture, structure and bulk density will occur except for special management practices.

5.2.3 Crop Management factor (C):

This is the measure of protective ability of a crop against soil erosion. It is really the most complicated factor that there is an almost infinite number of different ways of managing the crop growth. The worst practice has a C value of 1, but good management techniques have C values down to 0.05 (Hudson, 1984). This means a reduction of erosion to one twentieth of the worst, by following good management practices.

There is a wealth of information on the C values of various crops. Battawar and Rao (1969) observed that C values were high in the initial stages due to poor cover. As vegetative cover increased, C values decreased and soil loss was reduced. Nema et al. (1978) reported C values of 0.47, 0.37 and 0.32, respectively, for mung, groundnut and cowpea. Rao (1984) observed a C value of 0.35 for paddy and Narain et al. (1982) 0.01 for grass.

6. Universal soil loss equation (USLE):

According to Morgan (1985 a) the most widely used tool in conservation planning is the USLE (Wischmeier and Smith, 1978). In a given situation total soil loss is predicted as per the equation.

$$A = RKLSCP$$

Where A = Soil loss in tonnes

R = Rainfall erosivity index

K = Soil erodibility factor

L = Slope length factor

S = Slope steepness factor

C = Crop management factor

P = Conservation practice factor

But many authors are of the opinion that it is far from being 'universal'. In fact it is very limited both in its geographical applicability and its purpose. In many situations, it renders over estimation or poor estimation (Rose, 1984 and Karmer, 1984). Hart (1984) observed greatçly over estimated values on dry soils but were within 13-51 per cent of measured losses on pre-wetted plots with a 10 per cent slope. USLE estimated values were much poorer on steeper slopes beyond 10 per cent.

7. Mechanical composition of eroded soil:

Eroded soils are richer than the soil matrix in respect of colloided particles (Alberts et al. 1977 and Loch and Donnollan, 1983). This is attributed to the basic differences in the mechanism of detachment and transport of rill and interrill aggregates (Alberts et al. 1977). The rill flow transports greater proportion of larger particles as compared to interrill flow.

8. Nutrient loss:

The extent of loss of nutrients through surface run-off and soil erosion by water may be quite formidable in subtropical and tropical soils. Kanwar (1972 a) reported that even at the lowest approximation, India is annually losing about 2.5, 3.8 and 2.6 million tonnes of

N, P_2O_5 and K_2O, respectively, which is much greater than the consumption of these nutrients in India through fertilizers.

Soil erosion and run-off of NO_3 (or total N) may be the most significant cause of pollution of surface water from the agricultural lands resulting in N enrichment and eutrophication (Singh and Biswas, 1982). Though there are reports of 0.01 to 2.20 ppm of N in run-off, well below the accepted public health standards (Barnet et al. 1972), higher contents are observed especially from well fertilized plots (Mc Coll, 1983 and Alberts and Spomer, 1985). However, it has been emphasized that well managed and fertilized lands under efficient crop rotation would have lesser or no N losses as compared with fallow, poorly managed and fertilized lands (Kanwar, 1972 b; Barisan et al. 1978; Mc Dowell and Mc Gregor, 1980 and Jayaram et al. 1984).

Phosphate losses may take place basically through soil erosion by water. Run-off loss of P is usually small (Barisan et al. 1978 and Singh and Biswas, 1982). But Mc Coll (1983) found dramatically higher concentration of P in surface run-off of a fertilized pasture land in Newzeland. From the available studies it is generally contented that, under tropical and sub-tropical conditions, P loss due to erosion by water may not be much (Singh and Biswas, 1982).

Erosion is the most serious cause of K loss and it may be substantial (Kanwar 1972 b). Since K contents are higher in soil, the eroded materials has more K than N and P but the recyling process is so strong that K seldom enriches the water. Effective crop rotation and grass cover reduces K loss through eroded soil to negligible level (Jayaram et al. 1984). The fate of applied potash in soil is determined by the CEC of a soil and the reaction rate with which water soluble potassic fertilizers contribute K ions and their adsorption on the exchange complex. This would mean that in soils of low CEC there would be greater chances of K loss (Singh and Biswas, 1982).

However, not much is known about the loss of soil nutrients under tropical farming systems. In view of the implications for pollution and loss of soil productivity, research is urgently required to collect basic information from farm situations (Morgan, 1985 b).

9. Crop management measures for soil conservation:

The orderly arrangement of all the factors affecting erosion into the universal soil loss equation provides an opportunity to compare the relative importance of each factor in the control of erosion. The humanly controllable variables are slope length (L), conservation practice (P) and crop management (C). By restoring the improved methods, both L and P values can be reduced to half resulting in a halving of soil loss (Hudson, 1984). But the effect of crop management is very different. The worst practice has a C value of 1.00 and good management techniques have C values down to 0.05. This means a reduction of erosion to one twentieth of the worst case, and good crop management can be upto ten times more effective in reducing erosion than any other measures. Further, the conventional soil conservation efforts in the form of peurtorican terraces are costly and take time to complete (Menon, 1984). If soil conservation programmes are to be successful, they must be taken up by farmers and they must work. Therefore, they must be compatible with the current farming system and relevant to the erosion system (Hudson, 1984; Morgan, 1985 a and Abujamin et al. 1985). Here comes the importance of agronomic and crop management measures for soil conservation.

Agronomic measures of soil conservation relate to the role of crop cover and soil management includes the use of fertilizers and tillage practices. Because of the greater erosivity of tropical humid climate, the maintenance of a cover over the soil assumes greater importance (Hudson, 1957). Shaxson (1981) argues that the effects of crop cover are so enormous that more effort should be made to integrate crop cover with other soil conservation works.

Experimental evidences are exhaustive to support that soil detachment hazard is inversely proportional to the resistance factor of surface covers and mulches in reducing run-off and soil loss (Robinson, 1979; Orsi, 1984 and Ghidey et al. 1985). But defective cultivation practices like mound planting of cassava without any ground cover or row planting of maize/sorghum down the slope can aggravate the process of soil erosion. Similarly, closely growing crops like grass, rice and cover crop will usually suffer less soil erosion. On analysing the effect of crop management, (Hudson,1984) strongly criticises the topical classification of some crops as 'soil-depleting' and some as 'soil-binding' and emphasise that it is not the crop which is or is not soil depleting but the crop management. Various management practices such as intercropping (Bhola et al. 1975; Bhatia, 1980 and Hudson, 1984), crop rotation (Moldenhauer et al. 1967; Saraiva et al. 1982 and Hudson 1984), strip cropping (Robinson, 1979; Abujamin et al. 1985), mulching (Robinson 1979 and Ghidey et al. 1985) and conservation tillage (Mutchler et al. 1985) have been recommended for reducing soil loss.

The comparison of soil conservation experiences in different countries highlighted the difficulty of transferring technologies from one country to another. Local environmental conditions and farming systems, need to be taken into account, so that technology can be made more appropriate before it is adopted. There is urgent need for soil erosion control in all countries but the planning and implementation of soil conservation must necessarily be country specific and sometimes region-specific or even economic-sector specific (Morgan, 1985 b).

Cassava growing has been widely adopted by subsistence farmers because of the low maintenance cost, quick returns and high resistance to pests and diseases. But heavy rainfall, coupled with faulty methods of cultivation, results in severe soil loss from cultivated area during the early stages. In Kerala, consequent to lack of proper conservation measures, an alarming majority of hill slope farmers suffer from the self generating cycle of poverty, erosion and low crop productivity. Agri-silvi-pastural measures involving woody perennials and soil binding crops such as grass/rice can yield economically and ecologically viable solutions to this

(Nair, 1984). Researches on this line are still at the infant stage.

10. Taungya systems:

Taungya is an agricultural operation, in which forest land is used for growing agricultural crops during the initial two-three years of forest plantation. Like shifting cultivation, the taungya system in the tropic is also a fore runner to agro-forestry. Crops such as rice, cassava, ginger, sesamum and pulses are grown along with the trees. It is reported to have originated in Burma (Blanford, 1958) and the word in Burmese language means hill (taung) cultivation (ya). Most of the forest plantations that have been established in Asia, Africa and Latin America owe their origin to the taungya systems (King, 1979 and Nair, 1984). Taungya is in vogue in Kerala forestry since 1922 (Alexander et al. 1980).

11. Taungya and soil erosion:

Soil erosion hazard is the most severe problem in many of the taungya plantations. During the initial years of tree growth the protective mechanism of trees is not properly developed. This factor, along with the hazardous agricultural operations and management practices, aggravate the process of soil loss in taungya lands. Experiments at International Institute of Tropical Agriculture

Ibadan, Nigeria indicate a soil loss of upto 120 t/ha in the first year after land clearing (IITA, 1980). A report from China indicates that under tropical monsoon climate, on gentle eroded slopes there will be about 15000 m^3 of soil loss per km^2 during the initial 10 years of forest establishment (Xiaoliang Experimental and Extension Station of Soil Conservation, 1977). Alexander et al. (1980) observed that soil loss is so visible in many taungya areas that the surface horizons are partly being eroded and the subsurface horizons are gradually exposed. Though indirect projections on soil loss are available (Alexander et al. 1980) correct quantification of soil, run-off and nutrient losses in various taungya system practiced in Kerala based on clearly laid field studies are practically absent. This still remains as a lacuna in conservation planning and sediment control.

The situation of effective nutrient conservation and sustainable soil productivity of a tropical forest does not exist in man made commercial timber plantations. After a comprehensive study, Lundgren (1978) concluded that the establishment of the most commonly used fast growing plantations after forest clearing (conifers, eucalyptus and teak) is associated with pronounced deterioration of soil physical, biological and/or chemical conditions. A rapid decline in fertility and changes in bulk density of the soil have also been reported (Cornforth, 1970 and Wood, 1977). Alexander et al. (1980) reported that, if the forest land is not properly managed in taungya, productive land will be converted into unproductive marginal land. Two years of cultivation without proper soil management practices can convert productive area into unproductive one. However, from investigations in three ecological zones of southern Nigeria, Ojeniyi et al. (1980) opinioned that the practice of interplanting young forest plantations with food crops would not have any adverse effect on soil fertility. Further, interplanting of young Gamelina arborea with maize, yam or cassava resulted in slight but insignificant increase in soil N and P (Ojeniyi and Agbede, 1980).

Taungya with proper soil management practices is protective as well as productive in nature. Cultural soil conservation methods such as maintenance of vegetate cover, under growth, undercrops, mulches and intercropping are preferred during taungya periods against the expensive mechanical methods of soil conservation (Alexander et al. 1981). Contour planting of trees and grass stripping etc. are reported to control soil erosion even on steep mountain slopes of above 50 per cent (Misra et al. 1982; Hurni and Nuntapong, 1983 and Abujamin et al. 1985).

Materials and Methods

MATERIALS AND METHODS

A field experiment was carried out under taungya systems of cultivation with the main objective of minimising run-off and soil loss in a steeply slopping farm situation. The trial was conducted at the Instructional Farm, College of Horticulture, Vellanikkara for a period of two years from May 1984 to April 1986.

1. Materials:

1.1 Site characteristics:

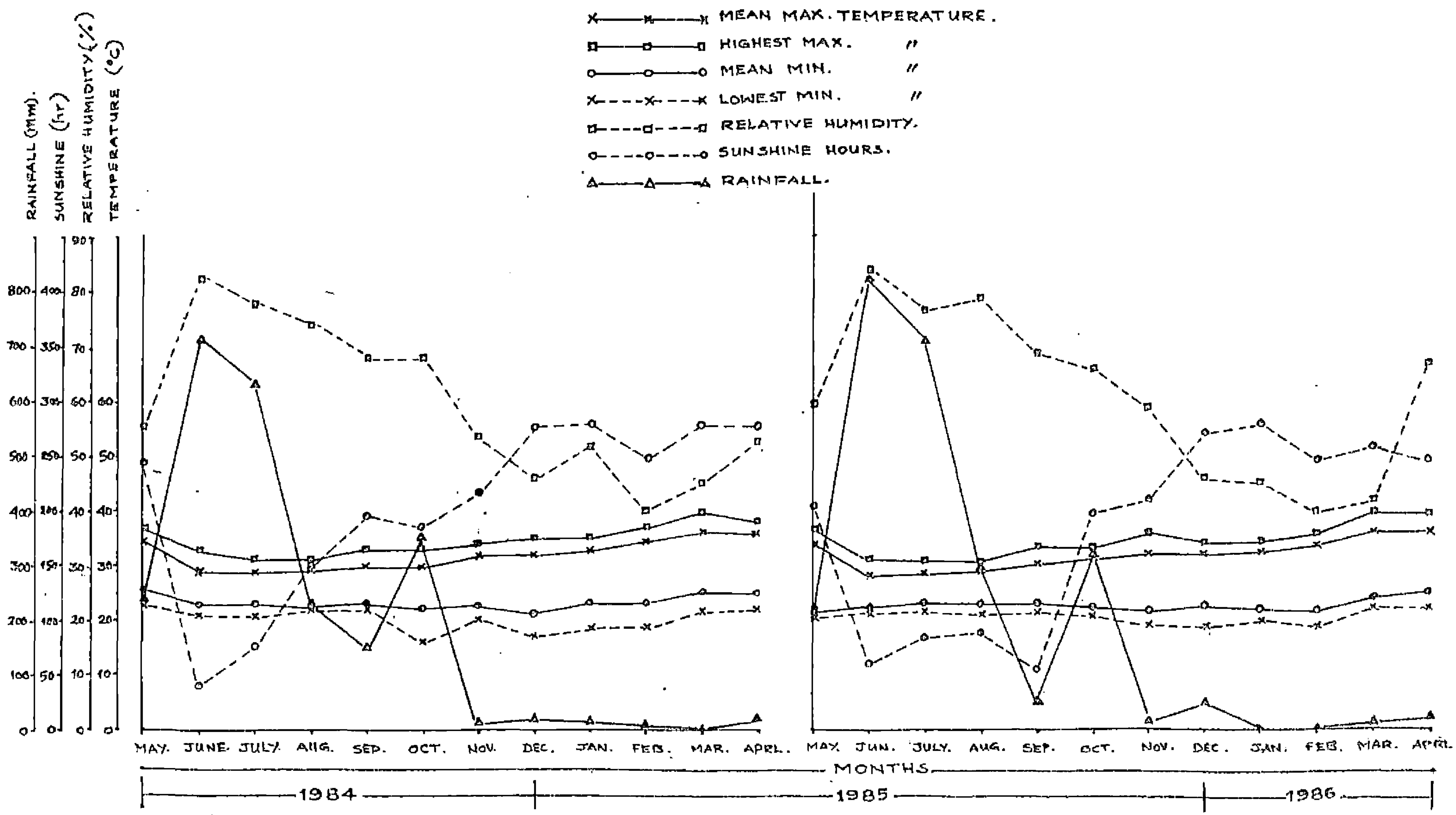
The field was situated at 10° 32' N latitude and 76° 10' E longitude with an altitude of 22.25 m. The area had a slope of 25 per cent towards north. General view of the experimental site is given in Plate-I.

1.2 Climate:

The area enjoyed a humid tropical climate. Monthly average values of important meteorological parameters observed during the period of experiment are furnished in Appendix-I and Fig.1.

The maximum temperature varied between 28°C and 36°C with a highest daily maximum of 40°C in March in both years. With regard to the minimum temperature in the first year, the lowest value of 20.8°C was recorded

FIG. 1. _MONTHWISE METEOROLOGICAL DATA.



in December and the highest of 25.8°C in May. These values were 21.3°C and 24.3°C, respectively, in May and March during second year. The lowest minimum was 16°C in October, 1984. June was the most humid month recording average humidity above 80 per cent and February the most dry with 40 per cent in both years. In 1984, a total of 2383 mm rain was received through 141 events spreading over 115 rainy days. The corresponding values for 1985 were 2517, 132 and 108, respectively. In both years, June received the highest rainfall and it was 709 mm in 1984 and 829 mm in 1985. The north-east monsoon peak was observed in October in both years with a value of 351 mm in the first year and 321 mm in the second year.

1.3 Soil characteristics:

The soil of the experimental area was shallow, well drained, moderately acidic oxisol with a sandy clay loam surface texture. Morphological features of a typical profile of the experimental area are presented below:

Location	:	Instructional Farm, College of Horticulture, Vellanikkara.
Vegetation	:	Heavily infested with weeds such as <u>Chromolaena odorata</u>, <u>Pennisetum polystachyon</u> and <u>Passiflora edulis</u>
Parent material	:	Weathered Gneiss

Topography	:	Slopping land - 25 per cent slope towards north.
Drainage	:	Well drained with moderately rapid to moderate permeability.
Ground water table	:	Deep > 10 m.

Horizon	Depth (cm)	Description
AP	0-25	Reddish brown (5 YR 4/4); moist sandy clay loam, medium moderate granular; moist friable slightly sticky and slightly plastic, fibrous roots abundant, permeability rapid, clear wavy boundary.
B21	25-56	Yellowish red (5 YR 4/6); dark red (2.5 YR 3/6); clay loam, medium moderate sub-angular blocky; dry hard; moist firm, wet sticky and plastic; fine quartz, gravel and weathered rock fragments present. Permeability moderately rapid; diffuse wavy boundary.
B22	56-110+	Yellowish red (5 YR 5/8) yellowish red (5 YR 4/6) clay loam, moderate coarse sub-angular blocky, moist firm, wet sticky and plastic; red (2.5 YR 4/6) and strong brown (7.5 YR 5/8) mottles plenty. Initial stages of laterisation, moderate permeability.

1.3.2 Physical and chemical characteristics:

The physical and chemical characteristics of the soil are given in Table 1.

1.3.3 Infiltration:

The steady-state infiltrability of the soil was 11.40 cm/hr with an initial infiltration rate of 82.80 cm/hr for the first five minutes. Cumulative infiltration was 81.70 cm over a period of 300 minutes. Average initial moisture content of the soil upto a depth of 30 cm was 17.63 per cent at the time of observation.

1.4 Crops:

Crop combinationsof the trial consisted of the following:

1.4.1 Tree:

Eucalyptus teriticornis, a fast growing species was the tree component of the experiment.

1.4.2 Cassava:

A local variety called 'Velanki', commonly cultivated in the hill tracts, was used.

1.4.3 Rice:

Modan (upland) rice variety Ptb.28 was used.

Table 1. Physical and chemical properties of 2 mm sieved soil of the experimental area

No.	Characters	Depth (cm)			
		0-25	25-50	50-75	75-100
I.	Physical properties:				
1.	Particle size distribution:				
	a) Coarse sand (%)	28.96	26.94	24.48	24.00
	b) Fine sand (%)	21.18	24.18	18.96	16.71
	c) Silt (%)	14.56	14.78	16.38	16.31
	d) Clay (%)	31.32	31.10	38.76	42.80
2.	Particle density (g/cm^3)	2.56	2.54	2.56	2.58
3.	Bulk density (g/cm^3)	1.34	1.40	1.51	1.58
4.	Total porosity (%)	48.43	44.88	41.02	38.76
5.	Field capacity (%)	20.42	19.36	19.10	19.78
6.	Permanent wilting point (%)	13.09	14.48	14.41	14.36
II.	Chemical properties:				
1.	N (%)	0.148	0.135	0.112	0.100
2.	P (%)	0.054	0.046	0.048	0.034
3.	K (%)	0.226	0.180	0.170	0.114
4.	Ca (%)	0.058	0.043	0.035	0.049
5.	Mg (%)	0.224	0.174	0.144	0.145
6.	S (%)	0.101	0.080	0.071	0.069
7.	Fe (%)	3.460	3.960	4.650	4.880
8.	Zn (ppm)	96.27	92.53	94.14	113.30
9.	Mn (ppm)	456.87	428.07	312.43	236.25
10.	Organic carbon (%)	1.46	1.41	1.18	1.10
11.	pH	5.80	5.85	6.00	6.15
12.	CEC (meq/100 g)	12.34	11.39	12.00	10.31

1.4.4 Grass:

A drought tolerant spreading type grass known as 'Congosignal' (*Brachiaria ruziziensis*) was selected.

1.5 Season:

The experiment was started in the first week of May 1984 and continued upto the last week of April 1986.

1.6 Fertilizers:

The crops, except eucalyptus were fertilized as per the schedule indicated below (KAU, 1982).

Crop	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Cassava	50	50	50
Rice	40	20	20
Congosignal	100	50	50

Urea (45%), single Superphosphate (18%) and Muriate of Potash (60%) were used to supply the nutrients at the above rates.

1.7 Plant protection:

Plant protection operations were done as and when required.

2. Methods:

2.1 Lay out of the experiment:

Design : 7 x 3 RBD.

Plot size : 24 x 4 m^2.

Lay out plan is given in Fig.2. The plots were arranged lengthwise along the slope facing north.

2.2 Treatments:

T_1 - Eucalyptus alone.

T_2 - Eucalyptus + five cassava on mounds in between four trees.

T_3 - Eucalyptus + four cassava on ridge across the slope in between four trees.

T_4 - Eucalyptus + one cassava on mound as laid down in the taungya contract regulations.

T_5 - Eucalyptus + congosignal grass.

T_6 - Eucalyptus + modan rice.

T_7 - Cultivated fallow*

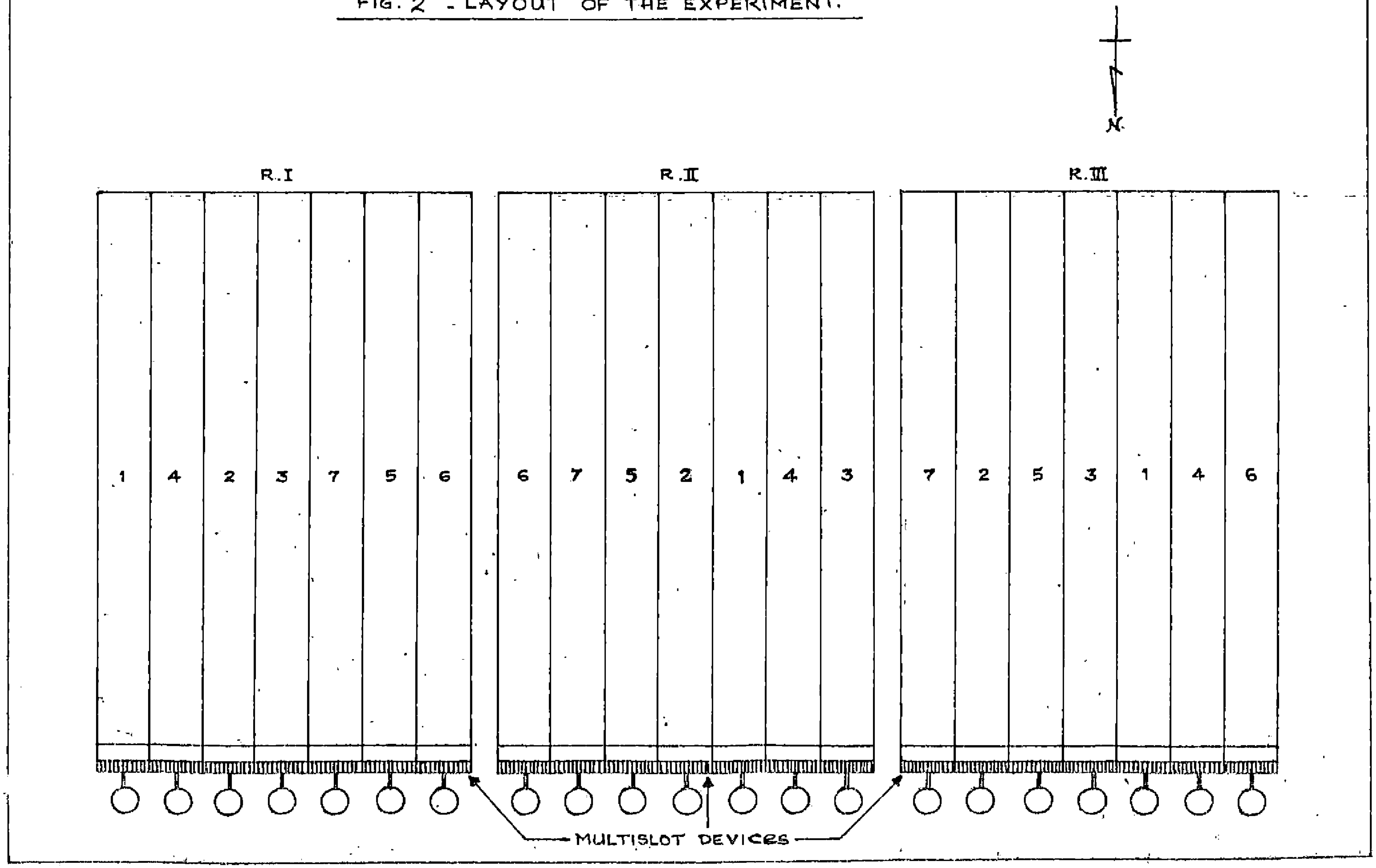
In the second year of the experiment cultivated fallow plot was changed to Eucalyptus + cassava on mounds as in T_2 + congosignal grass strips. Three grass strips of one m width each were uniformly spaced.

Spacing details of trees and crops are presented in Fig. 3 and 4 and Plates II - IX.

2.3 Demarcation of plots:

Strong earthen bunds and drainage channels were

FIG. 2 - LAYOUT OF THE EXPERIMENT.



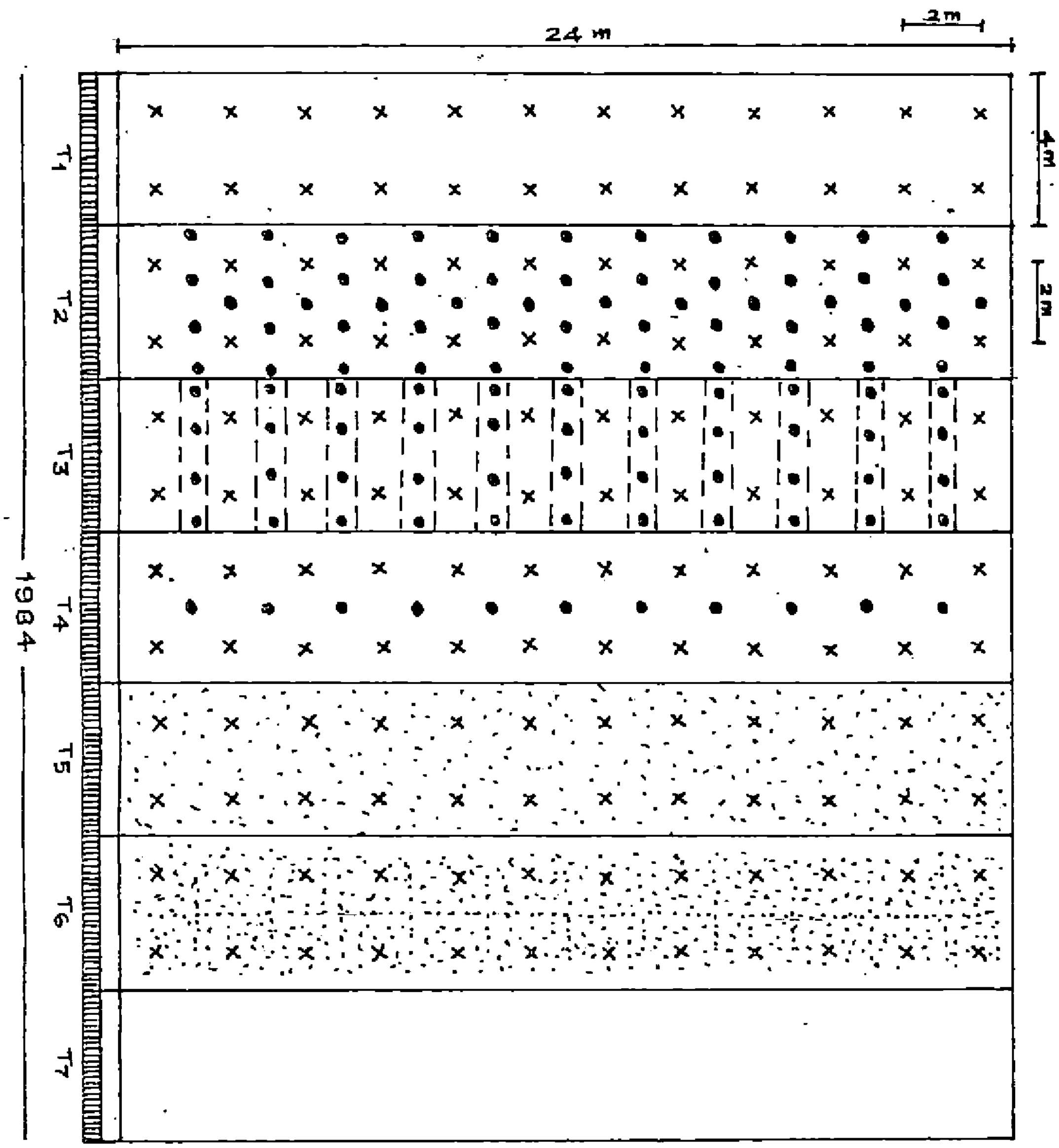
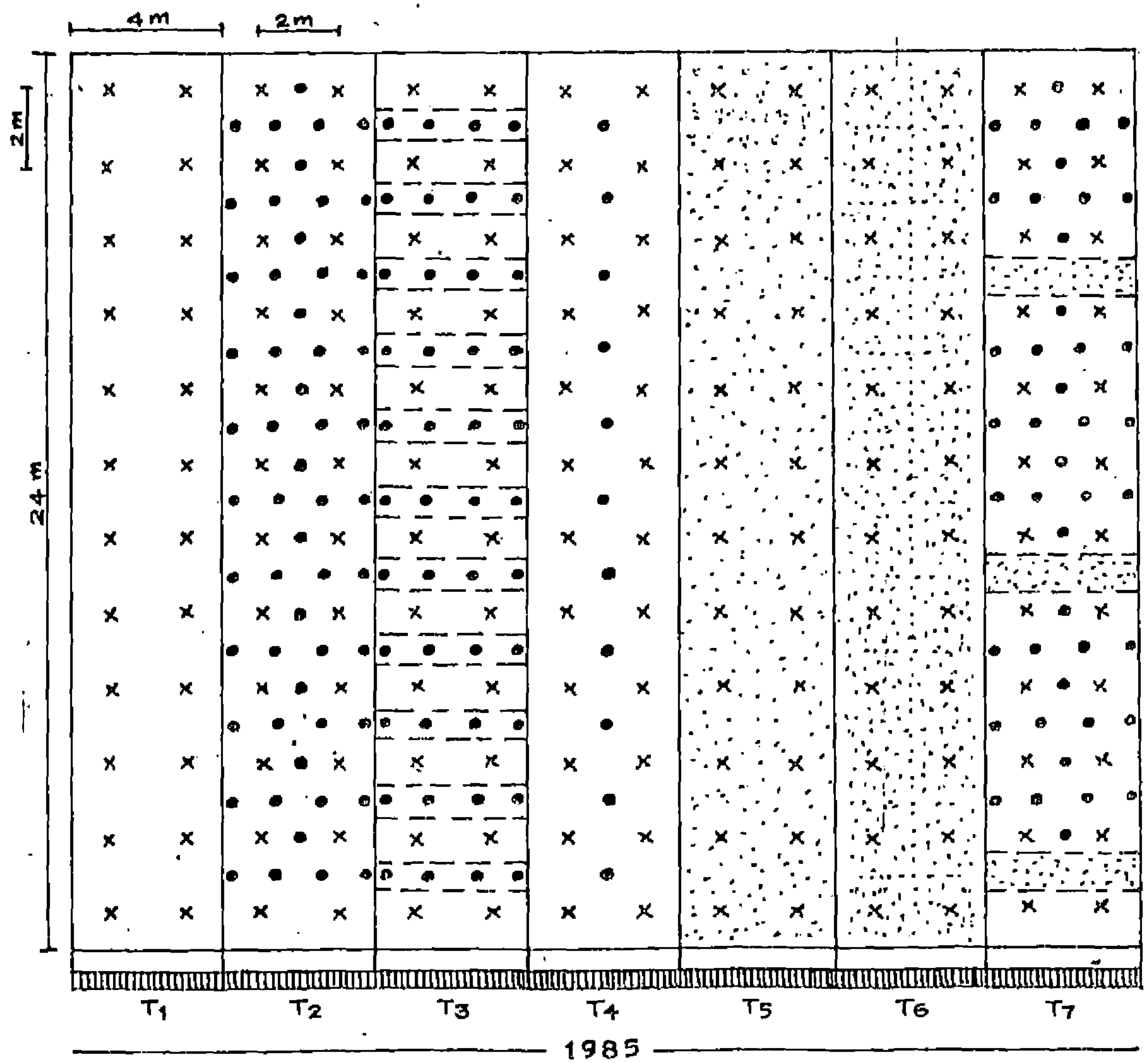


FIG. 3 - TREATMENTS - 1984

T1 - EUCALYPTUS ALONE.
T2 - EUCALYPTUS + CASSAVA ON MOUNDS (TRIANGULAR PLANTING).
T3 - EUCALYPTUS + CASSAVA PLANTED ON RIDGES ACROSS THE SLOPE.
T4 - EUCALYPTUS + CASSAVA ON MOUNDS AS LAID DOWN IN THE TAUNGYA-CONTRACT REGULATION.
T5 - EUCALYPTUS + CONGOSIGNAL GRASS.
T6 - EUCALYPTUS + MODAN RICE.
T7 - CULTIVATED FALLOW.

FIG. 4 - TREATMENTS - 1985



T1 - EUCALYPTUS ALONE.
T2 - EUCALYPTUS + CASSAVA ON MOUNDS (TRIANGULAR PLANTING).
T3 - EUCALYPTUS + CASSAVA PLANTED ON RIDGES ACROSS THE SLOPE.
T4 - EUCALYPTUS + CASSAVA ON MOUNDS AS LAID DOWN IN THE TAUNGYA-CONTRACT REGULATION.

T5 - EUCALYPTUS + CONGOSIGNAL GRASS.
T6 - EUCALYPTUS + MODAN RICE.
T7 - EUCALYPTUS + CASSAVA ON MOUNDS + GRASS STRIPS.

provided around the experimental area to prevent the outside run-off from entering the experimental plots. The individual plot was also demarcated by mud-plastered round topped earthen bunds of 60 cm width and 30 cm height.

2.4 Run-off collection:

A run-off collection device specifically designed for this purpose was made use of for collecting the run-off. Brick masonry tank was provided at the bottom end of each plot so as to cover its effective width. The tank of size 3.4 x 0.75 x 0.35 m^3 served as the settling tank as well as the initial container to receive the eroded soil and run-off. A multi-slot device with 47 slots of size 2.5 x 10 cm^2 each was fixed at 0.35 m height on the outer edge of the settling tank exactly on the horizontal plane (Fig. 5 and Plate-X) so as to divide the run-off into 47 equal parts (Plate-XI). A plastic net was fixed vertically inside the tank, 15 cm ahead of the multi-slot device to filter the floating debris. A polythene delivery tube of 4 cm diameter and 1.25 m length attached to the spout provided around the central slot of the device was connected to a run-off receiving drum. The drum was covered with G.I. sheet to avoid addition of direct rain.

Fig. 5 - MULTI-SLOT DEVICE.

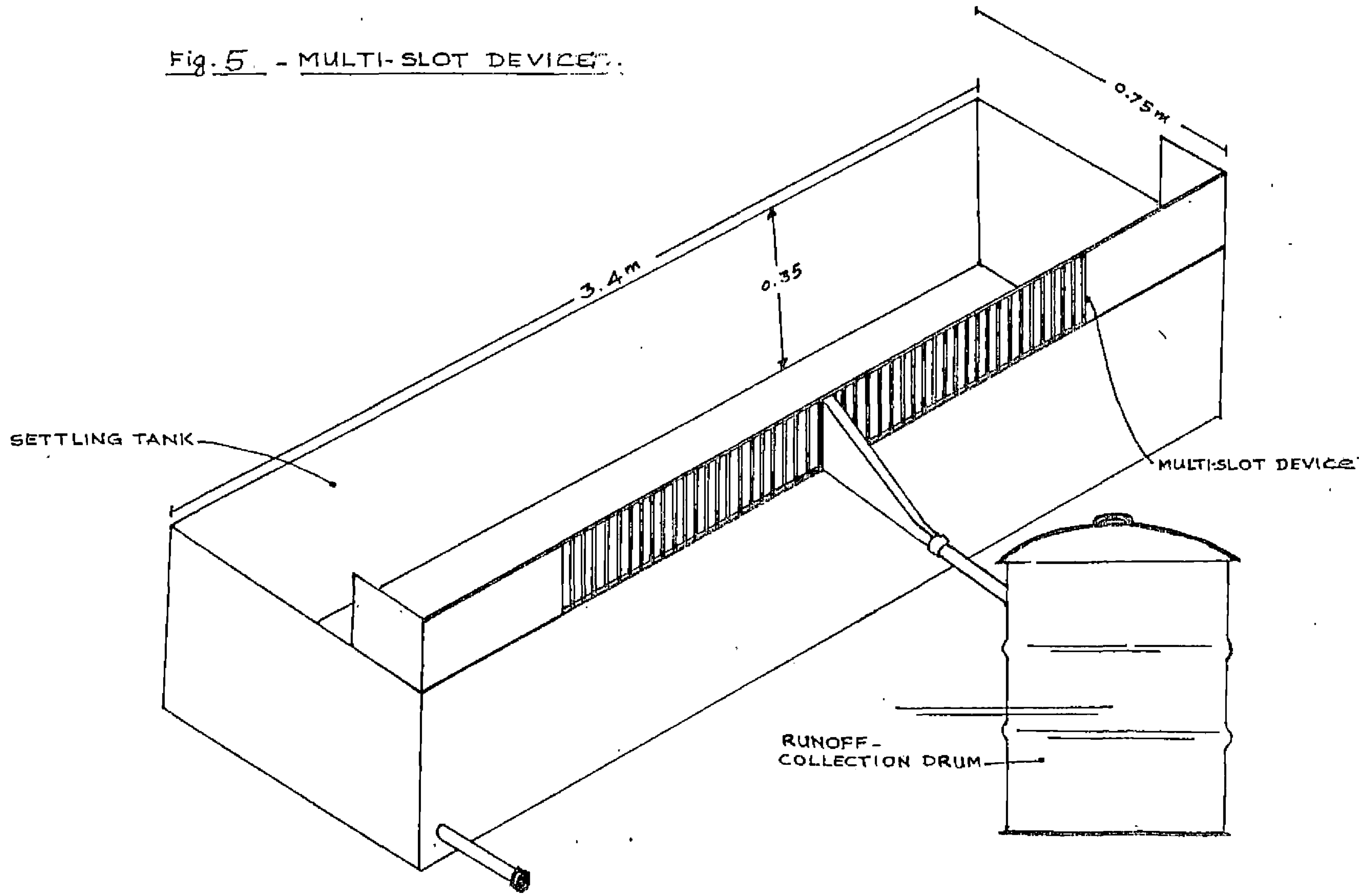


Plate I General view of the experimental area.

Plate II T_1-Eucalyptus alone
(One month after the experiment)

Plate
I

Plate
II

Plate III T_2 - Eucalyptus + five cassava on mounds in between four trees
(One month after the experiment)

Plate IV T_3 - Eucalyptus + four cassava on ridge across the slope in between four trees
(One month after the experiment)

Plate III

Plate IV

Plate V T_4 - Eucalyptus + one cassava on mound in between four trees (One month after the experiment)

Plate VI . T_5 - Eucalyptus + congosignal grass (One month after the experiment)

Plate V

Plate VI

Plate VII T_6 - Eucalyptus + modan rice
(One month after the experiment)

Plate VIII T_7 - Cultivated fallow

Plate VII

Plate VIII

Plate IX T_7 of the second year - Eucalyptus + five cassava on mounds + 10% grass strips (two months after the experiment)

Plate IX

Plate X The whole set of multi-slot devices.

Plate XI Working of a multi-slot device.
Note the uniform flow of run-off through each slot.

Plate X

Plate XI

2.5 Run-off estimation:

Run-off was estimated once in 24 hours at 8.30 AM by the procedure outlined below.

The height of the water column in the run-off collection tank was measured and the total volume of run-off and settled sediment load was calculated. Volume of settled sediments was also determined using mass density relationship. The actual volume of run-off in each tank was found out by deducting the sediment volume from the total volume.

The volume of water collected in the run-off collection drum was calculated and this was multiplied by the number of slots viz. 47, to arrive at the total quantity of run-off flowing down through the device. Total run-off from each treatment was then found out by adding this to the volume of run-off in the collection tank, calculated earlier. Since the settling tanks were not covered, corrections were made to the total volume of run-off for evaporation losses and rainfall received (if any) directly in the tank.

2.6 Estimation of soil loss:

2.6.1 Settled sediments:

The conventional method of estimating soil loss by drawing and drying thoroughly stirred run-off samples from the run-off collection tanks (Verma, 1984) was not followed because of the observed error of upto 16.32 per cent. This was mainly because of the difficulty in getting the heavier soil particles in suspended state while sampling. Procedure followed in the investigation is explained below.

The water in the tank was slowly and carefully drained out through the outlet provided at the lower end of the tank. After draining off the water completely, soil collected in the tank was thoroughly stirred and a representative sample of 500 g was drawn for moisture determination. Wet weight of the whole eroded soil in the tank was noted and the corresponding dry weight was worked out based on the moisture content.

2.6.2 Suspended sediments:

Suspended sediment in the run-off was estimated as follows:

A representative sample of 250 ml was collected in plastic bottles from three different depths of the collection tank. A bottle closed with forefinger tip was immersed carefully to the bottom of the tank without disturbing the settled sediments. Then the fingertip was slowly released to fill approximately 1/3rd of the bottle. Water from two more levels viz. middle and upper, was also collected to make the bottle full.

A sample of 250 ml was drawn from the run-off collection drum by stirring the water thoroughly with a laddle.

The sample of soil suspension collected was flocculated, the sediments separated and dried to constant weight separately. Weight of suspended sediment was then multiplied by the corresponding volume of run-off and added to get the total suspended sediments.

2.6.3 Total soil loss:

Sum of settled and suspended sediments constituted the total soil loss of each treatment and was expressed in t/ha.

2.7 Sampling for analyses:

2.7.1 Run-off:

About 250 ml of run-off drawn both from the settling tanks and drums on each day were preserved by adding a few drops of toluene. These were pooled together and representative monthly samples were taken for analyses.

2.7.2 Settled sediments:

Roughly 250 g of representative sample of settled sediments on each day was drawn, dried and pooled together month-wise. Sufficient quantities of samples were taken from this lot for various analyses.

2.7.3 Suspended sediments:

As explained in item 2.6.2, samples of soil suspension were taken on each day, mixed and pooled month-wise. Required quantities of representative samples were taken and dried to get adequate amounts of sediments for analyses.

2.8 Rainfall characteristics:

To understand and arrive at the actual relationship between various rainfall characteristics vis-a-vis run-off and soil loss, daily rainfall were studied in detail. An automatic recording raingauge, installed at the experimental area sufficiently away from all sorts of crop canopy hinderance provided the required data. Rainfall which produced run-off were subjected to analyses. The raingauge chart observation were checked with a 122 mm ordinary raingauge. The daily rainfall chart was used for studying the following characteristics of rainfall.

2.8.1 Total rainfall (mm).

2.8.2 Maximum rainfall intensities for 15 and 30 minutes intervals (cm/hr).

2.8.3 Total kinetic energy of rain as per the equation.

$$K.E. = 210.3 + 89 \log_{10} I$$ (Wischmeier and Smith, 1958)

where;

K.E. = Kinetic energy (mt/ha cm of rainfall)

and

I = Rainfall intensity (cm/hr)

2.8.4 Rainfall erosivity factor (R):

Two rainfall erosivity indices viz. EI_{15} and EI_{30} were calculated for each storm (Wischmeier and Smith, 1958) as follows. All storms which produced erosion were considered for computing R.

$$EI_{15} = \frac{\text{Total kinetic energy} \times \text{Maximum rainfall intensity in 15 minutes}}{100}$$

$$EI_{30} = \frac{\text{Total kinetic energy} \times \text{Maximum rainfall intensity in 30 minutes}}{100}$$

2.8.5 Amount x Intensity maximum factor (AI_m)

It is the product of total amount of rainfall and the peak storm intensity (Lal, 1976 a).

2.8.6 Total duration of the rainfall (hr)

2.8.7 No. of rainfall events per day. Events separated by more than 6 hours were considered as different storms (Verma, 1984).

2.9 Determination of parameters of Universal Soil Loss Equation (USLE)

Most widely used USLE proposed by Wischmeier and Smith (1960) is

$A = RKLSCP$ where,

A = Computed soil loss per unit area expressed in the same units as K for period specified for R. It is generally expressed as t/ha/yr.

R = Rainfall intensity factor

K = Soil erodibility factor

L = Slope length factor

S = Slope gradient factor

C = Crop management factor

P = Supporting conservation practice factor

2.9.1 Rainfall erosivity factor (R):

Two rainfall erosivity indices viz. $EI_{15} (R_1)$ and $EI_{30} (R_2)$ were worked out as described in item 2.8.4.

2.9.2 Soil erodibility factor (K):

$$K = \frac{\text{Total adjusted soil loss (A)}}{R_1 \quad \text{or} \quad R_2}$$

$$A = \frac{AO}{S} \quad (t/ha)$$

Where A = Soil loss from a cultivated fallow plot of 22.13 m length and having 9 per cent slope.

AO = Observed soil loss (t/ha)

S = Slope factor (65.41 Sin 14.04^2 + 4.56 Sin 14.04 + 0.065)

2.9.3 Topographic factor (LS):

L and S factors mentioned above have been combined and topographic factor was worked out as follows:

$$LS = \left(\frac{24}{22.13}\right)^{0.5} \times (65.41 \sin 14.04^2 + 4.56 \sin 14.04 + 0.065)$$

(Wischmeier and Smith, 1960)

2.9.4 Crop management factor (C):

C factor for any stage of crop growth is equal to the product of per cent of annual R value and per cent soil loss for that stage divided by 10,000 i.e.

$$C = \frac{\% R \times \% \text{ soil loss}}{10{,}000}$$

Consequent to the change of treatment in T_7 as specified in item 2.2. C values in the second year were estimated based on the soil loss observed from a cultivated bare fallow plot laid temporarily on identical situation.

2.10 Splash erosion:

Splash erosion in each treatment was measured by installing the splash collection apparatus suggested by Verma (1984).

The splash measuring device (Fig.6) was installed as follows:

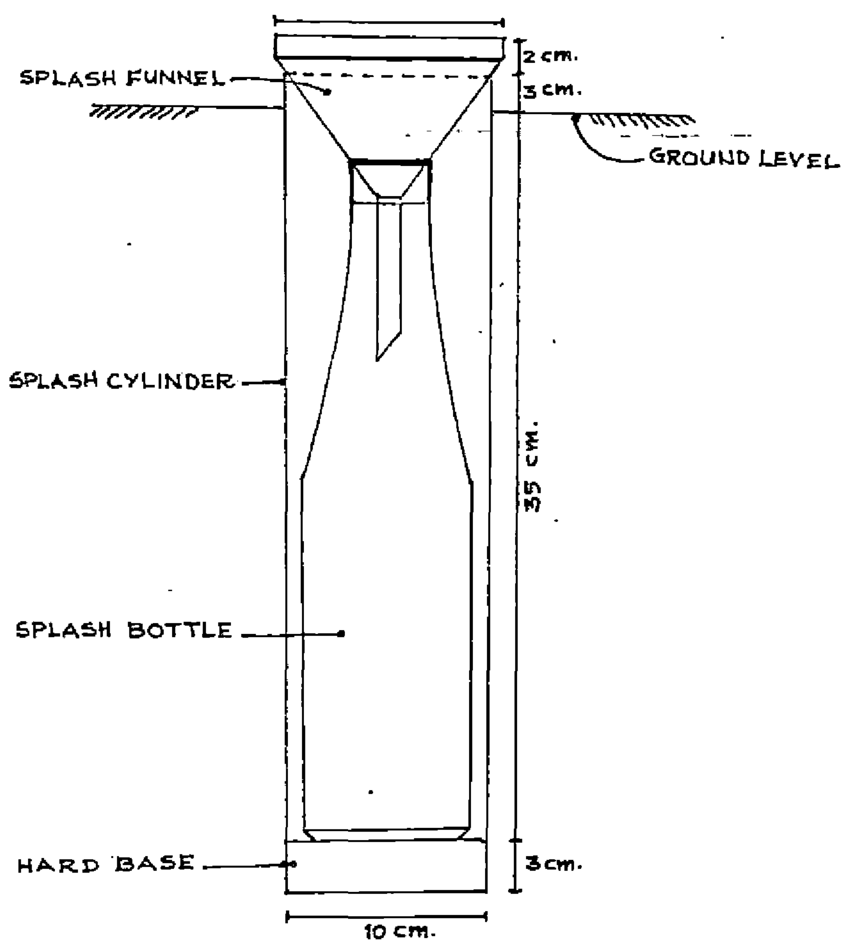
The soil was escavated with the help of a post-hole auger, so as to contain the splash cylinder. The splash cylinder was then embedded into the ground ensuring that there was no gap between the outer wall of the cylinder and soil. To avoid the possible entry of run-off along with the splash, the tip of the cylinder was kept projected two cm above the ground level. The splash funnel was placed so that its stem entered the bottle by atleast five cm. Two such devices were installed in each plot one at the upper and the other at the lower end, below the canopy cover. Average of the two values gave the corresponding plot value.

On each day at 8.30 AM soil particles received in the splash bottles were collected, pooled together, dried and weighed at monthly intervals. Data are presented as g/100 cm^2.

2.11 Rainfall interception by vegetal cover:

The extent to which the vegetal cover protects the ground from direct hit of rain drops, by way of interception, was assessed by measuring the throughfall in each treatment under the canopy cover. Two ordinary rain-gauges (locally made low cost device) were kept in each

FIG.6-SPLASH COLLECTION ASSEMBLY.



plot below the canopy cover, one at the bottom and the other at the top. Daily in the morning, rainfall in the two raingauges was measured and the average, worked out. From the actual rainfall and throughfall in each treatment, the percentage interception was calculated and added to get the monthly value.

2.11 Total canopy cover index:

Monthly total canopy cover (m^2) of each crop (dealt seperately) was added together to give the total vegetal cover in each treatment. This was divided by the plot area and expressed as canopy cover index.

2.12 Earthworm activity:

Wormcast produced from unit area in unit time is a measure of earthworm activity (Douglas et al. 1980). Wormcast in each plot was collected at weekly interval from three sites (lower, middle and upper) of one m^2 each and the average dry weight worked out and presented as monthly values in g/m^2.

2.13 Field culture:

2.13.1 Preparation of the mainfield:

The experimental area was initially cleared off weeds by sickle weeding and burning. The entire area was thoroughly tilled with spade and cleared off rocks, pebbles and plant debris. Plots of desired size were formed and pits, mounds and ridges were taken as per the treatments.

2.13.2 Planting and spacing:

Trees and crops were planted/sown at the end of April, each year.

i) Eucalyptus: Six months old, polythene bagged, treated seedlings of Eucalyptus tentricornis were used. Seedlings were planted in pits of size 30 x 30 x 30 cm^3, at a spacing of 2 x 2 m^2 and filled with fertile top soil.

ii) Cassava: One cassava was planted on mound in T_4 between four trees. While in T_2, five sets were planted on mounds. In T_3, four cassava sets were planted with a spacing of 90 cm between plants on ridges of 90 cm width and 60 cm height taken in between four Eucalyptus, across the slope.

iii) Rice: After the minimum land preparation, rice was broadcasted at a seed rate of 100 kg/ha leaving a circular gap of 30 cm diameter around each eucalyptus seedling to avoid possible shading of eucalyptus in the early stages.

iv) Grass: Congosignal was planted with 2 to 3 slips per hill, accommodating on an average 25 nos. of hills/m^2. Thirty cm circular space was left around each eucalyptus seedling.

2.13.3 Manuring:

All crops except eucalyptus were fertilized as per the package of practices recommendations (KAU, 1982).

2.13.4 Weeding and interculturing:

In all the plots weeding was very essential, especially during the initial stages of crop growth, and hand weeding was followed. For rice and grass, only one weeding, 15-20 days after sowing/planting was needed. T_2, T_3 and T_4 received three weedings at an interval of 20-25 days after planting in the first year and two weedings in the second year. T_1 needed only three weedings for the whole period of experimentation, that too in the initial three months of planting. In the first year T_7 required no weeding due to the periodic tilling but in the second year it also received two weedings.

Cassava in all the treatments required earthing up in August-September due to severe soil erosion in the south-west monsoon. Grass plot received light digging after fertilizer application.

2.13.5 Harvesting:

Cassava was harvested in the end of March every year. Rice attained maturity, at 115 days after sowing. Grass was cut once in thirty days.

2.14 Biometric observations:

2.14.1 Eucalyptus:

The following biometric observations were taken at quarterly interval. Five plants at random were selected for the observation.

a) Plant height (m).

b) Collar girth (cm) at 10 cm above the ground level.

c) Girth at breast height over bark (GBHOB) at 1.35 m above the ground level (cm).

The observation d and c were taken at monthly interval.

d) Canopy diameter: Canopy diameter was arrived at from the average of two measurements of each plant taken north-south and east-west.

e) Canopy cover: (m^2) Assuming the shape of the canopy as almost cylindrical, the circular area corresponding to the mean canopy diameter was taken as the canopy cover of each tree. Total of 24 trees at each time constituted the canopy cover of eucalyptus.

f) Volume (m^3): As destructive sampling was not envisaged, at the end of the experiment, total wood volume of euecalyptus in each treatment was determined using the equation. $V = -0.0001 + 0.3114\ D^2H$ (Chaturvedi, 1973).

Where V = Volume (m^3)

D = Diameter (m)

H = Height (m)

2.14.2 Cassava:

In cassava also the following observations were taken at monthly interval.

a) Plant height (m)
b) Canopy diameter (m)
c) Canopy cover (m^2)

At harvest the following observations were recorded:

a) Tuber yield per plant (kg)
b) Total tuber yield (kg/ha)
c) No. of marketable stems per ha.

2.14.3 Rice:

Observations mentioned below were taken at monthly interval.

a) Plant height (cm)

b) Canopy cover (m^2): Total leaf area at each month was taken as the canopy cover. Non destructive method of leaf area determination suggested by Gomez (1972) was adopted.

c) Soil binding ability: From a trial plot laid under identical situations, roots were escavated from one m^2 area to a depth of 30 cm. Extreme care was taken to collect all the rice roots. Collected roots were washed and made dirt free. Volume (v) and mean radius (r) of the roots were determined.

Soil binding ability (F) was worked out by the formula $F = \frac{v}{r}$ (Bhimaya, 1950).

Where v = total volume of the roots

r = mean radius of roots.

At harvest, the following observations were taken:

d) Grain yield (kg/ha)

e) Straw yield (kg/ha)

2.14.4 Grass:

Observations were made on:

a) Height (cm)

b) Canopy cover (m^2). Punch method of leaf area determination was followed.

c) Soil binding ability: As explained in the case of rice.

d) Grass yield (kg/ha)

2.15 Particle size analysis:

Particle size analysis of the gravel free eroded and plot soils were conducted by the pipette method (Piper, 1967). Gravel content was also determined and expressed as percentage.

2.16 Physical characteristics:

The following physical characteristics of surface soil at six months interval were determined in each treatment.

1. Infiltration rate:

Infiltration rate was determined using a double ring infiltrometer (Black, 1965).

2. Particle density, bulk density and void ratio:

Methods suggested by Singh (1980) were adopted. Total, macro and micro-pore space distribution were calculated using the following equations:

a) Total pore space % (TPS) $= 1 - \frac{\text{bulk density}}{\text{particle density}} \times 100$

b) Macro-pore space % = TPS % - (M.C. % at field capacity x bulk density)

M.C. - Moisture content

c) Micro-pore space % = TPS % - Macro-pore space %

3. Aggregate analysis:

Sieving machine (Yodder, 1936) and sieves of sizes 5 mm, 2.5 mm, 1.00 mm, 0.50 mm and 0.25 mm were used for this purpose. Following indices were also worked out (Singh, 1980).

a. Mean weight diameter

b. Stability Index

c. Structural coefficient

d. Percentage of aggregate stability

e. Aggregation index.

4. Water holding capacity:

Water holding capacity at 0.3 and 15 bars was determined using pressure plate apparatus.

2.17 Rainfall acceptance:

It is the measure of the water absorptive capacity of a treatment and is determined by the equation.

$$1 - \frac{\text{Total run-off}}{\text{Total rainfall}} \times 100 \quad \text{(Uriyo, 1979)}$$

Run-off occurred in each treatment during the whole year was taken into account.

2.18 Chemical analyses:

The total N, P, K, Ca, Mg, S of eroded and plot soils and their soluble forms in run-off were determined (Jackson 1958 and Black, 1965). Nitrogen contents of the soil and run-off were determined by macrokjeldahl's method. Total phosphorus was estimated colourimetrically by the vanedomolybdo phosphoric yellow colour method in nitric acid systems, using Spectronic 20 Spectrophotometer and dissolved phosphorus in run-off by AOAC (1980) method. Potassium was determined using Corning-Eel flame photometer. Turbidimetric procedure was employed for determining total Sulphur in soil. Dissolved sulphur was not measurable. Total and dissolved Ca, and Mg were determined by using Atomic Absorption Spectrophotometer.

Organic matter and CEC of the plot soil were determined by the procedure suggested by Jackson (1958). The p^H of soil samples were determined using Elico digital p^H meter.

2.19 Statistical analyses:

The data obtained were subjected to statistical analyses by the analysis of variance technique suggested by Snedecor and Cochran (1967). Simple correlations between various rainfall characteristics and run-off and soil loss have been worked out and linear regression equations arrived at.

Results and Discussion

RESULTS AND DISCUSSION

The results of the present experiment are presented and discussed with suitable illustrations in the following text.

1. Basic studies:

1.1 Rainfall characteristics which determine the run-off and soil loss:

To findout the effect of various rainfall characteristics on run-off and erosion under the given edapho-climatological conditions, daily run-off and soil loss data collected from the cultivated fallow plot were used. Thirty four such data selected at random, occurred during the most rainy months of 1984 were regressed with corresponding rainfall characteristics viz. amount of rainfall, duration, average intensity, maximum intensity, total kinetic energy, EI_{15}, EI_{30} and AI_m. Simple correlation coefficients and regression equations were worked out and presented in Table 2 and 3.

In the case of run-off, maximum correlation was obtained with total amount of rainfall (r = 0.930**) closely followed by total kinetic energy (r = 0.912**) and AI_m (r = 0.848**). Even the lowest correlation (r = 0.452*) observed with average intensity was significant at 5 per cent level.

Table 2 Correlation between rainfall characteristics (X) and run-off (Y)
(No. of observations = 34)

No.	Rainfall characteristics	r	Regression equation
1.	Rainfall amount (mm)	0.930**	Y = -6.153 + 0.798 X
2.	Duration (hr)	0.593**	Y = 3.894 + 5.280 X
3.	Average intensity (cm/hr)	0.452*	Y = 5.079 + 18.904 X
4.	Maximum intensity (cm/hr)	0.677**	Y = -5.611 + 6.757 X
5.	Kinetic energy (mt/ha cm)	0.912**	Y = -4.064 + 0.031 X
6.	EI_{15}	0.842**	g = 9.422 + 0.247 X
7.	EI_{30}	0.828**	Y = 10.214 + 0.336 X
8.	AI_m	0.848**	Y = 7.057 + 0.779 X

* Significant at 5% level
** Significant at 1% level

Table 3. Correlation between rainfall characteristics (X) and soil loss (Y) (No. of observation = 34)

No.	Rainfall characteristics	r	Regression equation
1.	Rainfall amount (mm)	0.783**	Y = -29.650 + 2.422 X
2.	Duration (hr)	0.292	Y = 28.362 + 9.380 X
3.	Average intensity (cm/hr)	0.434	Y = -4.417 + 65.539 X
4.	Maximum intensity (cm/hr)	0.864**	Y = -76.907 + 31.067 X
5.	Kinetic energy (mt/ha cm)	0.822**	Y = -29.600 + 0.101 X
6.	EI_{15}	0.977**	Y = 1.270 + 1.033 X
7.	EI_{30}	0.941**	Y = 3.584 + 1.377 X
8.	AI_m	0.931**	Y = 6.649 + 3.079 X

** Significant at 1% level

EI_{15} showed the maximum correlation (r = 0.977**) with soil loss. EI_{30} and AI_m closely followed it with r values of 0.941** and 0.931**, respectively. The duration (r = 0.292) and average intensity (r = 0.434) were the least correlated characteristics.

Run-off is the water that remains from precipitation after evapotranspiration and infiltration. The infiltrability of soil which determines the run-off tends to decrease monotonically and eventually to approach assymptotically a constant rate over time (Hilel, 1971). On a rainy day in the rainy season, the soil will always be saturated or near to that stage. At this stage, with each successive rainfall on bare soil, the infiltration rate is reduced due to the increasing blocakage of macropores by the translocated soil particles and run-off point occurs at lower time and/or lower intensity leading to erosion (Uriyo, 1979). With increase in energy and intensity of rainfall, the above run-off promoting processes will get accelerated. The observed highest correlation of run-off with the amount of rainfall closely followed by the kinetic energy and AI_m in this study is hence understandable.

The highly significant correlation coefficients of EI_{15}, EI_{30} and AI_m and the lowest coefficients of single value characteristics viz. amount, intensity and duration of rainfall observed in the case of soil loss, will strongly establish the relation of erosive power of rainfall to compound parameters derived from combinations of more than one physical property. But among the compound parameters, the highest correlation coefficient was observed with EI_{15} than the widely used EI_{30}. Heavy downpour of tropical climate with maximum intensities sustained only for a few minutes (De Castro, 1980 and Hudson, 1984) contrary to the low rate and quantity of temperate rainfall can be the reasons for better correlation of EI_{15} than EI_{30}, an index developed from temperate rainfall data. Khybri et al. (1978) and Viswambharan (1980) observed maximum correlation with erosivity index of still lesser duration viz. EI_5 for southern parts of India. These findings clearly warrent a rethinking on the continued use of EI_{30} as the rainfall erosivity factor (R) when USLE is used as the erosion prediction tool in tropical climates.

1.2 Relation between run-off and soil loss:

The run-off (X) and soil loss (Y) of the selected events were correlated and regression equation was worked out. There was a strong linear correlation ($r = 0.790^{**}$) with regression equation of $Y = -6.639 + 2.809 X$. But the correlation coefficient was far below that of EI_{15},

EI_{30} and AI_m, indicating lesser influence of run-off on soil loss as compared to the intensity characteristics of the rainfall.

1.3 Relation between depth of rainfall and its important characteristics:

Simple correlation coefficients and regression equations were worked out between depth of daily rainfall, duration, maximum intensity, EI_{15}, AI_m and kinetic energy, the important characteristics, which decide the run-off and erosion, as described previously. The data are presented in Table 4.

It can be seen that all the above characteristics were strongly correlated with the depth of rainfall. Increase in rainfall will, therefore, reflect positively in other characteristics which determine run-off and soil loss. Among the characteristics studied, kinetic energy showed the highest correlation (r = 0.975**) followed by AI_m (r = 0.909**), EI_{15} (r = 0.859**), maximum intensity (r = 0.714**) and duration (r = 0.712**).

1.4 Important rainfall characteristics occurred during the experimental period:

The amount of daily rainfall occurred during the both years are depicted in Fig. 7 and 8. Important rainfall characteristics were grouped monthwise and presented

Table 4. Correlation between depth of rainfall (X) and its important characteristics (Y)

(No. of observations = 34)

No.	Important rainfall characteristics	r	Regression equation
1.	Duration (hr)	0.712**	Y = 1.394 + 0.069 X
2.	Maximum intensity (cm/hr)	0.714**	Y = 2.183 + 0.061 X
3.	EI_{15}	0.859**	Y = 36.675 + 2.514 X
4.	AI_m	0.909**	Y = 10.010 + 0.850 X
5.	Kinetic energy (mt/ha cm)	0.950**	Y = -22.507 + 24.582 X

** Significant at 1% level

FIG. 7 - DAILY RAINFALL - 1984

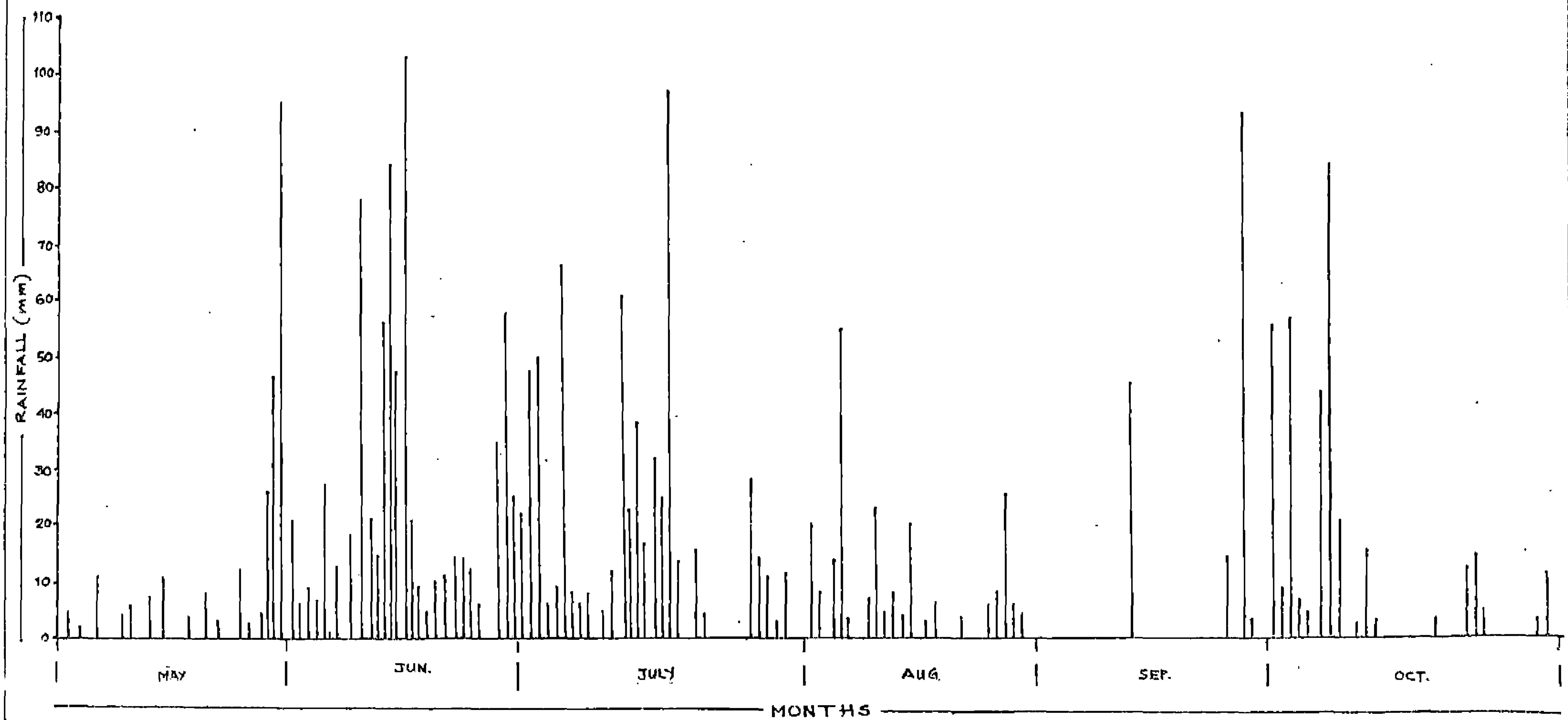
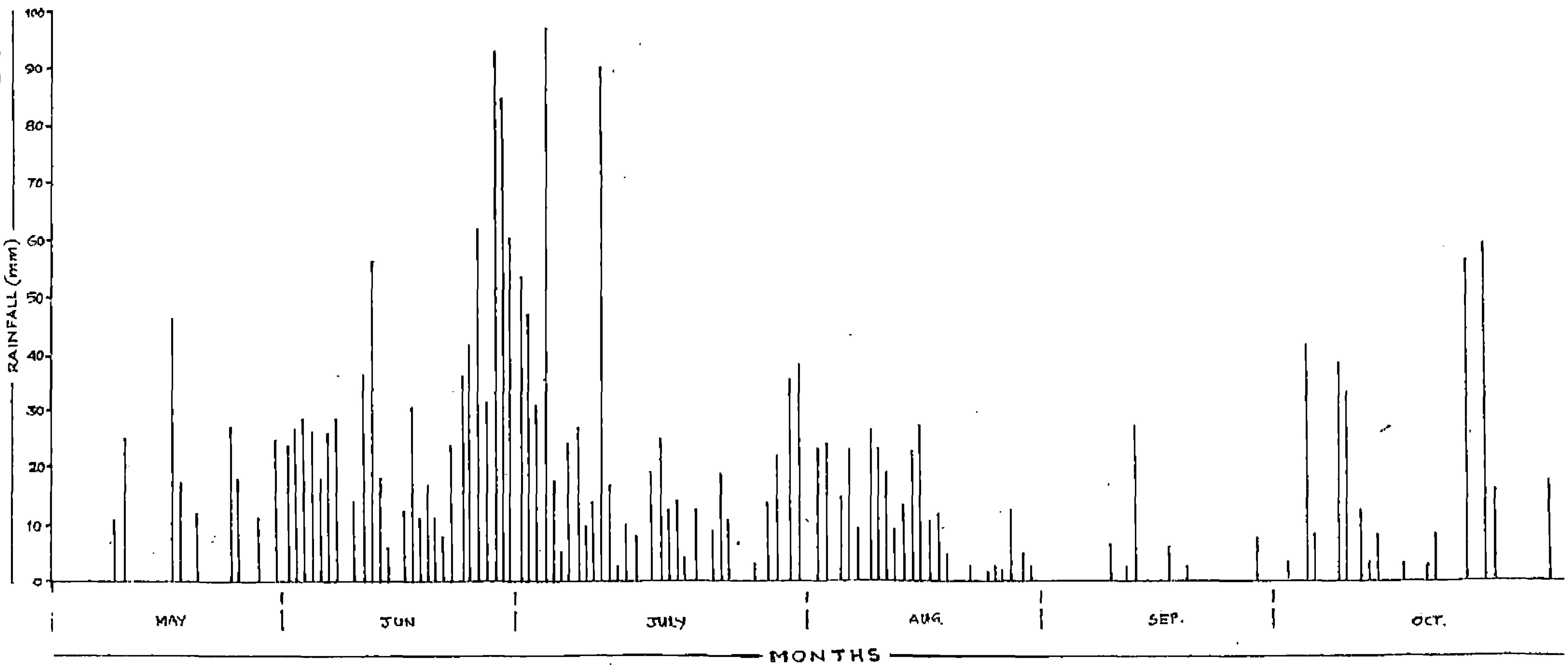


FIG. 8 - DAILY RAINFALL - 1985



in Table 5, Fig. 9 and 10. Fig. 11 illustrates the annual rainfall characteristics.

In 1984, a total of 2383 mm of rainfall was received. For 1985, the same was 2517 mm. Total kinetic energy, EI_{15} and AI_m were 45255 m t/ha cm, 2036 and 1005 for the first year and 51928 m t/ha cm, 2164 and 1042, respectively, for the second year.

The south-west monsoon which spreads from May to August contributed to 76.30 per cent of the total rain in the first year whereas its share was 81.03 per cent in the second year. Among the four months, June recorded the highest amount closely followed by July. North-east monsoon gauged 21.11 per cent of the total rain in 1984 and 14.86 per cent in the second year with October as the rainiest in both years. This illustrates an almost same distribution pattern of rainfall over different months for both years.

The monthly kinetic energy varied from 3806 to as high as 13158 in the first year and 574 to 17819 mt/ha cm in the second year. In general, there was a proportionate increase in the kinetic energy with an increase in rainfall amount. But there were months where kinetic energy was not proportionate to the quantity of rainfall. For example, though the September of first

Table 5. Important rainfall characteristics of 1984 and 1985

No.	Characteristics	Months							Total
		May	June	July	August	September	October	November to April	
	1 9 8 4								
1.	Rainfall (mm)	243.90	709.35	627.75	237.70	152.55	350.50	61.60	2382.75
2.	Duration (hr)	24.00	62.08	76.77	31.85	8.72	30.77	14.30	248.49
3.	EI_{15}	165.88	538.20	521.76	120.77	373.37	267.67	48.10	2035.95
4.	AI_m	79.42	294.01	254.94	72.77	146.55	146.74	10.46	1004.89
5.	Kinetic energy (mt/ha cm)	3806.31	12819.44	13158.22	3707.56	3805.95	7539.60	418.19	45255.27
	1 9 8 5								
1.	Rainfall (mm)	205.90	829.25	709.50	294.50	53.00	321.05	103.35	2516.55
2.	Duration (hr)	10.33	102.27	83.00	36.72	6.25	27.22	24.42	290.21
3.	EI_{15}	266.32	642.29	617.77	311.07	9.11	265.60	52.16	2164.40
4.	AI_m	71.69	316.06	358.99	93.40	10.31	163.52	28.20	1042.17
5.	Kinetic energy (mt/ha cm)	2667.24	17819.35	16195.97	6536.91	574.46	6216.03	918.10	51928.06

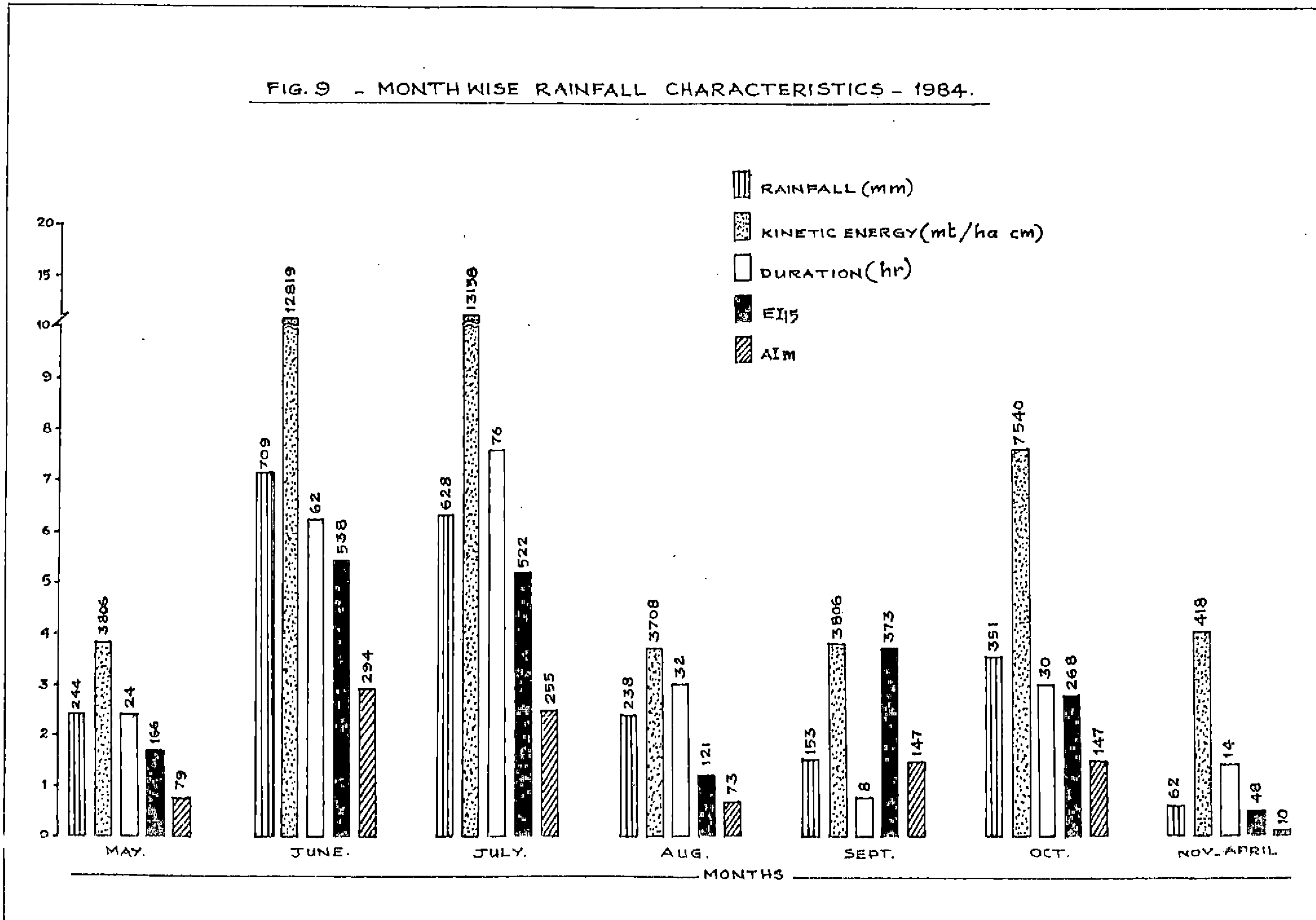


FIG. 9 - MONTH WISE RAINFALL CHARACTERISTICS - 1984.
RAINFALL (mm)
KINETIC ENERGY (mt/ha cm)
DURATION (hr)
EI15
AIm
0
1
2
3
4
5
6
7
8
9
10
15
20
244
3806
24
166
79
709
12819
62
538
294
628
13158
76
522
255
238
3708
32
121
73
153
3806
8
373
147
351
7540
30
268
147
62
418
14
48
10
MAY.
JUNE.
JULY.
AUG.
SEPT.
OCT.
NOV.-APRIL
MONTHS

FIG. 10 - MONTHWISE IMPORTANT RAINFALL CHARACTERISTICS - 1985

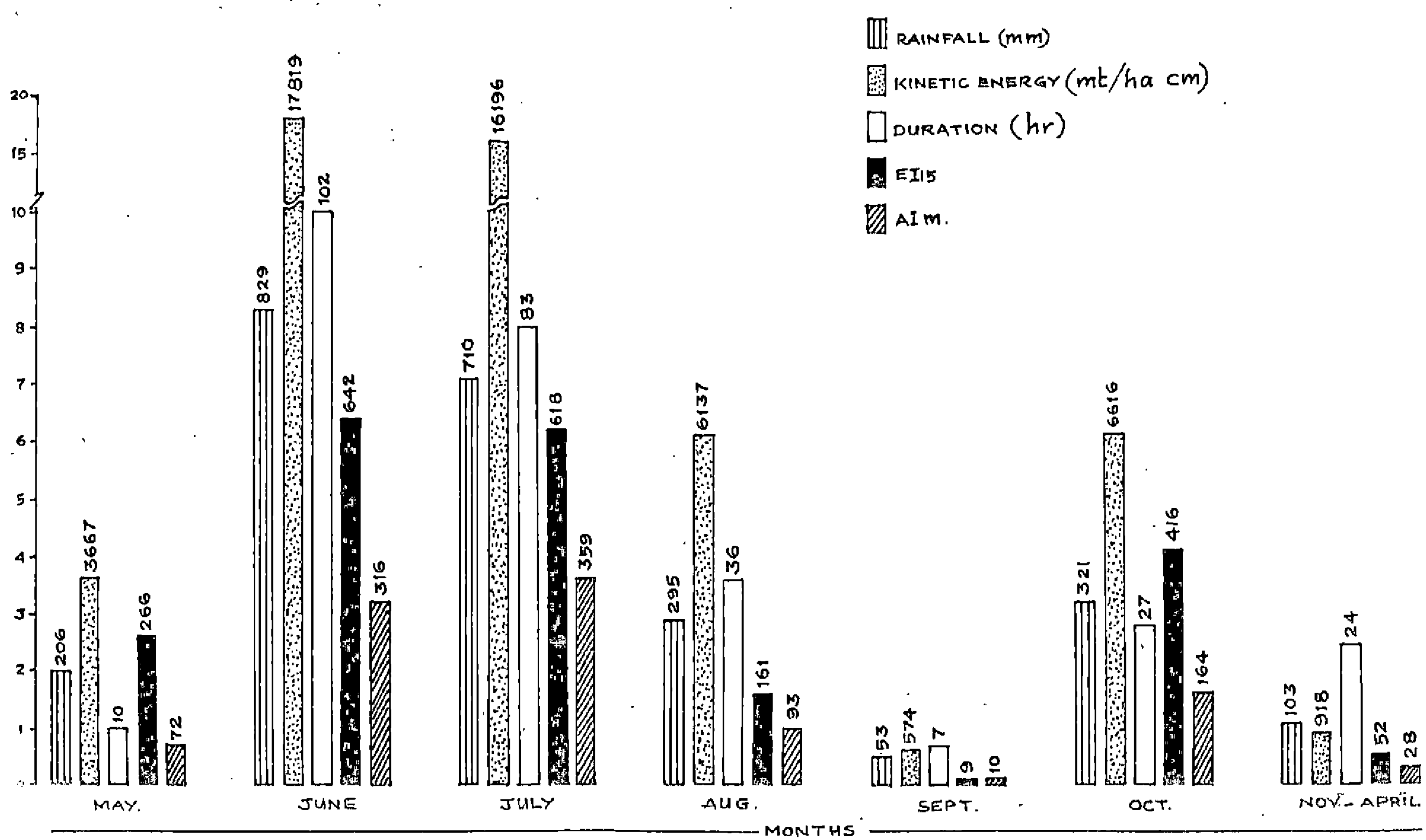
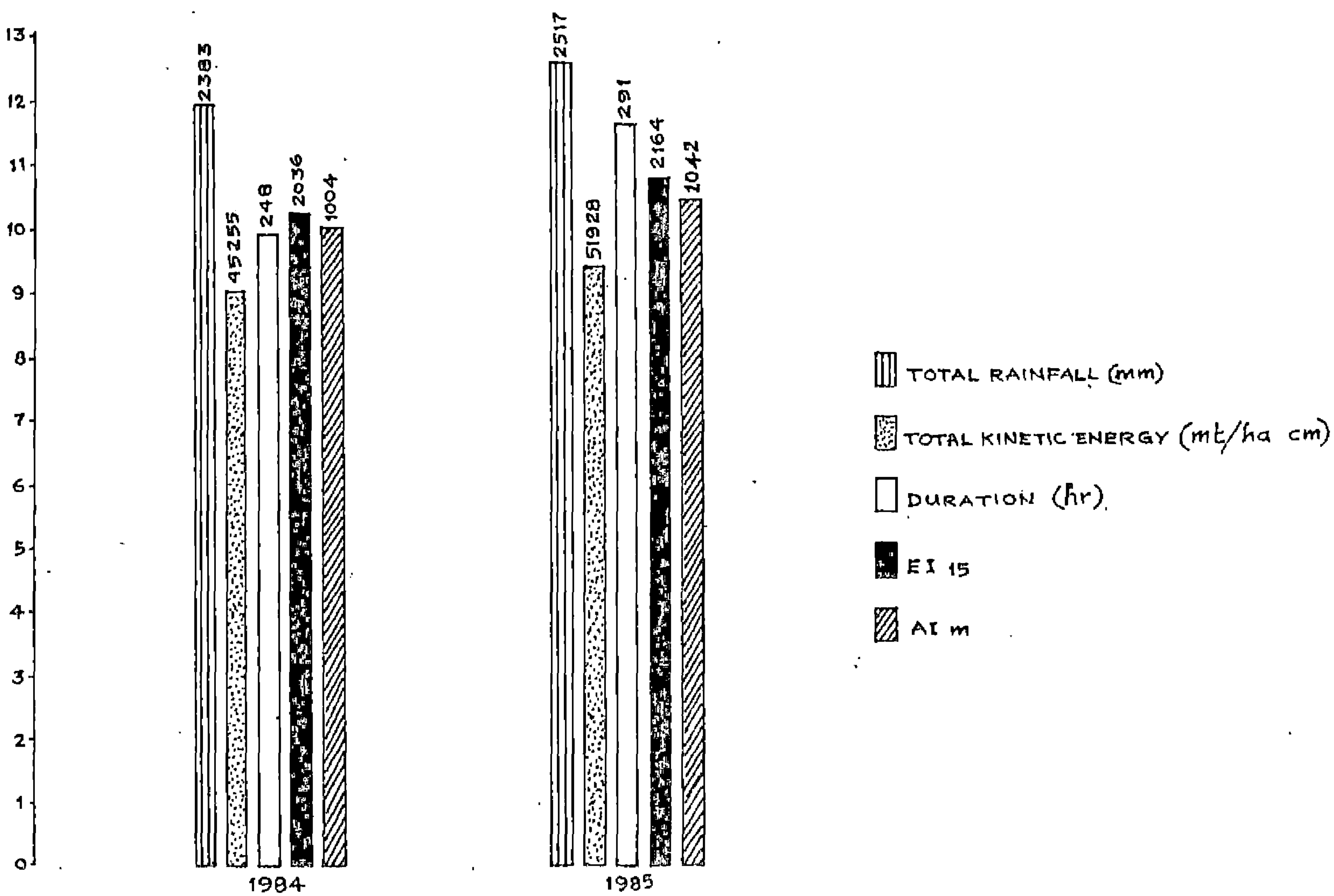


FIG. 11 _ IMPORTANT RAINFALL CHARACTERISTICS



year had lower quantity of rainfall as compared to August, the kinetic energy was more in the former than the latter (Table 5). This indicates that kinetic energy is negatively influenced by the duration of downpour especially when there is no corresponding increase in rainfall with increase in duration. EI_{15}, AI_m and total duration also followed an almost same trend as that of kinetic energy.

2. Run-off and soil loss:

Run-off and soil loss as influenced by various treatments are discussed below. With treatments as main-plots and months as sub-plots, data were analysed in split-plot design. Zero values indicate zero erosion.

2.1 Run-off:

Monthly and annual run-off observed in different treatments are presented in Table 6 and Fig. 12.

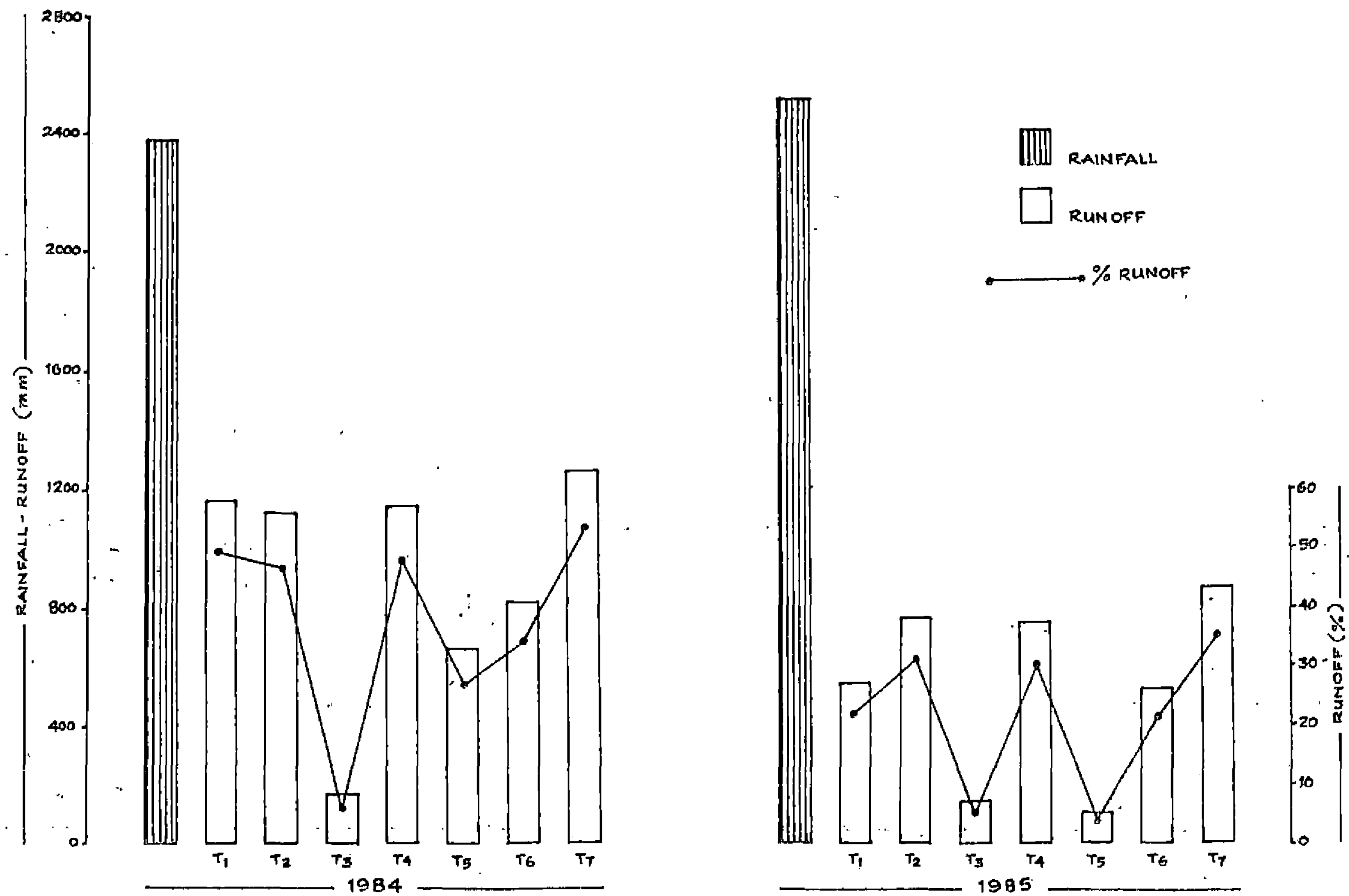
Data showed that all the treatments differed significantly barring T_4 and T_2 which were on par. Monthly run-off values between main plots also showed an almost similar trend. T_7 gave the highest value among treatments and T_3 the lowest throughout the months, except in September where T_5 gave the lowest value. Among the months, June recorded highest run-off

Table 6. Month-wise run-off (mm)

Year/Month	Treatments T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
1 9 8 4								
May	117.22	114.07	8.25	117.50	84.30	93.32	119.41	93.43
June	434.94	422.67	81.53	426.58	270.77	320.94	453.48	344.48
July	375.73	381.32	41.86	375.59	260.55	305.61	417.63	308.33
August	53.69	47.12	9.31	46.36	14.03	35.54	63.09	38.45
September	61.77	56.09	9.29	61.45	8.77	14.57	68.56	40.07
October	126.63	100.98	16.35	109.38	18.36	45.07	136.88	79.09
Mean	195.00	187.04	27.77	189.48	109.46	135.84	209.84	
CD (0.05)	a = 2.53		b = 1.86		c = 5.03		d = 4.91	
1 9 8 5								
June	260.09	352.24	58.60	356.31	48.64	263.92	423.40	251.89
July	222.66	306.50	53.06	276.72	36.20	228.76	324.11	206.86
August	42.31	63.69	17.32	63.00	15.18	15.12	74.47	41.59
September	0.81	1.30	0.40	1.14	0.81	0.79	1.29	0.93
October	18.71	42.37	10.28	52.07	9.98	21.62	44.33	28.48
December	2.82	2.26	0.87	2.42	0.99	1.69	2.22	1.90
Mean	91.23	128.06	23.42	125.28	18.63	88.65	144.97	
CD (0.05)	a = 2.95		b = 3.84		c = 7.54		d = 7.64	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

FIG. 12 _ ANNUAL RAINFALL, RUNOFF AND RUNOFF % TO TOTAL



and August the lowest, with significant differences between them. Within each treatment too, the trend, in general, was the same between months.

In the second year also, T_7 recorded the maximum value. But instead of T_3, T_5 gave significantly lower run-off than all other treatments. As against first year, T_5 gave significantly lower values in June and July. T_1, which closely followed T_7 in the first year, started producing lesser run-off than T_6 in the above months. T_7 also showed decreased rate of run-off after August. Regarding the monthly means, barring September and December, all other months differed significantly and followed the order June > July > August > October > December > September. Within each treatment also, this was the general trend, over the months. In May and November, there were no run-off.

The highest quantity of run-off produced in T_7 in all the months of first year may mainly be due to the decreased rate of infiltration consequent to direct, continous and uninterrupted hitting of raindrops which will puddle the soil surface and plug the macro-pores with fine soil particles (Hudson, 1984). This becomes further clear by realizing the possible effects of vegetation/ground cover in dissipating rainfall energy as discussed by Hudson (1977) and Venkataraman (1978).

Reduced run-off observed in other treatments coupled with data on rainfall interception (Table 43 a & b), splash erosion (Table 45 a & b), infiltration rate (Table 35), and earthworm activity (Table 49 a & b) are in support to this. As evident from these data, with increase in canopy cover, there is an increase in rainfall interception and subsequent reduction in throughfall and run-off. In grassed plot, high initial infiltration rate, an indication of the high flux controlled infiltrability, will invariably reduce the run-off. Further, the increased moisture storage capacity of soil provided by the transpiratory withdrawal of dense grass cover might also have contributed to the decreased run-off. T_3 recorded the least run-off throughout the first year. Ridges taken across the slope effectively prevented run-off by retaining it in-between them which gradually and subsequently infiltrated into the soil. Though T_2 and T_4 behaved almost similarly in the initial months, the reduced run-off in T_2 towards the end can probably be attributed to the rainfall interception ability of the dense canopy cover due to high cassava population. Rice crop was also effective in controlling run-off to a significant extent, which in effect behaved almost similarly as that of congosignal.

Many of the above effects were transmitted more conspicously to the second year. Though there was higher rainfall than the first year, all the treatments recorded comparatively lesser run-off in the second year because of the stabilization effect of the treatments. The notable reduction in run-off in T_1 and T_5 than the first year will explain this. Though canopy cover in T_1 was much less than many other treatments, it was almost equal to T_6 in controlling run-off. This is mainly because of the undisturbed nature of soil consequent to no inter-cropping. The structural improvements observed in T_1 (Tables 33 & 34) are also in support to this. T_5, giving the lowest values in all the months suggest that, grass once established, is better than ridging in controlling run-off. Grass interstripping as in T_7 also started showing positive tendency in controlling run-off.

In both years the rainiest month produced maximum run-off in all treatments. As run-off is most strongly correlated with depth of rainfall than any other characteristics (Table 4) increased run-off with increase in rainfall is understandable. But the total amount of rainfall is not the only factor responsible for run-off. When the amount is enough to produce run-off, the hitting power as decided by the kinetic energy will be more influential in producing it. High correlation coefficient of kinetic energy with run-off ($r = 0.912^{**}$) together with the observations of August and September of the first year in many treatments and August and November of the second year in all the treatments are in support to this finding.

2.2 Rainfall acceptance:

That portion of rainfall after run-off expressed as percentage to total is the rainfall acceptance. The data are presented in Table 7.

When cultivated bare plot could accept only 47 per cent of the rainfall, ridge farming of cassava across the slope helped to harvest 93 per cent in the first year. Grass and rice cropped plots were also efficient in accepting more rainfall. In the second year, all the treatments substantially increased their acceptance ability and grassed plot even overtook T_3 by accepting almost 96 per cent of the total.

Rainfall acceptance is a measure of the effectiveness of each treatment in harvesting the rainfall and infiltrating it into the soil matrix. Factors responsible for reducing run-off and increasing infiltration rate will explain the variation seen in each treatment.

2.3 Soil loss:

2.3.1 Settled sediments:

Total soil loss includes both suspended as well as

Table 7. Annual run-off (mm) and rainfall acceptance (%)

	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
Run-off (%)	49.10	47.10	6.99	47.69	27.56	34.21	52.84
Run-off amount (mm)	1170.00	1122.24	166.62	1136.38	656.76	815.04	1259.04
Rainfall acceptance (%)	50.90	52.90	93.01	52.31	72.44	65.79	47.16
Rainfall amount (mm)	1212.75	1260.51	2216.13	1246.37	1726.00	1567.71	1123.71
1985							
Run-off (%)	21.75	30.53	5.58	29.87	4.44	21.14	34.56
Run-off amount (mm)	547.38	768.36	140.52	751.69	117.78	531.90	869.82
Rainfall acceptance (%)	78.25	69.47	94.42	70.13	95.56	78.86	65.44
Rainfall amount (mm)	1969.17	1748.19	2376.03	1764.87	2404.77	1984.65	1646.73

settled sediments carried away by the run-off. The data on settled sediments which forms the lions share of soil loss is presented in Table 8. Erosion in each treatment, on an intense rainy day, one month after the experiment, is illustrated in Plates XII-XVIII.

In 1984, all the treatments differed significantly. As in the case of run-off, T_7 stood first in eroding the soil and T_3 the last. T_7 was significantly higher than all other treatments throughout the first year except in August when it was on par with T_4 and T_2. Similarly T_3 was significantly lower than others upto and including July and thereafter attained statistical parity with T_5 and T_6. Among the months, June was the most erosive followed by May, July, September, October and August in that order. Except May and July, all the months differed significantly. Within each treatment also, June produced the highest soil loss.

In the second year T_7, T_2 and T_4 were significantly higher. T_6 was on par with T_1. T_5 gave the lowest value and was on par with T_3. T_7 was significantly higher to all followed by T_2 and T_4 in most of the months. Differences between T_5 and T_3 were always insignificant. T_1 and T_6 became comparable to T_7 towards the end. The monthly means showed significant differences. June was the most erosive and October, the least. There was practically no soil loss

Table 8. Month-wise settled sediment loss (t/ha)

Year/Month	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
1984								
May	44.99	46.85	2.30	46.93	34.19	38.21	49.99	37.64
June	122.53	142.37	4.53	125.73	62.30	71.91	146.27	97.26
July	41.07	57.64	0.15	55.20	13.02	23.49	62.58	36.16
August	5.61	7.04	0.01	7.12	0.05	0.43	7.83	4.01
September	20.36	13.45	0.00	16.55	0.10	0.23	31.04	11.68
October	10.93	5.52	0.00	9.81	0.07	0.74	17.85	6.42
Mean	41.91	45.48	1.15	43.56	18.29	22.38	52.59	
CD (0.05)	a = 1.22		b = 0.78		c = 2.17		d = 2.06	
1985								
June	23.84	64.18	0.58	55.11	0.16	32.77	100.30	39.56
July	6.81	33.50	0.04	30.00	0.03	4.90	48.48	17.68
August	0.36	2.79	0.00	2.67	0.00	0.00	4.25	1.44
September	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
October	0.03	1.12	0.00	1.40	0.00	0.00	0.36	0.45
Mean	6.26	20.32	0.12	17.84	0.04	7.53	30.68	
CD (0.05)	a = 1.52		b = 0.92		c = 2.49		d = 2.43	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Plate XII. Erosion in cultivated fallow plot on an intense rainy day, one month after the experiment (12 t/ha/day).

Plate XIII Erosion in tree alone treatment - a 33% reduction over the cultivated fallow (8 t/ha/day).

Plate XII

Plate XIII

Plate XIV Erosion in eucalyptus + five cassava on mounds - as severe as that of cultivated fallow. (11 t/ha/day).

Plate XV Erosion in eucalyptus + cassava on ridges across the slope - there is practically no soil loss.

Plate XIV

Plate XV

Plate XVI Erosion in eucalyptus + one cassava on mound - a 25% reduction over the cultivated fallow (9 t/ha/day).

Plate XVII Erosion in grassed plot - a 96% reduction over the cultivated fallow (0.5 t/ha/day).

Plate XVI

Plate XVII

Plate XVIII Erosion in riced plot - a 75% reduction over the cultivated fallow (3 t/ha/day).

Plate XVIII

in September. Within each treatment too, this was almost the same trend and the differences were insignificant towards the end. In T_3 and T_5, the monthly differences were not at all significant.

Soil erosion is a function of rainfall erosivity and soil erodibility (Wischmeier, 1966; Alexander et al. 1980 and Verma, 1984). Erodibility being an inherent character of the soil, under a given edaphological condition, the erosion is decided by erosivity of rainfall and land management practices. As explained in item 1.1 erosion is most strongly correlated with EI_{15} than any other rainfall characteristics. The observed variations in soil loss between months were the reflections of this fact and the highest soil loss was seen in the month with highest EI_{15} and vice-versa, irrespective of the quantity of rainfall and runoff. A single exception to this, throughout the period of experiment, was May of the first year where comparable values were observed with July. This can be due to the initial soil disturbances consequent to land preparation coupled with the heavy downpour. For May of the second year also this would have been the situation had there been sufficient run-off to cause erosion.

Differences in the settled sediments exhibited by each treatment can be attributed to its effects on influencing the rainfall erosivity and run-off. T_7 was subjected to the direct hitting of rainfall since it was kept as cultivated fallow in the first year. As there was no protective cover or management practices in T_7, the soil detachability of the falling raindrops and transportability of the run-off were very high which explains the higher values recorded in all the months. High rate of splash erosion (Tables 45 a & b) and low infiltration (Table 36) seen in this treatment further substantiate the same. The sediment losses in T_2 and T_4 were higher than most of the treatments except T_7, inspite of the low run-off recorded during the highly erosive months. As explained in item 1.2, this reiterates the fact that the run-off alone is not responsible in determining soil loss. Very severe soil disturbance caused by mound planting of cassava, that too five times that of T_4, might have nullified any little protective role by the developing cassava canopy. In addition to this the downflowing run-off forming rills, quite often encircling the newly formed mounds, might have brought down maximum soil from the mounds. The lower sediment loss observed in T_5 and T_6 might be attributed to the reasons already explained for run-off. Further the ramifying effect of fibrous roots of grass and rice would have protected the individual soil particles from being detached by the falling raindrop and transported down by the flowing water. These effects of the grass crop became increasingly evident in the second year by making it most effective in controlling soil loss. The observed reduction of settled sediments in T_7 as compared to the first year indicates the positive effect of grass strips in controlling soil loss. As in the case of run-off, a general decrease in settled sediment loss observed in second year, can be attributed to some extent, to the protective role of trees.

2.3.2 Suspended sediments:

The quantities of suspended sediments carried away by the flowing water in each treatment are presented in Table 9.

The annual mean followed an almost similar trend as that of settled sediments except for the statistical parity showed between T_2 & T_4 and T_4 & T_1. Over different months too, the trend was exactly same as that of settled sediments till July. Afterwards, a slight superiority of T_4 over T_1 and T_2 was observed. June registered the highest value and August, the lowest. The differences were also significant except for August and September which were on par. This was almost the same trend within each treatment too.

Table 9. Month-wise suspended sediment loss (t/ha)

Year/Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
1 9 8 4								
May	3.54	3.67	0.20	3.53	2.19	2.71	4.54	2.91
June	9.94	13.05	1.17	12.61	4.76	6.67	15.58	9.11
July	6.36	7.75	0.15	7.33	1.18	3.30	11.10	5.45
August	0.34	0.48	0.01	0.45	0.02	0.11	0.93	0.33
September	0.44	0.55	0.00	0.68	0.01	0.12	0.96	0.38
October	1.08	1.34	0.00	1.62	0.00	0.15	2.87	1.01
Mean	3.62	4.47	0.25	4.37	1.53	2.16	6.00	
CD (0.05)	a = 0.19		b = 0.15		c = 0.40		d = 0.40	
1 9 8 5								
June	2.98	9.44	0.58	9.01	0.15	2.60	14.52	5.61
July	1.30	5.45	0.04	5.44	0.03	2.09	7.89	3.18
August	0.05	0.57	0.00	0.73	0.00	0.03	0.93	0.33
October	0.20	0.18	0.00	0.35	0.00	0.04	0.29	0.15
Mean	1.13	3.91	0.16	3.88	0.05	1.19	5.91	
CD (0.05)	a = 0.27		b = 0.13		c = 0.37		d = 0.34	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

In the second year also, T_7 was significantly higher over others. T_5 recorded the lowest value. T_2 & T_4, T_6 & T_1 and T_3 & T_5 were on par. The monthly loss followed the order June > July > August > October with significant differences between them. There was no suspended sediment loss in September. In T_5 the monthly differences were insignificant.

Table 10 provides the rate of loss of suspended sediments as influenced by different treatments. In both years, the trends between treatments were exactly same as that of the quantity. But the differences were, in general, insignificant between many treatments especially in the initial months of the first year and significant in the second year. The first month which produced erosion recorded the highest value and September the lowest, in both years. While in the first year, the differences between months within most erosive treatments were insignificant, they were significant in the second year.

As the suspended sediment loss is determined by the rate of loss of suspended particles and the total volume of run-off, such of those factors which are responsible for soil detachment, transportation and run-off, will help explain the differences observed in each treatment. The highest quantity of suspended sediment

Table 10. Monthly rate of loss of suspended sediment in runoff (kg/ha cm)

Year/Month	Treatments T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
1 9 8 4								
May	301.92	321.61	238.77	299.94	259.55	290.01	379.94	298.82
June	228.61	308.71	143.73	295.67	175.81	207.86	343.49	243.41
July	169.36	203.38	35.50	195.27	83.78	107.80	265.81	151.56
August	64.14	100.87	5.36	97.78	15.77	31.44	144.48	65.69
September	71.14	98.08	2.16	110.84	6.86	12.34	138.33	62.82
October	85.46	132.38	0.00	147.78	0.00	138.43	210.94	101.43
Mean	153.44	194.17	70.92	191.22	90.30	130.48	247.16	
CD (0.05)	a = 20.74		b = 19.10		c = 49.52		d = 50.52	
1 9 8 5								
June	114.02	268.23	98.62	252.76	31.61	98.57	343.08	172.41
July	57.93	180.16	7.62	196.78	7.79	90.43	243.63	112.41
August	11.82	88.70	0.00	115.61	0.00	18.53	125.73	51.48
October	104.30	50.54	0.00	66.27	0.00	20.32	65.75	43.88
Mean	79.44	146.88	26.56	141.28	9.87	56.96	194.55	
CD (0.05)	a = 10.94		b = 5.23		c = 14.92		d = 13.84	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

seen in T_7 in both years is attributed to the high rate and volume of run-off exhibited by it. The apparent similarity in the rate of loss of suspended sediment between treatments especially in the first year can be an indication of the inexpressibility of treatment effects responsible for bringing down the dispersive action of raindrops. The differences seen over months between and within treatments are indicative of their respective protective abilities against raindrop impact and erosion. Clear and practically sediment free water produced in T_3 and T_5 towards the final stages of investigation is in support to this.

2.3.3 Total soil loss:

Data on total soil loss of each treatment over the whole period of investigation are provided in Table-11 and Fig. 13.

T_7 eroded the maximum soil in both years. In T_3 the soil loss was always less than the tolerable limit. In the second year, grass treatment over took T_3 and there was practically no soil loss in it.

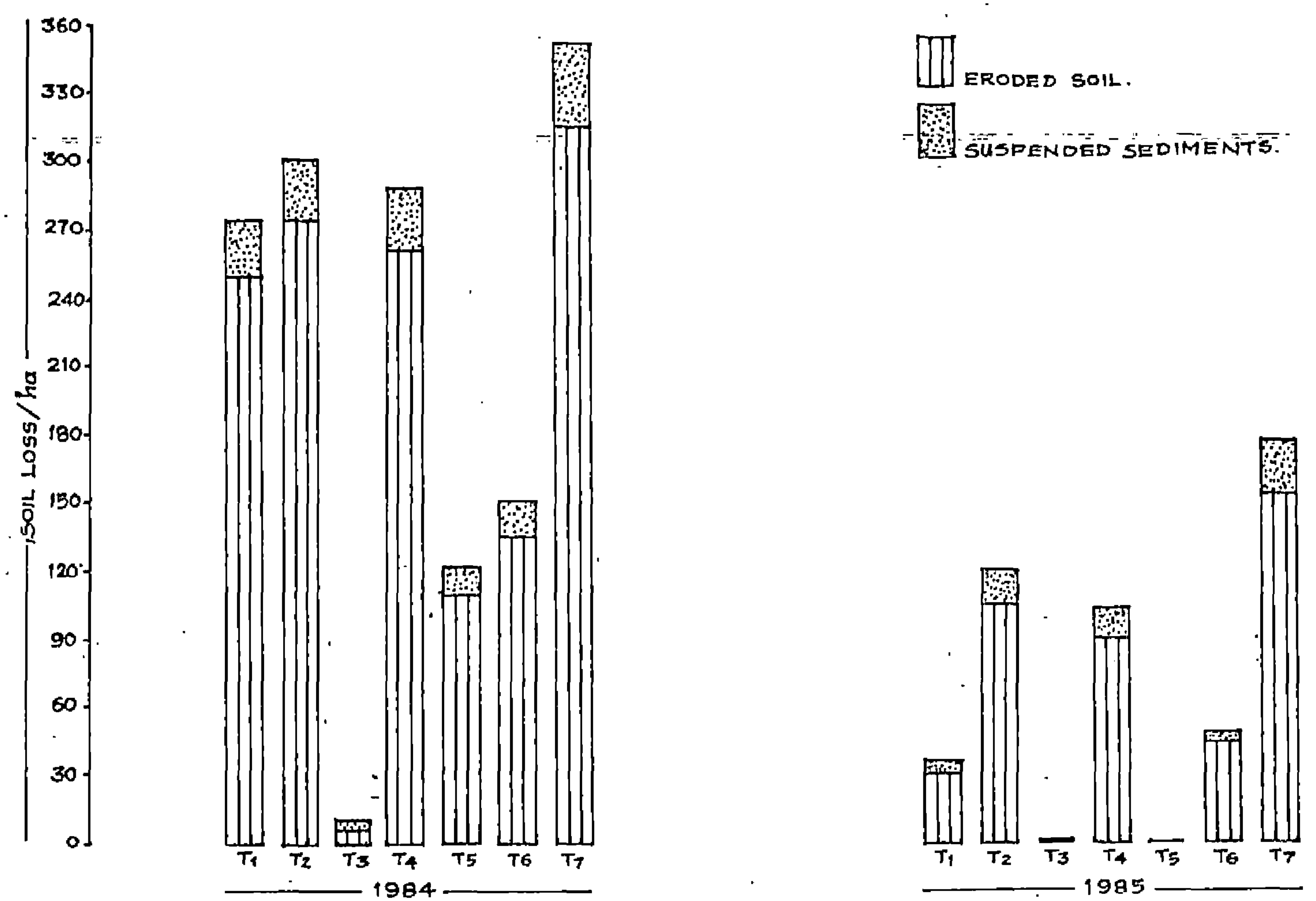
Even by taking 10 t/ha/yr as the tolerable level of soil loss (Requier, 1982 and Verma, 1984) it could be seen that all the treatments except T_3 where highly

Table 11. Year-wise quantity and depth of eroded soil

Treatments	Settled sediments (t/ha)		Suspended sediments (t/ha)		Total (t/ha)		Depth of eroded soil (mm)		% reduction over first year
	1984	1985	1984	1985	1984	1985	1984	1985	
T_1	251.46	31.30	21.71	4.50	273.17	35.80	13.66	1.79	86.90
T_2	272.88	101.60	26.83	15.64	299.71	117.24	14.99	5.86	60.91
T_3	6.90	0.60	1.52	0.62	8.42	1.22	0.42	0.06	85.00
T_4	261.36	89.20	26.20	15.52	287.52	104.72	14.38	5.24	63.56
T_5	109.74	0.19	9.17	0.18	118.91	0.37	5.95	0.02	99.83
T_6	134.29	45.18	12.96	4.76	147.25	49.94	7.36	2.50	66.03
T_7	315.24	153.40	35.98	23.63	351.52	177.03	17.58	8.85	40.96*

* Percentage reduction was calculated over T_2 of the first year as second year T_7 was an improvement of T_2.

FIG. 13 - ANNUAL TOTAL SOIL LOSS (ERODED SOIL + SUSPENDED SEDIMENTS) IN t/ha



vulnerable. As evident from T_1 of first year even the very minimum land clearing and tillage operations can erode as high as 273 t/ha/yr i.e. about 14 mm of top soil from a slope of 25 per cent. Mound planting of cassava, the widely practiced method in taungya lands can further embitter the situation by causing 30 times higher the permissible level of erosion i.e. 300 t/ha/yr. Incidentally, it can also be noted that, even when cassava population was increased to five times (T_2) than that of the taungya contract regulation (T_4) the increase in soil erosion was only marginal and not proportional to the degree of land disturbances caused. This may be due to the protective role of dense cassava canopy as compared to T_4. Severity of erosion was about 12 and 15 times higher than the permissible limit, respectively, in T_5 and T_6 in the first year. Grass could control soil erosion almost completely and emphasises its paramount importance in hill-slope management. As evident from T_7 of second year, interstipping about 10 per cent of the area with grass could reduce 41 per cent of soil loss even in T_2, one of the most erosive treatments, within one year. Observations of T_1 in comparison with others illustrate the interference of man through agricultural operations in accelerating erosion. If interculture and consequent land disturbance are absent, tree planting alone could reduce erosion by 87 per cent in the second year. These findings are in support to the possibility of agri-silvi-pastural land management systems for controlling soil erosion in hill-slopes.

3. Particle size distribution of eroded soil:

Gravel, sand, silt and clay contents of both settled and suspended sediments were determined at monthly intervals. The data are reported and discussed below.

3.1 Settled sediments:

3.1.1 Gravel:

Data are presented in Table 12.

In the first year all treatments differed significantly. T_7 recorded the highest mean of 12.95 per cent and T_3 the lowest of 2.81 per cent. The order of significance of the treatments were T_2, T_4, T_1, T_6 and T_5. Over the months too, this was the same trend with a drastic reduction in gravel content, as months passed by. The monthly means also differed significantly, in the order May > June > July > October > August > September. Within each treatment, the initial months gave the highest gravel content and final months, the lowest with comparable values in many cases.

Table 12. Gravel content (%) of settled sediment

Year/Month	Treatments T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
1984								
May	17.26	17.49	11.96	17.37	16.92	16.58	18.97	16.65
June	17.03	19.48	4.87	19.18	13.47	12.72	20.24	15.29
July	10.92	14.22	0.00	11.14	8.21	10.75	16.28	10.26
August	5.96	6.83	0.00	5.86	0.00	0.00	7.88	3.79
September	2.88	4.90	0.00	3.82	0.00	0.00	6.51	2.59
October	6.22	4.84	0.00	6.48	0.00	6.68	7.80	4.59
Mean	10.04	11.29	2.81	10.69	6.43	7.81	12.95	
CD (0.05)	a = 0.31		b = 0.30		c = 0.78		d = 0.80	
1985								
June	18.06	19.62	11.78	18.38	14.48	16.94	20.36	17.09
July	14.89	17.69	4.32	15.46	6.18	11.30	13.09	11.85
August	8.79	7.72	0.00	6.94	0.00	0.00	6.99	6.09
October	3.72	5.36	0.00	4.88	0.00	0.00	4.51	3.70
Mean	11.37	12.59	4.03	11.42	5.16	7.06	11.24	
CD (0.05)	a = 0.68		b = 0.35		c = 0.89		d = 0.79	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

T_2, became significantly higher by shifting T_7 even below to T_1 in the second year. The treatments T_4, T_1 and T_7 were on par. Differences between treatments over the months became insignificant making many treatments comparable to each other. Monthly differences were always significant. June gave the highest value and October the lowest in all the treatments.

3.1.2 Sand:

Data are furnished in Table 13 and Fig. 14 and 15.

Unlike gravel content, all the severely tilled treatments viz., T_2, T_4 and T_7 were always on statistical parity both in the annual and monthly values. Among these treatments, T_7 always registered the lowest value which varied between 40.69 per cent in June to 47.78 per cent in October. Though annual means of T_3, T_5 and T_6 were significantly different, the monthly values were, in general, on par. Contrary to the gravel content, sand content in all the treatments unveiled a gradual increase, as months passed by. This was more pronounced in T_5 and T_6. Within each treatment, the monthly differences were, in general, insignificant.

T_1 superseded all other treatments in the second year. Rest of the treatments followed exactly the same

Table 13. Sand content (%) of settled sediment

Year/Month	Treatments T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
1984								
May	46.96	47.19	48.63	46.24	46.23	45.84	46.49	46.80
June	45.91	41.31	44.46	43.49	54.37	53.29	40.69	46.21
July	44.89	43.27	0.00	44.97	57.72	58.20	42.97	41.72
August	50.12	46.97	0.00	47.40	0.00	0.00	46.54	27.28
September	51.15	48.04	0.00	50.87	0.00	0.00	47.37	28.21
October	35.73	51.02	0.00	51.18	0.00	63.50	47.78	35.60
Mean	45.78	46.30	15.52	47.36	26.39	36.80	45.31	
CD (0.05)	a = 3.08		b = 2.55		c = 6.76		d = 6.74	
1985								
June	46.85	44.96	50.78	44.31	64.71	46.59	41.75	48.56
July	48.58	44.05	56.08	42.16	70.10	51.47	42.82	44.61
August	53.27	44.78	0.00	46.71	0.00	0.00	45.35	27.16
October	60.62	55.54	0.00	55.10	0.00	0.00	55.98	32.46
Mean	52.28	47.33	26.72	47.07	33.71	24.51	46.48	
CD (0.05)	a = 1.62		b = 1.02		c = 2.40		d = 2.22	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

FIG. 14 - SAND, SILT AND CLAY CONTENTS (%) OF ERODED SOIL - 1984.

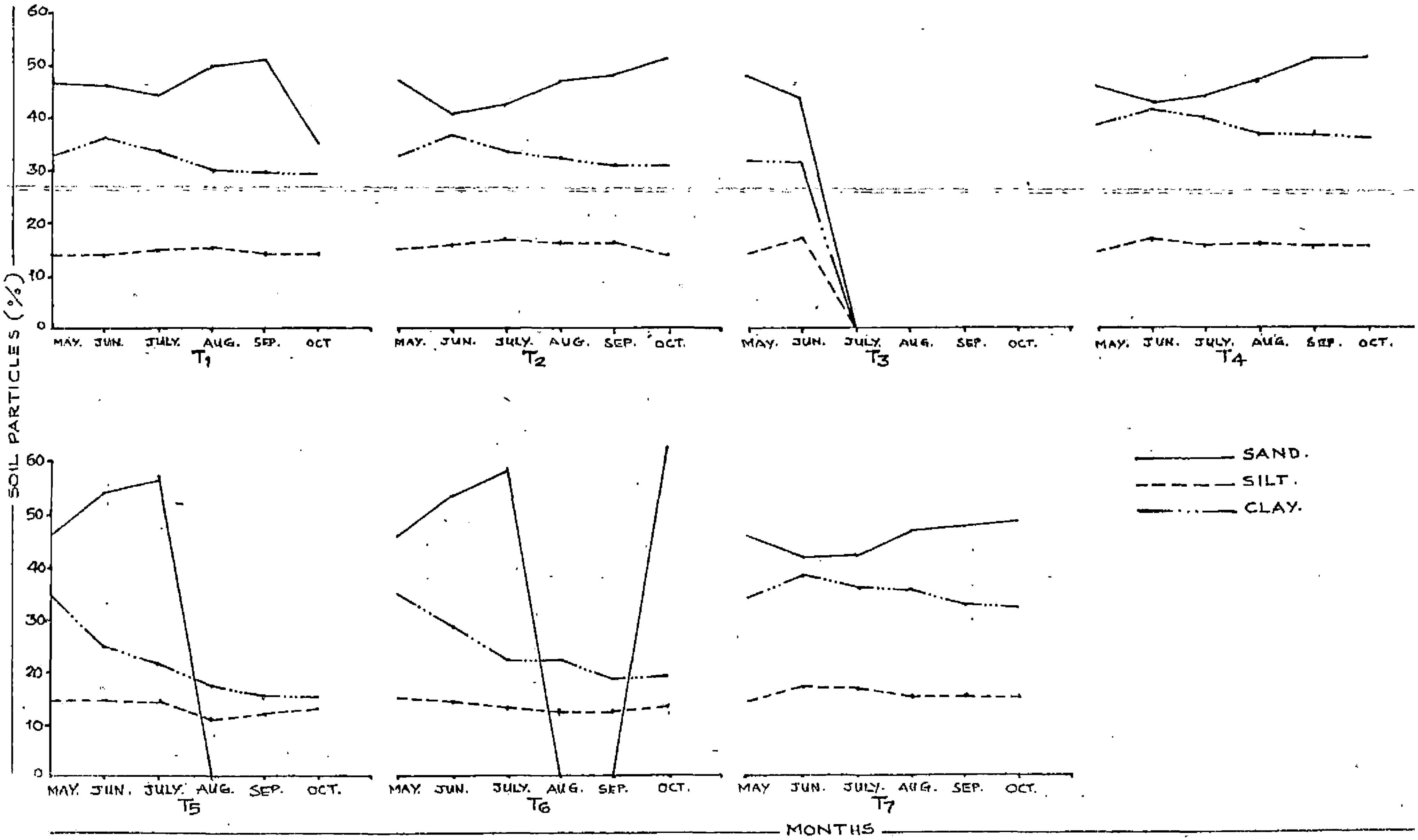
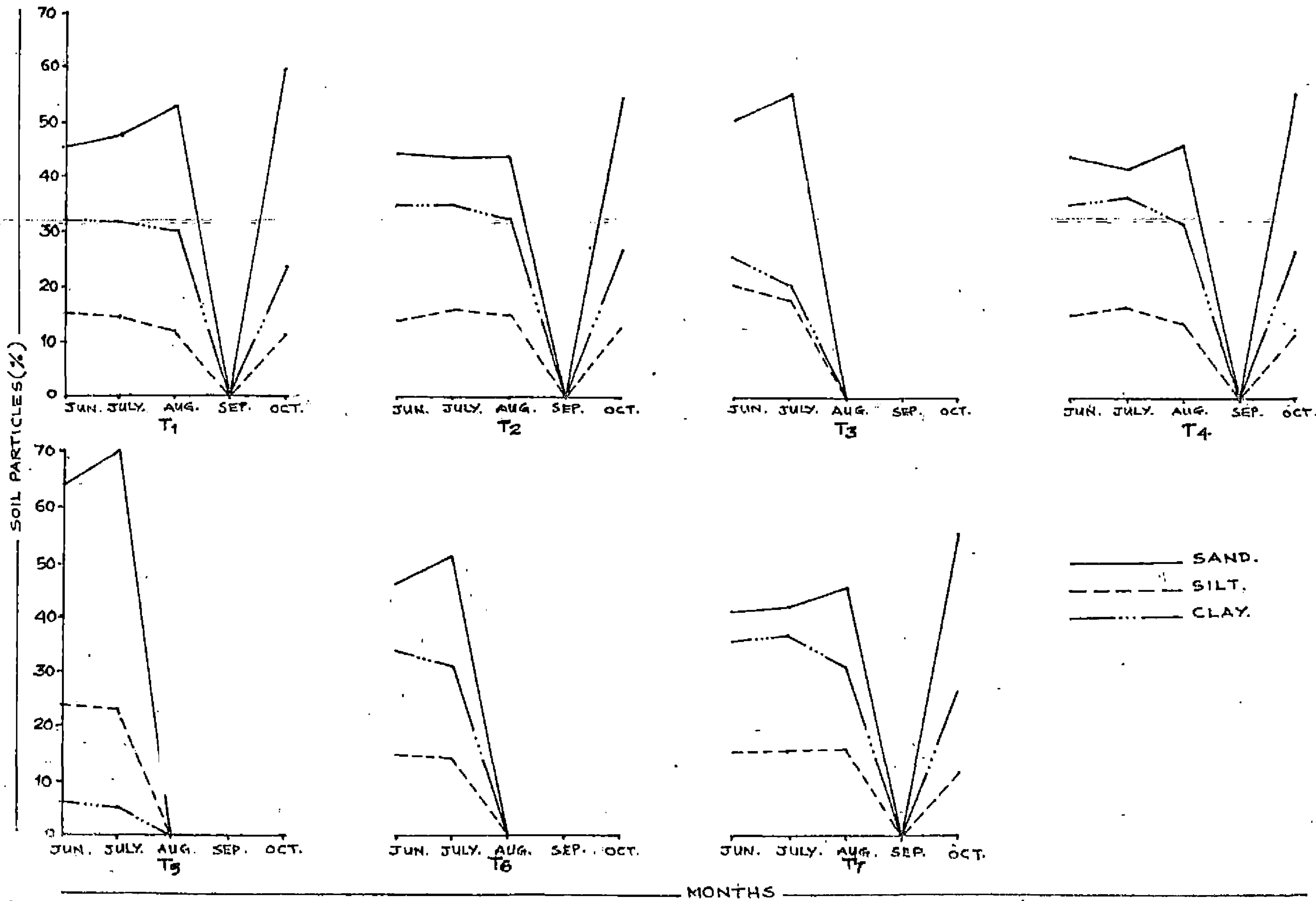


FIG. 15 – SAND, SILT AND CLAY CONTENTS (%) OF ERODED SOIL – 1985



trend as that of the first year, as far as the annual values were concerned. Over the months, the differences between and within each treatment became much more magnified and were significant in many cases.

3.1.3 Silt:

Table 14 and Fig. 14 and 15 show the data on silt content.

T_7 recorded the highest annual value of 15.87 per cent very closely followed by T_2 and T_4. T_3 registered the lowest value of 5.29 per cent. Monthly values failed to show any specific trend between T_1, T_2, T_4 and T_7. But T_5 and T_6 were inferior to all towards the end of the year and many times were on par. Within the treatment, there was no definite trend, between months.

As in the case of sand, treatment differences were more pronounced in the second year. Barring T_7 and T_2, all other treatments differed significantly. T_5 and T_3 recorded higher values. Other treatments followed these two without a definite trend. Over the months, within each treatment, a decreased silt content was observed and October recorded the lowest value always.

3.1.4 Clay:

Data are reported in Table 15 and Fig. 14 and 15.

Table 14. Silt content (%) of settled sediment -

Year/Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
1984								
May	14.73	15.30	14.56	14.71	14.66	14.92	14.83	14.82
June	14.09	16.35	17.19	16.73	14.70	14.03	17.11	15.74
July	15.39	16.66	0.00	15.51	13.62	13.09	16.82	13.01
August	15.15	16.02	0.00	15.66	11.64	12.63	15.35	12.35
September	14.25	16.09	0.00	15.29	12.41	12.68	15.57	12.18
October	14.68	14.96	0.00	15.04	12.78	13.04	15.51	12.29
Mean	14.72	15.73	5.29	15.49	13.30	13.39	15.87	
CD (0.05)	a = 0.42		b = 0.33		c = 0.88		d = 0.87	
1985								
June	15.03	14.38	20.11	14.60	24.13	14.92	15.59	16.97
July	14.64	16.53	18.10	16.12	23.62	14.67	15.89	17.08
August	12.51	14.89	0.00	14.28	0.00	0.00	16.15	8.26
October	11.49	13.45	0.00	11.69	0.00	0.00	12.43	7.01
Mean	13.42	14.81	9.55	14.17	11.94	7.39	15.02	
CD (0.05)	a = 0.54		b = 0.42		c = 0.94		d = 0.93	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 15. Clay content (%) of settled sediment

Year/Month	Treatments T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
1 9 8 4								
May	34.25	33.75	32.53	33.93	34.60	34.94	34.44	34.06
June	36.87	37.40	32.67	36.89	25.35	28.68	38.63	33.78
July	34.51	34.87	0.00	35.19	22.33	22.81	36.05	26.54
August	30.13	33.55	0.00	32.43	18.95	23.96	35.19	24.89
September	30.56	31.62	0.00	30.95	15.24	18.77	33.76	22.98
October	29.97	31.11	0.00	30.90	15.21	19.88	32.24	22.76
Mean	32.71	33.72	10.87	33.38	21.95	24.84	35.05	
CD (0.05)	a = 0.49		b = 0.45		c = 1.19		d = 1.2	
1 9 8 5								
June	33.91	35.66	26.13	35.84	7.38	34.22	36.82	29.99
July	32.49	35.59	21.78	36.78	5.10	32.22	36.91	28.70
August	30.46	33.79	0.00	33.56	0.00	0.00	33.86	18.81
October	24.71	27.00	0.00	27.07	0.00	0.00	27.55	15.19
Mean	30.40	33.01	11.98	33.31	3.12	16.61	33.79	
CD (0.05)	a = 0.97		b = 0.51		c = 1.27		d = 1.13	

ents
atment

T_7 was significantly the highest and T_3 the lowest. The other treatments differed significantly except T_2 and T_4 which were on par in the first year. The dominance of T_7 was maintained throughout the year except in May when all the treatments were on par. There was a gradual decrease over the months. Monthly differences within each treatment were, in general, significant in the initial months and insignificant towards the end.

In the second year, an almost same trend of the first year was observed except for the fact that T_5 gave the lowest value. The pattern of prominence of each treatment over the months was also almost comparable to that of the first year.

The above results showed that the settled sediment was more clayey in the initial months and sandy in the final months. Silt and gravel content also showed reduction over the passage of time, but the rate of reduction of gravel content was manifested in a more conspicous way than that of silt. On direct continuous hitting of intense rainfall on heavily tilled soil, individual soil particles especially smaller ones will get easily detøached because of splash effect. When 95 per cent of the soil loss in sheet erosion process is due to the raindrop impact (Yadav, 1961) and more than 87 per cent of the aggregates of the interrill erosion is constituted by soil particles of less than 0.5 mm (Albert et al. 1977), the more clayey nature of the eroded soil in the initial months is cognisable. The comparatively high gravel content in the early months may be due to the high sediment carrying capacity arising out of the uninterrupted and accumulated flow of the run-off. With increase in protective role of the vegetal cover (Tables 42 a & b) and comparatively lesser erosive rains towards the end (Table 5 and Fig. 7 & 8), soil particle detachment and splash erosion are practically reduced and give only a little quantity of clay and silt. This will essentially increase the sand content of the eroded soil. The very high content of sand (70.10 per cent) and very low clay (5.10%) in the grassed plot are in support to this. The observed differences in gravel, sand, silt and clay contents between various treatments and months, can therefore be explained.

3.2 Suspended sediments:

Tables 16, 17 and 18 show the suspended sand, silt and clay percentages, respectively.

3.2.1 Sand:

Though, many of the treatments were comparable,

Table 16. Sand content (%) of suspended sediment

Year/Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
1984								
May	8.38	8.14	2.90	7.89	9.02	6.33	7.36	7.15
June	11.03	9.35	3.49	9.45	6.08	3.01	9.98	7.49
July	9.50	9.75	0.00	8.98	1.82	2.93	5.11	5.44
August	2.90	3.43	0.00	2.60	0.00	0.00	2.56	1.64
September	2.45	3.50	0.00	2.47	0.00	0.00	1.64	1.44
October	1.34	0.71	0.00	0.86	0.00	0.00	1.66	0.65
Mean	5.93	5.81	1.07	5.37	2.82	2.05	4.71	
CD (0.05)	a = 1.17		b = 0.66		c = 1.89		d = 1.75	
1985								
June	7.15	8.73	0.00	7.05	0.00	8.20	7.68	7.76
July	6.12	7.52	0.00	8.16	0.00	3.46	7.80	6.61
August	2.71	5.63	0.00	3.32	0.00	0.00	2.83	2.89
Mean	5.33	7.29	0.00	6.18	0.00	2.90	4.58	
CD (0.05)	a = 1.39		b = 0.70		c = 1.70		d = 1.57	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 17. Silt content (%) of suspended sediment

Year/Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
1 9 8 4								
May	45.57	44.17	33.08	45.85	43.71	47.86	44.74	43.57
June	46.36	48.86	31.75	48.51	46.30	38.90	46.95	43.95
July	43.56	46.46	30.07	49.59	37.20	35.29	47.38	41.36
August	38.25	37.98	20.13	42.05	15.99	21.80	45.52	31.67
September	38.85	38.42	0.00	39.78	0.00	17.82	42.02	25.27
October	32.49	35.21	0.00	37.28	0.00	14.66	41.03	22.95
Mean	40.85	41.85	19.17	43.84	23.87	29.39	44.61	
CD (0.05)	a = 0.79		b = 0.75		c = 1.95		d = 1.98	
1 9 8 5								
June	45.49	45.89	23.82	45.30	11.83	45.84	45.23	37.63
July	49.29	47.90	15.39	44.87	0.00	37.17	46.43	34.44
August	37.42	36.12	0.00	39.71	0.00	4.34	38.03	22.23
September	17.23	14.69	0.00	22.73	0.00	8.17	13.98	10.97
Mean	37.36	36.15	9.80	38.15	2.96	23.88	35.92	
CD (0.05)	a = .34		b = 0.88		c = 2.35		d = 2.33	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 18. Clay content (%) of suspended sediment

Year/Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
1 9 8 4								
May	46.05	47.69	64.02	46.25	47.27	45.81	47.91	49.28
June	42.61	41.79	64.76	42.03	47.62	58.09	43.24	48.59
July	43.28	43.79	69.93	41.42	60.98	62.48	47.50	52.77
August	58.85	58.59	79.85	55.35	85.04	77.53	51.92	66.73
September	58.69	58.08	100.00	57.75	100.00	82.18	56.34	73.29
October	63.17	64.77	0.00	61.86	0.00	85.34	53.98	47.44
Mean	52.61	52.45	63.09	50.78	56.82	68.58	50.14	
CD (0.05)	a = 1.58		b = 0.86		c = 2.50		d = 2.24	
1 9 8 5								
June	47.36	45.38	74.89	47.65	88.17	45.96	47.09	56.64
July	44.59	44.57	84.61	46.97	100.00	59.37	45.77	60.84
August	59.87	58.24	0.00	56.97	0.00	95.67	59.11	47.12
October	82.77	85.31	0.00	77.27	0.00	91.88	86.02	60.46
Mean	58.65	58.38	39.88	57.22	47.04	73.22	59.50	
CD (0.05)	a = 1.13		b = 0.92		c = 2.38		d = 2.43	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

T_1 and T_2 recorded significantly higher values than T_3 which gave the lowest value. Barring the initial two-three months, in T_3, T_5 and T_6 there were no sand at all. Over the months, sand content showed a drastic reduction in all the treatments with October recording significantly the lowest value.

In the second year, the initial values itself were lower than that of the first year. T_3 and T_5 throughout the year, and all other treatments towards the end, recorded zero values. The monthly differences were significant.

3.2.2 Silt:

The mean values showed that T_7, very closely followed by T_4, was significantly higher to all other treatments. T_3 gave the lowest value. As in sand, silt also showed a reduction over the months within each treatment. June gave the highest value and October the lowest. Monthly differences were significant in many cases.

In the second year, an almost similar trend was maintained between the treatments and months.

3.2.3 Clay:

Treatment means differed significantly. T_6 gave the highest value and T_7, the lowest. For the first three months, while T_3 gave the highest value, towards the final months T_5 superseded T_3. Contrary to sand and silt contents, there was a sharp increase in clay content over the months in each treatment. Except for the initial few months, the monthly differences were also significant. The clay content in T_3 and T_5 was very high that it reached even 100 per cent in September.

In the second year, the trend was almost same as that of the first year. T_3 and T_5 gave maximum values by July itself.

Suspended sediments are mainly constituted by minute particles which will not settle down quickly. Among the particles, clay, being the finest, will be in a suspended state for longer period than silt and sand. Therefore, the very high and low percentages of clay and silt, respectively, and negligible portion of sand seen in the run-off of all treatments are explainable. The presence of some quantity of sand in the suspended state may be attributed to the turbulent nature of the run-off while sampling consequent to high erosive rainfall especially in the initial months. In subsequent months, the sand content became negligible and was even absent in T_3, T_5 and T_6 probably because of the lesser erosive rainfall and better protective abilities of the treatments.

4. Total gravel, sand, silt and clay losses:

Figs. 16 and 17 illustrate the total quantity of gravel, sand, silt and clay particles eroded by each treatment in each year. Table 19 provides the percentages of individual fractions to the total soil loss.

It could be seen that T_7 in both years eroded the highest quantities of all soil particles. In the first year T_3 gave the lowest value and in the second year T_5. The 352 t of eroded soil of T_7 in the first year (Table 11) was constituted by about 53 t of gravel, 116 t of sand, 60 t of silt and 111 t of clay. Corresponding percentages of these fractions to the total eroded soil were 15, 33, 17 and 32, respectively. In T_3, out of the 8 t eroded soil, about 36 per cent i.e. 3 t was composed of clay. It contained relatively little gravel i.e. only 6 per cent (0.5 t). In the second year, in T_3 and T_5 there was no gravel loss; the coarser particles were relatively lesser and consequently the clay portion measured almost 50 per cent of the eroded soil.

Except T_3, the suspended sediment load of both clay and silt to total soil loss was less than 5 per cent in the first year in all the treatments. It was less than 10 per cent in the second year except in T_5 and T_3. Sand constituent of the suspended sediment, in general, could account only less than 1 per cent. Relatively high

Table 19. Year-wise gravel, sand, silt and clay contents (%) in eroded soil

Year/Treatment	Settled sediment				Suspended sediment			Total sediment			
	Gravel	Sand	Silt	Clay	Sand	Silt	Clay	Gravel	Sand	Silt	Clay
1984											
T_1	10.66	36.92	11.44	27.58	0.74	3.59	3.59	10.66	37.66	15.03	31.18
T_2	15.09	33.20	12.23	27.09	0.77	4.14	4.02	15.09	33.98	16.38	31.11
T_3	5.70	33.49	12.11	24.23	0.60	5.00	11.76	5.70	34.00	17.10	35.99
T_4	21.90	34.86	5.93	27.08	0.75	4.32	4.03	21.91	35.12	10.26	31.12
T_5	12.82	41.48	11.55	17.78	0.44	3.34	3.92	12.82	41.90	14.90	21.71
T_6	12.22	40.58	10.72	22.70	0.32	3.46	5.04	12.22	40.90	14.18	27.74
T_7	15.16	32.36	12.22	26.80	0.72	4.73	4.80	15.15	33.08	16.95	31.59
1985											
T_1	14.97	34.33	10.84	24.26	0.81	5.69	6.06	14.97	35.14	16.54	30.31
T_2	16.04	31.73	10.68	25.01	1.07	6.14	6.19	16.04	32.81	16.82	31.20
T_3	0.00	18.55	8.20	10.66	0.00	11.48	38.52	0.00	18.85	19.67	49.18
T_4	14.36	31.05	10.66	25.40	1.06	6.58	7.19	14.36	32.11	17.24	32.59
T_5	0.00	29.73	10.81	2.70	0.00	5.41	43.24	0.00	29.73	16.22	45.95
T_6	18.38	29.88	9.45	21.39	0.54	3.94	5.15	18.38	30.42	13.40	35.51
T_7	15.22	30.19	11.21	26.26	0.99	6.00	6.35	15.23	31.48	17.21	32.49

FIG.16 _ ANNUAL LOSS OF GRAVEL, SAND, SILT AND CLAY (t/ha) - 1984.

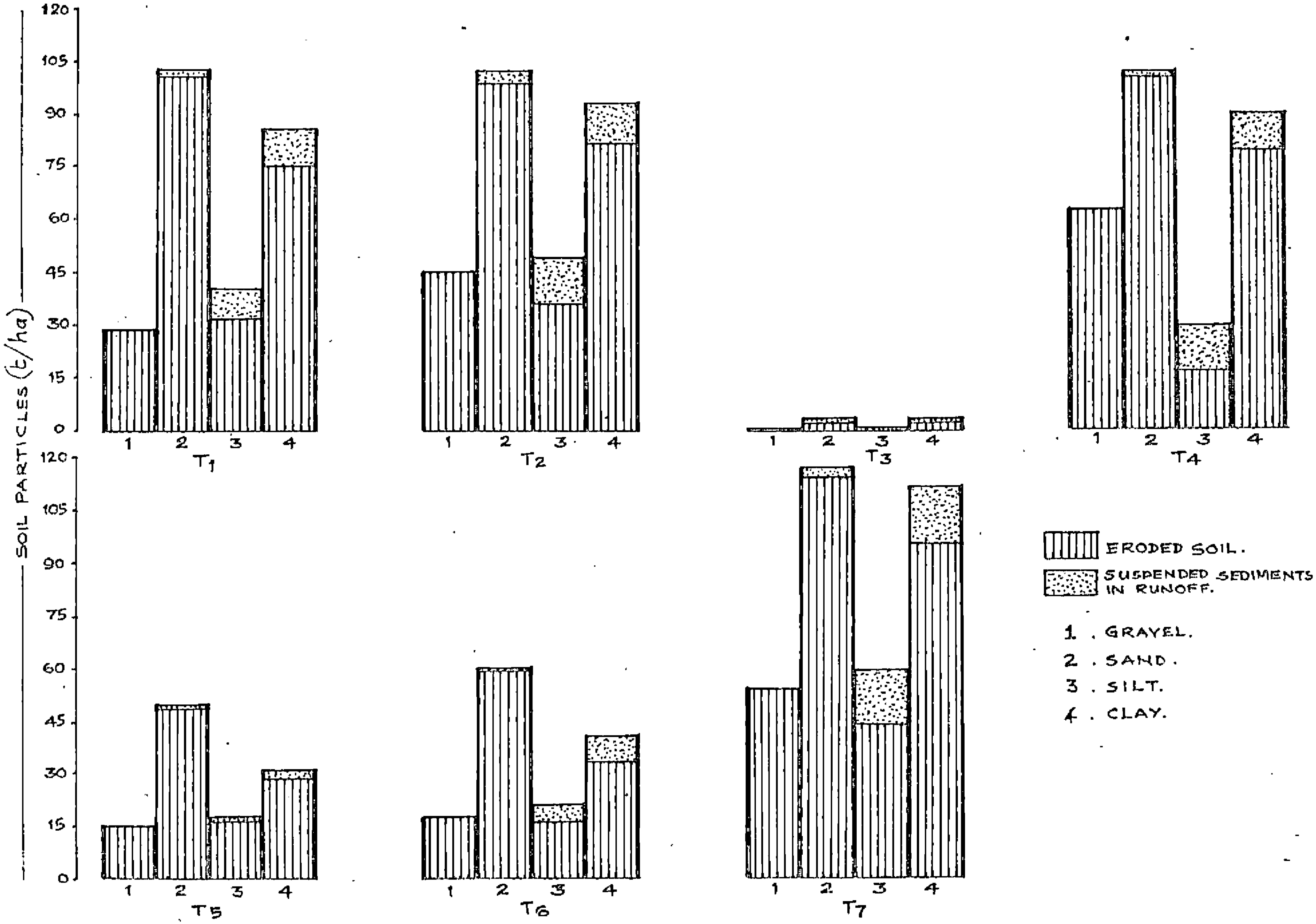
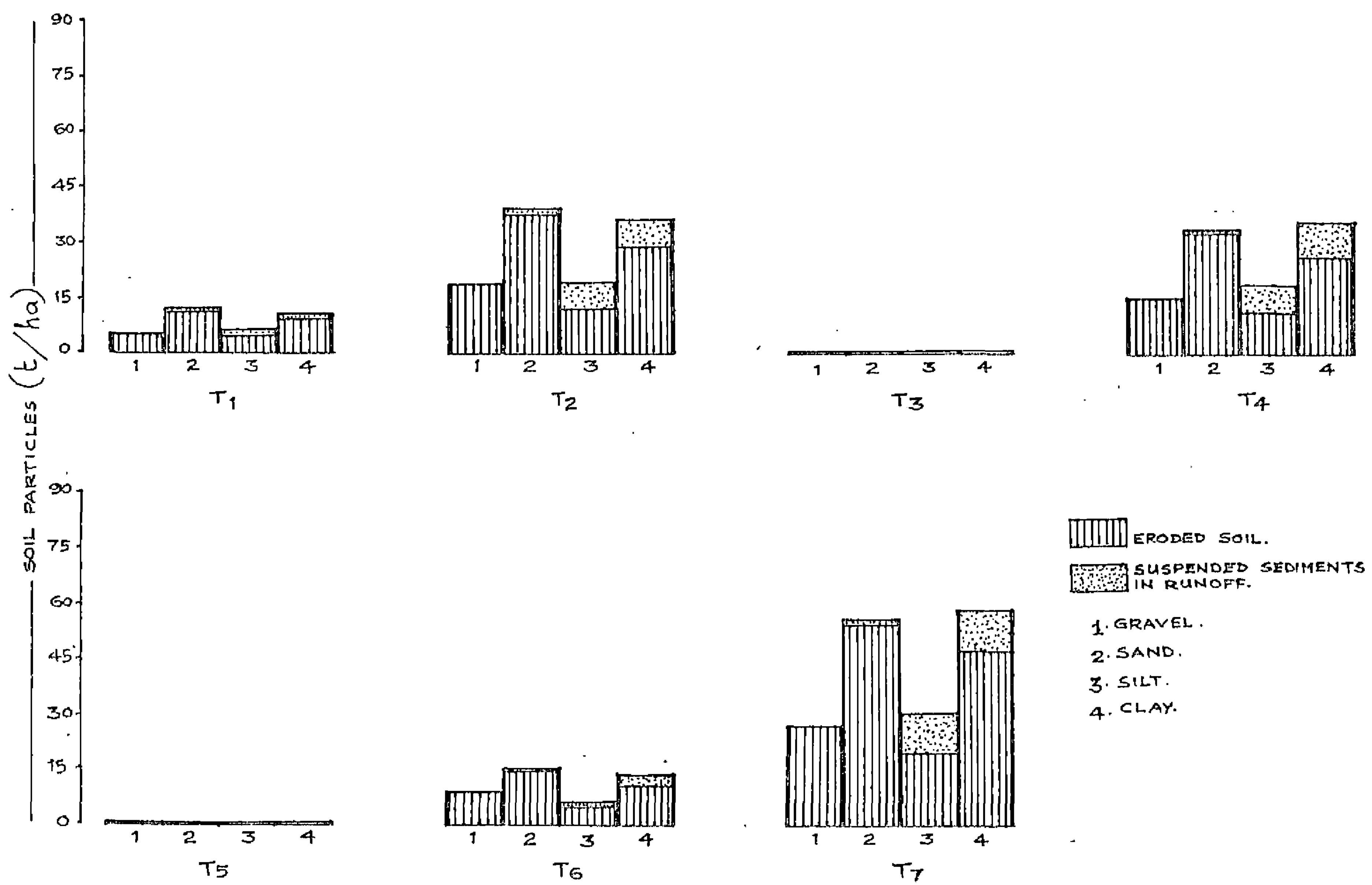


FIG.17 _ANNUAL LOSS OF GRAVEL, SAND, SILT AND CLAY (t/ha)- 1985



percentages of suspended sediment to total soil loss seen in T_3 and T_5 are indicative of the very low settled sediment losses.

5. Nutrient loss:

Percentage contents and total losses of the primary and secondary nutrients through eroded soil and run-off as affected by different treatments are discussed in the following section. Zero values are indicative of zero erosion consequent to treatment effects as already explained.

5.1 Primary nutrients:

5.1.1 Contents in eroded soil:

Total contents of nitrogen, phosphorus and potassium in the eroded soil at monthly intervals are presented in Tables 20, 21 and 22, respectively.

Perusal of the data showed that contents of all these nutrients were comparatively higher in the initial months. In some treatments, nitrogen and potassium contents were even higher than that of the soil matrix. For example, when the inherent N content of the surface soil was 0.148 per cent (Table 1) it was 0.151, 0.152 and 0.150 per cent, respectively, in T_2, T_5 and T_6 in the first month of first year. All the treatments except T_3 recorded higher values of K than the initial soil status of 0.226

Table 20. N content (%) in eroded soil

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
May	0.144	0.151	0.135	0.141	0.152	0.150	0.141
June	0.123	0.140	0.131	0.130	0.142	0.133	0.134
July	0.121	0.130	0.121	0.122	0.114	0.121	0.123
August	0.112	0.121	0.123	0.103	0.096	0.101	0.101
September	0.102	0.101	0.000	0.102	0.093	0.103	0.102
October	0.094	0.093	0.000	0.101	0.086	0.086	0.112
1985							
June	0.139	0.157	0.136	0.144	0.110	0.110	0.157
July	0.113	0.144	0.103	0.139	0.079	0.100	0.133
August	0.115	0.133	0.090	0.122	0.000	0.000	0.134
September	0.000	0.119	0.000	0.109	0.000	0.000	0.110
October	0.095	0.093	0.000	0.090	0.000	0.000	0.088

Table 21. P content (%) in eroded soil

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
May	0.043	0.051	0.041	0.044	0.053	0.044	0.046
June	0.040	0.050	0.041	0.040	0.041	0.043	0.039
July	0.038	0.036	0.039	0.036	0.036	0.034	0.041
August	0.033	0.041	0.023	0.033	0.022	0.031	0.022
September	0.030	0.031	0.000	0.034	0.021	0.022	0.031
October	0.031	0.030	0.000	0.029	0.013	0.031	0.033
1985							
June	0.035	0.039	0.032	0.031	0.033	0.034	0.036
July	0.031	0.036	0.032	0.033	0.024	0.037	0.033
August	0.026	0.033	0.019	0.031	0.000	0.000	0.032
September	0.000	0.033	0.000	0.031	0.000	0.000	0.031
October	0.030	0.035	0.000	0.035	0.000	0.000	0.033

Table 22. K content (%) of eroded soil

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
May	0.227	0.255	0.221	0.227	0.270	0.241	0.227
June	0.227	0.253	0.192	0.201	0.251	0.241	0.215
July	0.230	0.225	0.189	0.207	0.237	0.224	0.206
August	0.188	0.219	0.203	0.214	0.203	0.203	0.186
September	0.196	0.212	0.000	0.184	0.203	0.201	0.179
October	0.196	0.181	0.000	0.185	0.185	0.160	0.172
1985							
June	0.177	0.242	0.188	0.200	0.161	0.220	0.228
July	0.182	0.241	0.184	0.207	0.154	0.217	0.238
August	0.173	0.196	0.175	0.180	0.000	0.000	0.182
September	0.000	0.000	0.000	0.000	0.000	0.000	0.192
October	0.167	0.179	0.000	0.163	0.000	0.000	0.179

per cent. In general, over the months, all the treatments showed a gradual decrease, registering values as low as 0.086% for N in T_5 and T_6, 0.013 per cent for P in T_5 and 0.160 per cent for K in T_6 at the end of first year.

In the second year, the declining trend over the months was spectacular.

5.12 Contents in run-off:

Tables 23, 24, and 25 contain the concentrations of dissolved N, P and K, respectively, in run-off at monthly intervals.

As in the case of nutrient contents of eroded soil, here also the concentrations were higher in initial months and thereafter showed a decrease. T_5, the grassed plot, recorded the highest content of dissolved N in both years. Here the values varied between 1.08 and 3.75 ppm in the first year whereas 1.14 and 3.28 ppm in the second year. N concentrations in T_1 was comparatively lower than that in other cropped treatments with the initial value of 2.04 ppm narrowing down to 0.97 ppm in October of the first year. T_7, when fallow also recorded lower values comparable to T_1. P content was the least and K the highest among the three nutrients. P content was always less than 1 ppm

Table 23. N content (ppm) in run-off

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
May	2.04	3.06	3.11	2.53	3.75	3.03	2.04
June	1.99	3.07	3.10	2.15	3.54	2.88	2.07
July	1.80	3.22	3.18	2.19	3.04	2.03	1.79
August	1.26	1.93	1.62	1.38	2.32	1.51	1.26
September	0.96	1.33	1.00	1.00	1.42	0.96	0.98
October	0.97	1.05	0.96	0.99	1.08	0.93	0.99
1985							
June	2.04	2.93	2.99	2.07	3.28	3.20	3.23
July	1.75	2.59	2.65	2.09	3.30	3.01	3.12
August	1.44	2.11	1.72	1.64	2.94	2.06	1.93
September	0.91	1.65	1.51	1.06	1.87	1.34	1.03
October	0.82	0.96	0.99	1.07	1.29	0.92	1.03
December	0.93	0.97	1.04	1.06	1.14	0.99	0.92

Table 24. P content (ppm) in run-off

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1 9 8 4							
May	0.25	0.62	0.53	0.39	0.61	0.45	0.31
June	0.24	0.46	0.46	0.40	0.54	0.39	0.24
July	0.25	0.34	0.29	0.27	0.31	0.25	0.25
August	0.15	0.21	0.19	0.16	0.07	0.11	0.12
September	0.09	0.13	0.10	0.10	0.08	0.11	0.12
October	Tr	0.09	Tr	0.07	Tr	0.05	0.07
1 9 8 5							
June	0.19	0.46	0.44	0.39	0.45	0.39	0.43
July	0.13	0.46	0.38	0.35	0.36	0.30	0.37
August	0.08	0.24	0.24	0.22	0.13	0.20	0.19
September	Tr	0.22	Tr	0.10	Tr	0.08	0.09
October	Tr	0.09	Tr	0.06	Tr	Tr	0.09
December	Tr	0.08	Tr	0.05	Tr	Tr	Tr

Table 25. K content (ppm) in run-off

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
<u>1984</u>							
May	2.80	4.78	4.04	3.01	4.64	3.76	2.96
June	2.37	4.17	3.71	2.87	4.11	3.75	2.31
July	2.04	2.22	2.11	2.00	2.77	2.85	1.89
August	0.89	1.62	1.74	1.56	1.48	1.72	0.90
September	0.95	1.13	0.98	0.96	1.08	0.91	0.97
October	0.61	0.92	0.97	0.77	0.74	0.85	0.76
<u>1985</u>							
June	2.75	4.51	4.12	3.91	5.10	3.39	4.27
July	2.02	3.43	3.42	2.89	2.39	2.82	3.56
August	1.15	2.02	2.02	1.93	2.03	2.08	2.40
September	0.78	1.01	1.90	1.72	1.03	1.35	1.56
October	0.77	0.96	0.74	0.96	0.89	0.89	1.00
December	0.57	0.82	0.48	0.92	0.72	0.94	0.83

in all the treatments and even became undetectable in T_1, T_3 and T_5 towards the end. K content was higher in T_2, T_3 and T_5 in both years. T_1 recorded the lowest value. Over the months concentrations of dissolved K also showed a declining trend with the lowest value of 0.48 ppm in T_3. In general, all the intercropped treatments consistently recorded higher concentrations of dissolved nutrients in all the months during both years.

5.2 Secondary nutrients:

5.2.1 Contents in eroded soil:

Ca, Mg and S contents of eroded soil are reported in Table 26, 27 and 28 respectively.

As in the case of primary nutrients, a clearly decreasing trend in their contents over the months was the general feature observed in these nutrients too. The highest Ca content was revealed in T_7 where it varied from 0.073 per cent in May to 0.043 per cent in October of the first year. T_2 also registered slightly higher contents in the initial months, than the inherent values (Table 1). When the total Mg content of the soil matrix was only 0.248 per cent in T_2 it even reached 0.265 per cent in June of the first year, the highest value observed during the entire period of the experiment. T_7 also registered

Table 26. Ca content (%) in eroded soil

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1 9 8 4							
May	0.054	0.061	0.036	0.054	0.054	0.054	0.073
June	0.050	0.060	0.034	0.060	0.054	0.054	0.077
July	0.051	0.063	0.038	0.063	0.043	0.043	0.070
August	0.049	0.054	0.031	0.063	0.046	0.046	0.061
September	0.046	0.046	0.000	0.058	0.037	0.043	0.062
October	0.037	0.050	0.000	0.051	0.031	0.044	0.043
1 9 8 5							
June	0.030	0.042	0.032	0.043	0.037	0.041	0.042
July	0.030	0.043	0.031	0.041	0.033	0.034	0.042
August	0.030	0.040	0.029	0.040	0.000	0.000	0.041
September	0.000	0.036	0.000	0.035	0.000	0.000	0.038
October	0.032	0.041	0.000	0.040	0.000	0.000	0.041

Table 27. Mg content (%) in eroded soil

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
May	0.253	0.264	0.194	0.243	0.203	0.243	0.261
June	0.243	0.265	0.193	0.233	0.245	0.235	0.253
July	0.256	0.248	0.104	0.236	0.196	0.246	0.234
August	0.247	0.240	0.091	0.213	0.191	0.247	0.243
September	0.248	0.242	0.000	0.218	0.187	0.223	0.242
October	0.231	0.244	0.000	0.211	0.111	0.192	0.226
1985							
June	0.225	0.230	0.208	0.211	0.195	0.217	0.228
July	0.215	0.230	0.184	0.207	0.172	0.205	0.227
August	0.214	0.224	0.000	0.187	0.000	0.000	0.207
September	0.000	0.208	0.000	0.187	0.000	0.000	0.202
October	0.199	0.190	0.000	0.184	0.000	0.000	0.223

Table 28. S content (%) in eroded soil

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
May	0.090	0.093	0.081	0.082	0.071	0.073	0.094
June	0.090	0.096	0.074	0.082	0.072	0.071	0.082
July	0.088	0.087	0.070	0.093	0.084	0.080	0.084
August	0.073	0.096	0.053	0.084	0.078	0.072	0.080
September	0.074	0.087	0.000	0.071	0.079	0.070	0.086
October	0.065	0.081	0.000	0.070	0.071	0.064	0.077
1985							
June	0.062	0.073	0.062	0.071	0.051	0.073	0.073
July	0.054	0.066	0.063	0.070	0.043	0.061	0.071
August	0.046	0.061	0.000	0.062	0.000	0.000	0.068
September	0.000	0.071	0.000	0.063	0.000	0.000	0.061
October	0.041	0.062	0.000	0.061	0.000	0.000	0.061

high values and was 0.261 per cent in the initial month which decreased to 0.226 per cent at the end of first year. T_2, T_4 and T_7 registered the highest S content, where the values varied from 0.081 to 0.093, 0.070 to 0.082 and 0.077 to 0.094 per cent, respectively, in the first year. In the case of T_3 and T_5 all these nutrients gave comparatively lower values than the other treatments, throughout.

An almost similar trend with comparatively lower values was the general feature in the second year. However, T_5 recorded Mg and S levels even less than T_3, with values ranging from 0.172 to 0.195 and 0.043 to 0.051 per cent, respectively.

5.2.2 Contents in run-off:

Data are reported in Tables 29 and 30.

Eventhough, the total Mg content of soil was higher than that of Ca, the dissolved Ca was more than that of Mg. S content in run-off was below the detectable level, throughout. As in the case of eroded soil, concentration in run-off also came down with increase in time registering the lower values at the end. But in many cases the decrease was not progressive. T_2 recorded the highest Ca content of 2.75 ppm in July and 1.90 ppm at the end of

Table 29. Ca content (ppm) in run-off

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1 9 8 4							
May	2.10	2.10	2.08	2.24	2.06	2.09	2.29
June	2.10	2.14	2.07	2.26	1.85	2.09	2.14
July	2.54	2.75	2.03	1.99	1.34	1.98	2.15
August	2.36	2.55	1.89	1.84	1.59	1.20	1.87
September	1.82	1.99	1.49	1.81	0.84	1.06	2.18
October	1.58	1.90	1.61	1.89	0.95	1.06	1.68
1 9 8 5							
June	1.75	2.04	1.73	1.96	1.94	2.06	1.97
July	1.72	2.12	1.83	1.94	1.71	1.52	1.89
August	1.85	1.80	1.31	1.58	1.23	0.99	1.95
September	1.05	1.28	1.21	1.01	0.81	1.00	0.85
October	1.23	1.30	1.28	1.23	0.83	0.97	1.04
December	1.06	1.23	0.89	1.26	0.58	0.86	1.03

Table 30. Mg content (ppm) in run-off

Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
May	0.56	0.54	0.51	0.57	0.48	0.45	0.54
June	0.50	0.50	0.48	0.50	0.47	0.44	0.50
July	0.40	0.43	0.42	0.51	0.23	0.43	0.42
August	0.38	0.45	0.40	0.40	0.25	0.31	0.33
September	0.35	0.40	0.37	0.41	0.15	0.30	0.44
October	0.40	0.42	0.30	0.34	0.21	0.36	0.44
1985							
June	0.43	0.45	0.37	0.40	0.34	0.32	0.40
July	0.37	0.43	0.34	0.37	0.30	0.31	0.34
August	0.31	0.41	0.34	0.37	0.30	0.30	0.42
September	0.32	0.34	0.31	0.40	0.28	0.22	0.32
October	0.34	0.36	0.30	0.31	0.24	0.22	0.35
December	0.32	0.33	0.29	0.31	0.29	0.22	0.29

first year. The lowest initial and final values viz. 2.06 and 0.95 ppm were shown by T_5. In the second year also similar trend was followed but with lower values than the first year. In the first year higher initial values of Mg varied between 0.45 ppm in T_6 and 0.57 ppm in T_4 and lower final values between 0.21 ppm in T_5 and 0.44 ppm in T_7. These values were 0.32 ppm in T_6, 0.42 ppm in T_2, 0.22 ppm in T_6 and 0.33 ppm in T_2, during the second year.

Water erosion of soil is a selective process especially in the wash erosion stage (Hudson, 1984). Due to the dispersive action of raindrops and selective transporation of detached soil particles, the eroded sediment will be more clayey than the soil matrix for reasons already explained in item 3. As the colloidal content of a soil is the most decisive factor in determining its fertility (Sekhon and Ghosh, 1982) the increased concentration of majority of nutrients in the initial months is attributed to the high clay contents observed. To illustrate, T_5 though heavily fertilized, registered lower values of N in the eroded soil as compared to all other treatments from July onwards in the first year. The same decrease in contents of major cations of Ca and Mg were also seen in T_5. Consultation of the Tables 13 and 15 revealed that eroded soil in T_5 was more sandy and its clay content was around 15 per cent towards the end of the first year and reached even 5 per cent in July of the second year. Whereas in other treatments which registered comparatively higher contents of nutrients, the clay fractions of the eroded soil were also high. Hence the variations seen in the nutrient levels of eroded soils of different treatments can mainly be due to the differences observed in their colloidal fractions. The same reason, to a large extent, holds good for the decreasing trend in the nutrient levels observed over the stages in both years. Further, the reduced availability of nutrients consequent to continued cropping and erosion can also be a possible factor. Among the six nutrients, the highest concentration was seen with Mg closely followed by K. Other nutrients followed the order N > Ca > S > P. This sequence is in agreement with the inherent status of these nutrients in the soil matrix (Table 1) and suggest that nutrient loss through eroded soil is proportionate to their respective soil contents. Hence, higher losses of nutrients in T_7 and T_2 and lower losses in T_5 and T_3 can be explained.

The variations in nutrient levels of run-off can mainly be attributed to the relative mobility and leachability of various ions in the erosion cycle. In an acid humid region soil, Ca largely occurs in the exchangeable form. The laterite soils of Kerala, in general, is acidic with low CEC and the exchangeable cations occur in the order Ca > Mg > K > Na (Venugopal and Koshy, 1976). Though the total Mg in the soil was approximately 4 times that of Ca (Table 40) the dissolved Mg, in the run-off was only 1/5th to that of Ca especially in the initial months. Also, dominance of dissolved Ca over Mg was the trend in all the treatments throughout the period of experiment. The high contents of Ca observed, can therefore, be attributed to the higher exchangeable Ca in soils and the greater mobility of this cation in the acidic condition. Earlier reports (Kanwar, 1976 and Sanchez, 1976) are in conformity with the findings of the present study. K, as expected, recorded the highest concentration among the cations in run-off. Predominantly kaolinitic soils of the experimental area coupled with monovalent nature of K increase its leachability in erosion cycle. Higher content of N observed is possibily due to the greater mobility of NO_3^- N, it being weakly held by the colloids. The low contents of P recorded are probably related to the low levels of native available P and high P fixation capacity of the soils of the experimental area.

Among the treatments all intercropped and fertilized ones persistently showed higher contents of dissolved nutrients irrespective of the probably high crop removal. This can only be attributed to the increased readily soluble form of nutrients consequent to fertilizer application.

For instance, highest contents of N, P and K were obtained in the run-off of T_5 which received the maximum fertilizer dose (220 kg Urea, 310 kg Single Super Phosphate and 80 kg Muriate of Potash per ha per year). This view is further strengthened by the corresponding lower contents of dissolved N, P and K throughout in T_1, a non-fertilized plot, and T_7, a cultivated fallow plot, in the first year.

5.3 Total nutrient loss:

Table 31 and Fig. 18 and 19 furnish the details of total nutrient losses through eroded soil and run-off.

All the treatments eroded considerable quantities of nutrients especially in the first year. The data reveals that losses of all the nutrients except P and K were maximum in T_7 followed by T_2. The highest losses of P and K were observed in T_2. Quantities of eroded N, P, K, Ca, Mg and S in Kg/ha were 415.98, 115,89, 679.50, 241.80, 878.32 and 298.89, respectively in T_7. T_3 remained the lowest in nutrient drain, recording corresponding values of 13.94, 8.46, 12.28, 5.63, 13.49 and 5.45 respectively. In the case of primary nutrients, losses through run-off, in general, was lower than 10 per cent of the total except in T_3 where 32.78 per cent N, 67.61 per cent P and 25.49 per cent K were contributed by run-off. Among

Table 31. Loss of total nutrients (kg/ha) through eroded soil and run-off

Nutrients	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
				1984			
N	329.35	395.00	13.94	344.88	192.75	200.28	415.98
P	92.04	119.51	8.46	101.42	48.77	53.71	115.89
K	569.70	697.32	18.28	562.80	320.66	344.21	679.50
Ca	142.54	183.39	5.63	168.49	62.69	79.57	241.80
Mg	644.70	716.51	13.49	598.65	243.86	314.12	872.32
S	213.06	247.20	5.45	211.27	85.54	100.64	298.89
				1985			
N	51.55	174.11	4.41	139.11	3.58	56.95	248.12
P	11.40	41.53	0.70	30.90	0.43	14.48	58.07
K	68.02	271.66	6.65	203.08	4.13	95.56	384.12
Ca	18.84	57.97	2.62	51.82	1.90	24.22	80.96
Mg	71.50	240.72	1.77	188.35	0.65	83.25	345.53
S	19.03	67.71	0.35	58.56	0.08	25.49	107.72

FIG. 18 _ TOTAL NUTRIENT LOSS (SOIL + RUNOFF) IN Kg/ha AND RUNOFF LOSS AS % TO TOTAL - 1984

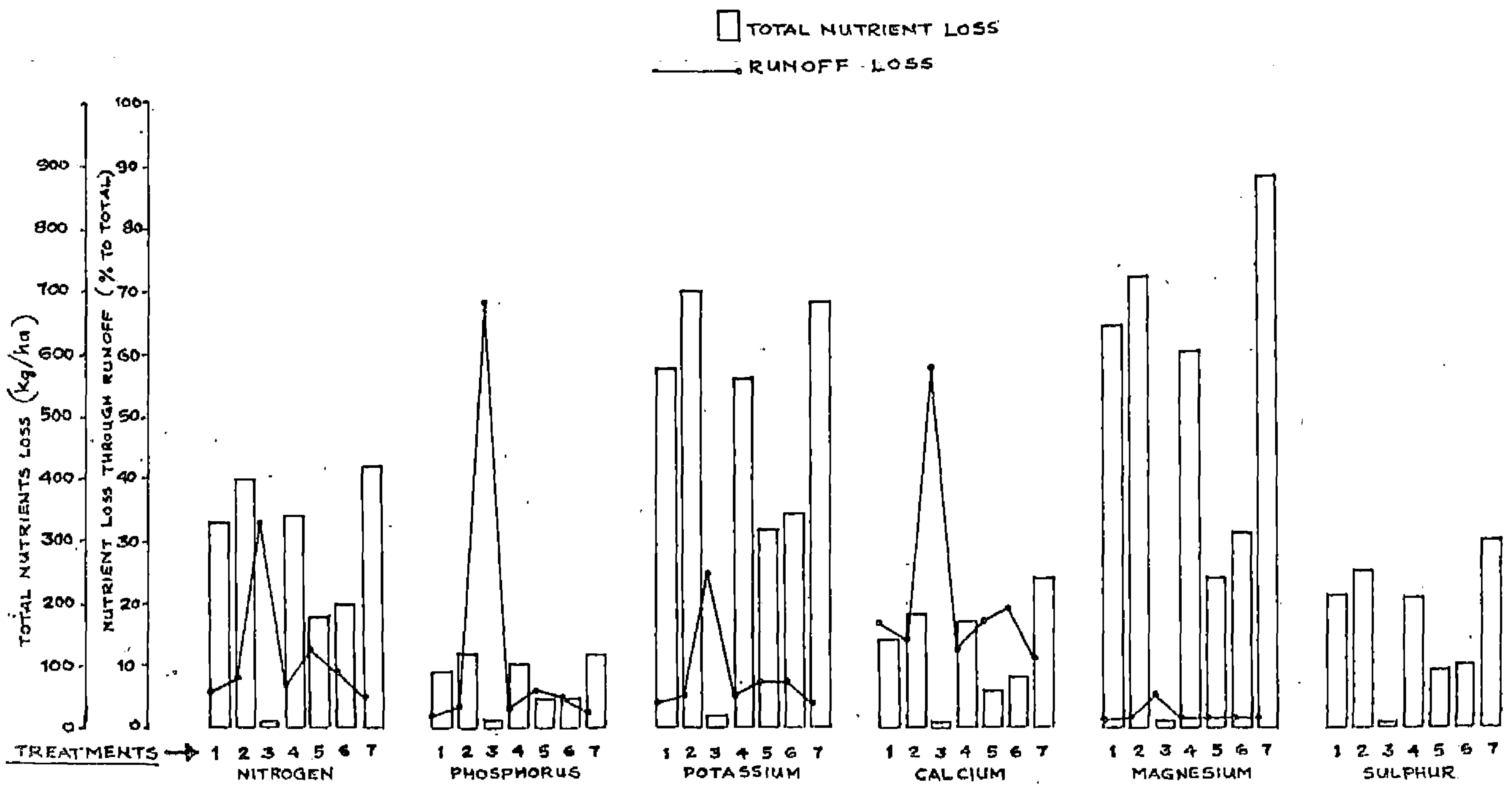
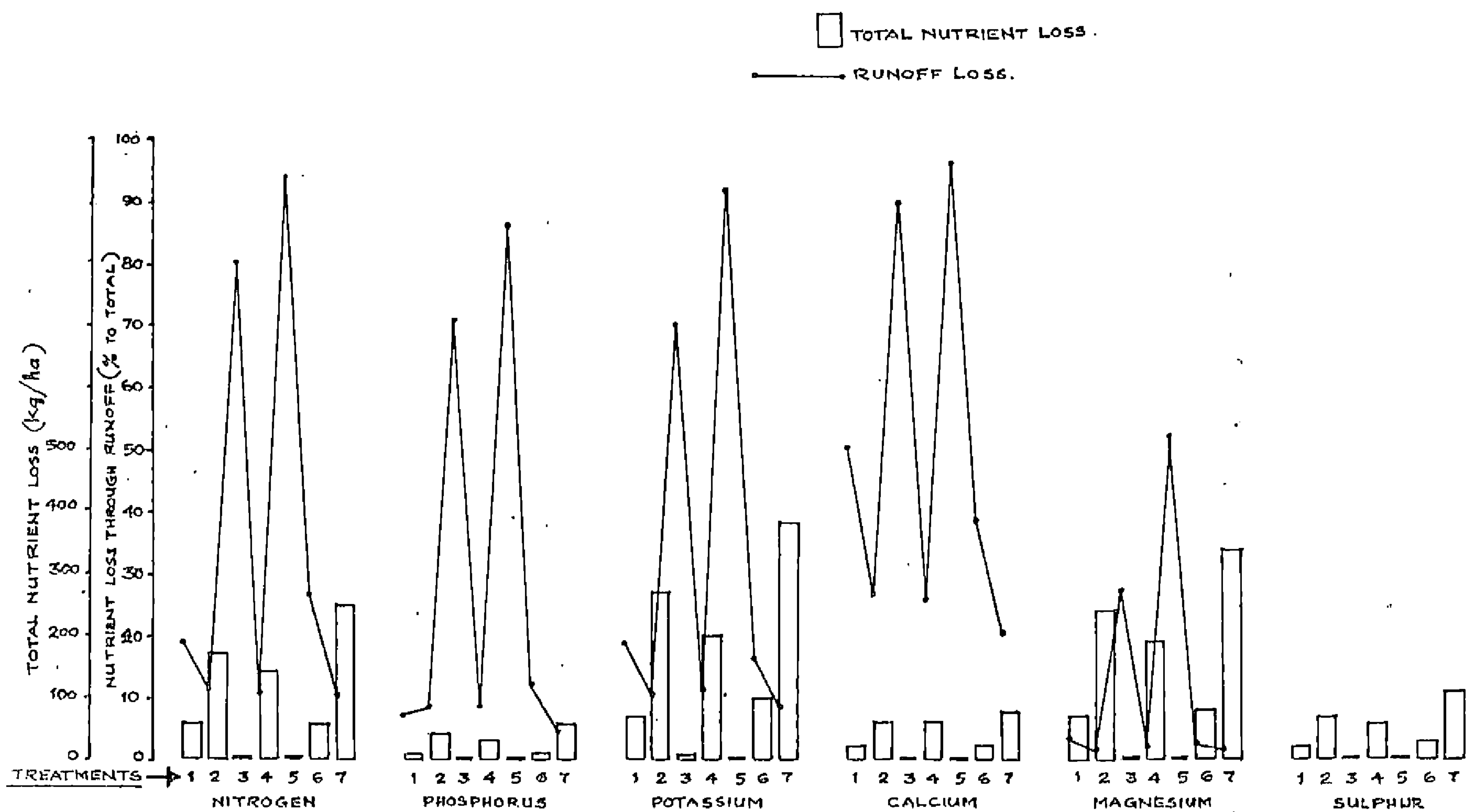


FIG. 19 – TOTAL NUTRIENT LOSS (SOIL + RUNOFF) IN Kg/ha AND RUNOFF LOSS AS % TO TOTAL – 1985



the secondary nutrients, S loss through run-off was so negligible that it could not be detected. Loss of dissolved Mg was very low and centered around one per cent while such loss of Ca was above 10 per cent, always. In the case of T_3, loss of dissolved Mg was only 5.64 per cent while that of Ca was 58.61 per cent.

There was very conspicous reduction of nutrient erosion in all the treatments in the second year as compared to the first year. However, T_7 continued to lose highest quantities of all nutrients. T_5 recorded the lowest value. Percentage loss to total through run-off as depicted in Fig. 19 was higher than the first year. T_5 and T_3 recorded higher values with T_5, recording the highest always.

The severity of nutrient drain consequent to soil erosion has extensively been documented(Khanwar, 1972 a; Goswami and Sarkar, 1975 and Singh and Biswas, 1982). Even at the lowest interpretable value, India is annually eroding much higher quantities of N, P and K than what is added through fertilizers (Kanwar, 1982). In the present study, the nutrient losses are at an alarming rate of 416 kg N, 116 kg P, and 680 kg K in the cultivated fallow plot. This amounts to about 924 kg Urea, 1500 kg Single Superphosphate and 1365 kg Muriate of Potash and is worth no less than Rs 5400/- a year (Appendix-III). Losses of 240, 880 and 300 kg/ha of Ca, Mg and S, respectively, are in addition to this. This illustrates the gravity of economic loss, in addition to the lose of fertile top soil and non-point source of environmental pollution from cultivated steep hill stopes, if soil erosion continues unabated. But by two years of grass cultivation the nutrient drain could so effectively be controlled, that it eroded only very negligible portion of nutrients. Though the grassed treatment received about 220 kg. Urea, 310 kg Single Superphosphate and 80 kg Muriate of Potash per ha per year total loss of the nutrients was less than one per cent as compared to unfertilized cultivated fallow plot of the first year. This protective ability of grass against soil degradation was manifested in a measurable way even in the first year and with 10 per cent of grass stripping as in T_7 of second year. Grass stripping could reduce more than 40 per cent and 60 per cent losses of major and secondary nutrients, respectively.

As there was not much differences in the percentage contents of nutrients in eroded soil between treatments within months (Tables 20, 21 & 22), variations in their quantities will essentially reflect the magnitude of soil loss. The differences observed in the quantities of elements in run-off between treatments and nutrients are the reflections of their relative mobility and leachability in erosion cycle. Since soluble fraction of the nutrients constitute a major share of the run-off loss, the comparatively high quantities seen in the fertilized plots are expected.

As the total amount of nutrient loss is a function of its concentration and magnitude of the transporting media, differences exhibited by each treatment are explainable in the light of the respective soil and run-off losses. The notable hike in percentage nutrient loss through run-off in T_3 in first year and T_3 and T_5 in the second year is an indirect indication of the low share by eroded soil to total loss. This becomes highly spectacular in second year, when soil loss was practically negligible in T_3 and T_5 (Table 8). Here, more than 70 per cent of N, P, K and Ca losses were constituted by run-off only. It even crossed 90 per cent in T_5 for N, K and Ca in the second year.

6. Soil physical changes:

The important soil physical characteristics viz. particle density, bulk density, total porosity, aggregate size distribution, infiltration rate, particle size distribution and water holding capacity were monitored at half-yearly intervals in all the treatments.

6.1 Particle density, bulk density and total porosity:

Particle density, bulk density and total porosity

Table 32. Particle density, bulk density and total porosity at half-yearly interval

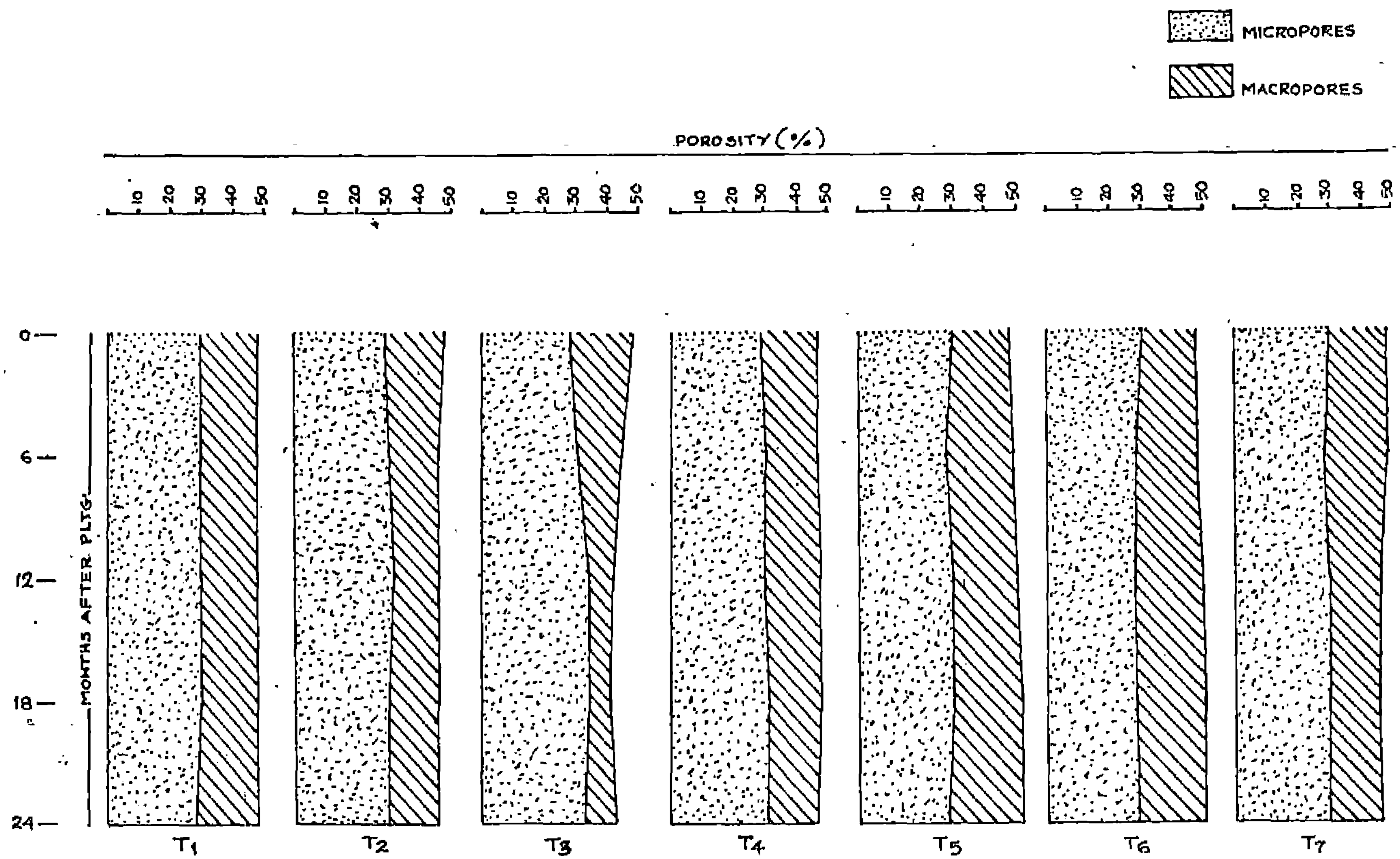
Months after planting	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
At planting:							
1. Particle density (g/cm^3)	2.76	2.74	2.77	2.74	2.77	2.77	2.78
2. Bulk density (g/cm^3)	1.45	1.45	1.43	1.45	1.45	1.43	1.43
3. Total porosity (%)	47.46	47.08	48.37	47.08	47.65	48.33	48.56
6 months:							
1. Particle density (g/cm^3)	2.76	2.76	2.77	2.75	2.75	2.78	2.77
2. Bulk density (g/cm^3)	1.48	1.48	1.56	1.46	1.40	1.43	1.44
3. Total porosity (%)	46.38	46.38	43.68	46.91	49.09	48.56	48.01
12 months:							
1. Particle density (g/cm^3)	2.78	2.76	2.78	2.76	2.78	2.77	2.76
2. Bulk density (g/cm^3)	1.46	1.50	1.60	1.46	1.38	1.40	1.49
3. Total porosity (%)	47.48	45.65	42.44	47.10	50.35	49.46	46.01
18 months:							
1. Particle density (g/cm^3)	2.77	2.78	2.78	2.78	2.78	2.78	2.78
2. Bulk density (g/cm^3)	1.44	1.51	1.63	1.47	1.36	1.40	1.51
3. Total porosity (%)	48.01	45.68	41.37	47.12	51.08	49.64	46.04
24 months:							
1. Particle density (g/cm^3)	2.76	2.78	2.77	2.77	2.78	2.77	2.77
2. Bulk density (g/cm^3)	1.42	1.50	1.60	1.48	1.35	1.40	1.50
3. Total porosity (%)	48.55	46.04	42.24	46.57	51.43	49.46	45.58

as influenced by different treatments are presented in Table 32 and details of porosity in Fig. 20.

Particle density, as expected, did not show any notable change between the treatments over the periods. It varied between 2.74 to 2.78 g/cm^3. Before imposing treatments, bulk density and total porosity ranged between 1.43 to 1.45 g/cm^3 and 47.08 to 48.56 per cent, respectively. In the case of T_3 and T_2, the bulk density, gradually showed an increase with corresponding decrease in the total porosity upto 18th month and thereafter a decrease. T_5 showed an exactly reverse trend with a definite decrease in bulk density values upto 24th month with corresponding increase in porosity values. The bulk density decreased from 1.45 to 1.35 g/cm^3 while total porosity varied from 47.65 to 51.43 per cent. T_1 also showed improvements in its physical characteristics though not at the rate of T_5, but in a notable way. Here, the bulk density registered a gradual decrease from 1.45 to 1.42 g/cm^3 with a corresponding increase of porosity from 47.46 to 48.55 per cent. In T_6, the bulk density decreased from 1.43 to 1.40 g/cm^3 by the 12th month and thereafter it was static. The porosity showed an increase of 48.33 to 49.46 per cent. However, in T_4 and T_7, erratic variations were observed in both of these characters.

Fig. 20 reveals the distribution of soil voids viz. inter and intra-aggregate voids. In the beginning, all

FIG. 20 – MICRO, MACRO AND TOTAL POROSITY.



the treatments, had about 18-20 per cent of their volume occupied by macropores. T_5 and T_6 showed a gradual increase over the stages and even crossed 20 per cent by the end of the experiment. In T_3, it showed a drastic reduction and went below 10 per cent. All other treatments, except T_1, exhibited a gradual decrease over different stages. T_1 registered an initial decrease and subsequent improvement.

The bulk density and in turn the total porosity which reflect the looseness or degree of compaction of a soil, are to a large extent, influenced by soil management practices (Russel, 1973 and Singh, 1980). Before imposing treatments, the soil was almost ideal for cultivation as exhibited by the bulk density values and pore-size distribution. But two years of experimentation made the soil in T_3 more compact bringing down the porosity from 48.37 to 42.24 per cent. This can be attributed to the occasional ponding of run-off in the inter-ridged area during the rainy season, which lead to siltation, surface crusting and subsequent compaction. Further, this might have also accelerated the vertical erosion and consequent clogging of macropores by the minute clay particles (Hudson, 1984). This was evident from the low infiltration rate recorded by T_3 (Table 36). Whereas in T_5, the grassed plot, there was a marked improvement in the physical condition. More root distribution, high earthworm activity and practically full protection of the soil surface (Tables 47, 49 a, 49 b, 42 a and 42 b) from the direct hit of raindrop might have contributed for the better physical conditions. All these factors are applicable to some extent in the rice cropped plots too. T_7 recorded slight deterioration in the physical conditions. Exposing the soil to direct, intense and continuous rainfall, affect its physical properties mainly because of the soil dispersion, vertical erosion and high sediment carrying capacity by the overflowing water (Hudson, 1984). Mound cultivation of cassava was as deliterious as that of cultivated fallow in causing deterioration of the physical condition of the soil. This became further established by T_1 wherein soil was subjected to less disturbance in the absence of inter crops.

6.2 Aggregate size distribution and stability indices:

The data on aggregate size distribution and stability indices are reported in Tables 33 and 34, respectively

Effect of grass (T_5) on aggregate size was conspicous even at the 6th month of observation as indicated by the bigger aggregates. But all other treatments showed a notable reduction in the proportion of this factor especially those of above 2.5 mm diameter. T_5, maintained higher values for aggregates of above 2.5 mm throughout the investigation. Percentage of aggregates of above 5 mm

Table 31. Aggregate size distribution (%) at half yearly intervals

Months after planting/Aggregate size	T_1	T_2	T_3	T_4	T_5	T_6	T_7
At the beginning							
1. 5.00 mm	10.13	10.08	11.00	10.14	10.48	10.41	11.01
2. 2.50 – 5.00 "	14.14	13.98	12.98	14.14	14.40	13.78	14.00
3. 1.00 – 2.50 "	20.24	21.11	20.24	20.20	20.13	18.11	20.10
4. 0.50 – 1.00 "	23.82	22.18	23.00	22.18	20.48	21.11	20.48
5. 0.25 – 0.50 "	20.30	19.14	20.00	20.10	20.49	20.10	21.11
6. 0.25 "	11.11	14.50	12.78	13.21	14.00	16.49	13.30
6 months							
1. 5.00 mm	7.79	7.99	7.14	8.01	14.10	9.78	4.78
2. 2.50 – 5.00 "	13.14	12.19	11.38	12.81	16.38	14.40	10.16
3. 1.00 – 2.50 "	13.78	13.11	16.11	21.33	11.10	10.97	13.19
4. 0.50 – 1.00 "	24.10	23.78	18.91	18.98	20.18	21.00	21.78
5. 0.25 – 0.50 "	21.78	26.11	26.19	23.10	20.10	22.10	23.80
6. 0.25 "	19.41	17.02	20.27	16.40	18.14	21.83	26.79
12 months							
1. 5.00 mm	9.90	7.89	6.91	7.89	15.00	10.10	5.01
2. 2.50 – 5.00 "	14.19	13.10	13.41	13.11	16.10	17.18	8.91
3. 1.00 – 2.50 "	14.10	11.70	14.98	10.21	10.11	11.10	14.13
4. 0.50 – 1.00 "	20.10	24.18	20.98	21.04	21.78	19.10	20.78
5. 0.25 – 0.50 "	21.17	24.99	26.10	24.04	18.00	23.18	24.38
6. 0.25 "	20.54	18.14	17.89	23.66	19.01	19.34	26.79
18 months							
1. 5.00 mm	10.14	6.81	6.89	7.50	16.00	11.78	6.81
2. 2.50 – 5.00 "	14.18	11.71	11.34	11.00	19.20	19.10	9.01
3. 1.00 – 2.50 "	16.19	14.89	14.10	10.18	11.12	10.11	11.48
4. 0.50 – 1.00 "	20.10	24.10	20.98	24.18	16.17	18.19	20.29
5. 0.25 – 0.50 "	20.00	21.08	24.10	26.10	21.10	20.17	24.18
6. 0.25 "	19.39	21.41	22.59	20.94	16.41	20.65	28.23
24 months							
1. 5.00 mm	11.00	5.50	6.80	7.81	18.41	10.60	6.90
2. 2.50 – 5.00 "	20.00	10.20	10.90	9.10	19.20	18.20	10.14
3. 1.00 – 2.50 "	17.10	12.50	11.35	11.75	12.00	10.80	11.16
4. 0.50 – 1.00 "	20.00	22.10	21.00	24.00	15.75	20.00	18.19
5. 0.25 – 0.50 "	16.00	24.84	20.00	26.10	19.60	20.00	24.78
6. 0.25 "	15.90	24.86	29.95	21.24	15.04	20.40	28.83

Table 34. Stability index, structural coefficient, % aggregate stability and mean weight diameter at half-yearly intervals

Months after planting	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
At planting							
1. Stability index	45.21	44.48	43.48	44.69	46.11	45.10	45.14
2. Structural coefficient	0.80	0.81	0.78	0.79	0.81	0.81	0.79
3. % aggregate stability	80.00	81.00	78.00	79.00	81.00	81.00	79.00
4. Mean weight diameter	1.75	1.68	1.66	1.72	1.71	1.76	1.70
6 months							
1. Stability index	39.00	39.19	40.18	39.46	46.48	45.14	33.28
2. Structural coefficient	0.71	0.69	0.71	0.70	0.76	0.74	0.64
3. % aggregate stability	71.00	69.00	71.00	70.00	76.00	74.00	64.00
4. Mean weight diameter	1.53	1.50	1.44	1.60	1.97	1.63	1.21
12 months							
1. Stability index	44.10	38.38	39.19	41.98	49.73	46.19	34.18
2. Structural coefficient	0.76	0.71	0.68	0.72	0.79	0.77	0.61
3. % aggregate stability	76.00	71.00	68.00	72.00	79.00	77.00	61.00
4. Mean weight diameter	1.68	1.51	1.48	1.46	2.01	1.75	1.18
18 months							
1. Stability index	46.14	35.14	38.19	38.81	50.10	48.10	35.10
2. Structural coefficient	0.74	0.66	0.64	0.65	0.80	0.78	0.67
3. % aggregate stability	74.00	66.00	64.00	65.00	80.00	78.00	67.00
4. Mean weight diameter	1.72	1.43	1.39	1.40	2.18	1.90	1.27
24 months							
1. Stability index	48.00	33.50	38.09	35.06	51.03	48.63	36.18
2. Structural coefficient	0.80	0.64	0.66	0.68	0.82	0.80	0.68
3. % aggregate stability	80.00	64.00	66.00	68.00	82.00	80.00	68.00
4. Mean weight diameter	1.99	1.25	1.32	1.36	2.34	1.88	1.29

increased from 14.10 to 18.41 and that of 2.5 to 5 mm from 16.38 to 19.20 in T_5. T_6 and T_1 also showed signs of structural improvement, but not at the rate of T_5. All other treatments registered structural instability and consequently increased the proportions of smaller aggregates bringing down the values of other indices.

The stability indices (Table 34) also revealed a clear picture of the dominating influence of T_5 on soil structure. This was evident from the high values registered for all the structural indices viz. stability index, structural coefficient, per cent aggregate stability and mean weight diameter as compared to other treatments, throughout the period of investigation.

Aggregates are secondary units of primary soil particles, particularly clays (Singh, 1980). These are formed under natural conditions and mainly influenced by methods of farming, root activity, addition of organic matter, activity of soil organism etc. (Uriyo, 1979). Structural stability is supported by the stability indices which are calculated based on the concept that a unit weight of large aggregates is more indicative of good structure than an equal weight of small aggregates. Structural coefficient values tending to zero is indicative of poor aggregation and a value close to unity, a high degree of aggregation. Judged from the above values, structural coefficient of 0.82, as seen in grassed plot at the final stage, explains the profound influence of grass on soil aggregation. Comparable values seen in T_6, the rice cropped plot, to T_5 can also be explained as the effect of vegetation. T_7 recorded the lowest value of 0.61 for this index in the 12th month. The total absence of vegetation, organic matter and, above all, the continuous impact of raindrops are the possible factors which impede the structural development. However, the slight increase in this index (0.64) observed towards the end of the experiment can be attributed to the grass stripping followed in the second year. Low values of T_2 and T_4 are indicative of the deteriorating effect of mound planting of cassava on soil aggregation. The beneficial effect of less soil disturbance in the interspace is evidenced by the high value of 0.80 in T_1.

6.3 Infiltration rate:

Table 35 provides the details of infiltration at the beginning for the whole experimental site. This represents the average values of three locations. Initial infiltration rate was as high as 82.80 cm/hr in the first five minutes. The steady-state infiltrability of the soil was 11.40 cm/hr with an accumulated infiltration of 81.70 cm within 300 minutes.

Table 35. Infiltration details at the beginning of the experiment

Elapsed time (minutes)	Qty. of water infiltrated (cm)	Infiltration rate (cm/hr)	Cumulative infiltration (cm)
5	6.90	82.80	6.90
10	5.10	61.20	12.00
20	6.90	41.10	18.90
30	4.80	28.80	23.70
45	5.60	22.40	29.30
60	4.70	18.80	34.00
90	6.80	13.60	40.80
120	6.00	12.00	46.80
180	12.10	12.10	58.90
240	11.40	11.40	70.30
300	11.40	11.40	81.70

Infiltration details were studied in each treatment at half yearly intervals. The data are presented in Table 36.

At the 6th month of observation, in all the treatments, there was a decrease in the initial infiltration rate as compared to 82.8 cm/hr before the experiment. Thereafter, it showed an improvement except in T_3. T_3 showed the lowest value of 21.6 cm/hr at the 18th month and T_5, the highest of 97.44 cm/hr at the end. The steady state infiltration remained more or less constant throughout the investigation in all the treatments except in T_3. T_3 recorded the lowest value of 3.11 cm/hr at the end with a gradual decrease over the months. Cumulative infiltration increased continuously in T_5 and recorded the highest value of 101.50 cm at the 24th month. Whereas in T_3 it was declining over the stages and registered the lowest final value of 24.38 cm.

High initial infiltration rate and cumulative infiltration seen in T_5 are the reflections of its water absorptive capacity. Better aggregation and consequent porous nature of the soil as already discussed, increase the infiltration rate to values close to hydraulic conductivity (Uriyo, 1979 and Zein et al. 1980). Further, the increased transpiratory withdrawal of dense grass canopy might have also influenced to a great extent, the initial

Table 36. Infiltration details at half-yearly intervals.

Months after planting	T_1	T_2	T_3	T_4	T_5	T_6	T_7
6 months:							
1.	19.48	19.11	20.10	20.10	20.00	19.48	19.49
2.	57.60	53.80	37.20	61.20	67.20	62.40	48.00
3.	10.30	11.10	8.10	11.20	12.40	11.80	8.50
4.	67.60	71.00	51.70	72.90	82.70	76.30	56.70
12 months:							
1.	18.40	18.11	19.10	19.14	18.48	18.98	18.74
21	81.50	73.20	33.60	75.60	90.00	85.20	69.60
3.	11.70	11.40	4.90	11.60	12.60	11.60	9.60
4.	86.40	82.60	38.50	85.10	96.40	88.30	69.00
18 months:							
1.	18.34	18.96	19.10	18.37	18.46	18.96	18.74
2.	81.60	74.40	21.60	73.20	88.80	84.00	62.20
3.	10.84	10.60	3.18	10.30	12.70	11.80	11.50
4.	71.90	67.70	28.80	67.10	95.70	87.60	76.20
24 months:							
1.	18.17	17.48	18.11	18.44	18.00	17.96	18.10
2.	79.20	76.80	25.20	73.20	97.44	81.60	75.60
3.	11.90	10.81	3.11	11.20	12.50	11.60	11.40
4.	73.10	73.76	24.38	70.30	101.50	84.60	80.80

Note:-

1. Average moisture content of upper 30 cm soil (%)
2. Initial infiltration rate for the first five minutes (cm/hr)
3. Steady-state infiltrability (cm/hr)
4. Cumulative infiltration for 300 minutes (cm)

flux controlled infiltration rate (Hillel, 1971). High values obtained in T_5 can be explained in the light of above observations. Crusted and compacted soil surface, for reasons already explained in item 6.1, might have made the soil less permeable to water in T_3 which resulted in low infiltrability. The comparatively low values observed in other treatments can be explained as follows. When the vegetative cover was not enough to provide proper protection to the bare ground against the impact of raindrops, with each successive rainfall, the infiltration rate was reduced due to the increasing blockage of macropores by translocated soil particles. (Uriyo, 1979 and Hudson, 1984). This resulted in low values as compared to other vegetally covered treatments.

6.4 Particle size distribution:

Influence of various treatments on the soil texture was determined by the particle size analysis of 2 mm sieved fraction. The data are presented in Table 37.

Proportions of sand, silt and clay remained constant around, 50, 15 and 30 per cent, respectively, throughout the experiment, irrespective of the treatments. This is infact expected, since particle size distribution is one of the most stable soil characteristics little, modified by cultivation or other practices within a short period of time. It

Table 37. Particle size distribution at half yearly intervals

Months after planting	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
At planting:							
Sand (%)	50.14	50.48	50.00	50.00	49.11	49.90	51.78
Silt (%)	14.56	15.00	14.96	15.11	16.66	15.78	14.78
Clay (%)	31.48	30.48	31.38	31.41	31.13	30.76	30.39
6 months:							
Sand (%)	50.11	49.78	48.79	48.78	48.11	50.11	50.46
Silt (%)	15.16	16.10	16.78	15.00	16.00	15.48	16.43
Clay (%)	31.11	31.10	32.34	32.38	31.98	31.00	30.00
12 months:							
Sand (%)	50.44	50.14	49.48	49.11	49.59	50.11	50.00
Silt (%)	14.78	16.00	16.00	16.40	15.78	16.43	16.11
Clay (%)	30.96	30.46	31.43	31.00	31.31	31.41	30.34
18 months:							
Sand (%)	49.46	50.11	49.33	50.00	49.14	50.06	49.47
Silt (%)	15.46	16.00	15.89	15.41	16.19	15.69	16.78
Clay (%)	31.04	31.10	31.90	31.60	31.48	31.28	30.78
24 months:							
Sand (%)	50.14	50.11	49.11	50.78	50.00	49.90	50.78
Silt (%)	16.00	15.78	16.00	16.19	15.11	16.41	15.44
Clay (%)	31.00	31.00	31.84	31.04	31.78	31.40	30.98

can also be assumed that selective transport of soil aggregates by water erosion process (Loch and Donnollan, 1983) has no influence in changing the soil texture, within a period of two years, no matter how severe be the erosion.

6.5 Water holding capacity:

Water holding capacity at 0.3 and 15 bars corresponding to field capacity and permanent wilting point of each treatment are presented in Table 38.

Between the treatments and different stages of observations, there were no noticeable changes in these values. Field capacity and permanent wilting point were centered around 20 and 12 per cent, respectively, in all the treatments, throughout the stages.

Water retention of a soil at a particular suction is more influenced by its texture than structure (Hillel, 1971). In the present study, the data on mechanical composition of soil (Table 37) showed that, the clay content remained unchanged between treatments. Hence, the uniform trends observed in the water retention capacities can be explained based on the above observations.

7. Soil chemical changes:

Changes in the total contents of all the primary

Table 38. Water holding capacity (%) at 0.3 and 15 bars at half-yearly intervals

Months after planting	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
At planting:							
1. 0.3 bar	20.18	20.11	19.98	20.41	20.11	20.98	20.36
2. 15 bars	12.39	13.18	12.31	12.11	13.45	12.38	11.98
6 months:							
1. 0.3 bar	19.78	20.48	20.48	20.11	20.36	20.19	19.37
2. 15 bars	13.44	13.16	12.32	11.48	12.41	12.36	11.48
12 months:							
1. 0.3 bar	21.00	20.78	21.14	19.98	21.40	20.46	20.41
2. 15 bars	12.34	12.13	11.48	11.78	12.06	11.48	13.00
18 months:							
1. 0.3 bar	20.78	20.14	21.13	20.13	21.48	19.98	20.36
2. 15 bars	11.34	13.00	11.16	13.08	11.48	12.00	12.01
24 months:							
1. 0.3 bar	20.04	19.98	20.48	20.00	21.39	20.00	19.00
2. 15 bars	12.20	12.80	11.98	12.88	12.31	11.98	12.36

and secondary nutrients, organic carbon, pH and C.E.C. were studied at half yearly intervals. The data are discussed below.

7.1 Primary nutrients:

Table 39 contain the data on N, P and K contents. Nitrogen content of soil recorded a progressive decline with different stages of sampling in T_7 ranging from 0.141 to 0.134 per cent. The trend in respect of other treatments was inconsistent. T_7, recorded the lowest N content among the treatments.

Phosphorus levels were nearly identical throughout the period excempt in T_7 where a definite decrease over the sampling stages was observed and the values varied from 0.054 to 0.047 per cent.

As in the case of nitrogen, a slight decline in potassium level over the stages of observation was noticed. However, none of the treatments revealed any definite trend in the content of this element. Among the treatments, the highest initial value of 0.231 per cent was observed in T_6 and the lowest final value of 0.220 per cent in T_1, T_4 and T_5.

7.2 Secondary nutrients:

Data are reported in Table 40.

Table 39. N, P and K content (%) of the soil at half-yearly intervals

Months after planting	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
				Nitrogen (N)			
At planting	0.142	0.141	0.144	0.141	0.144	0.143	0.141
6 months	0.140	0.142	0.143	0.140	0.141	0.139	0.138
12 "	0.138	0.137	0.141	0.140	0.144	0.141	0.137
18 "	0.140	0.136	0.138	0.134	0.143	0.140	0.134
24 "	0.138	0.136	0.139	0.136	0.140	0.138	0.134
				Phosphorus (P)			
At planting	0.058	0.057	0.055	0.053	0.056	0.056	0.054
6 months	0.054	0.056	0.051	0.053	0.056	0.054	0.050
12 "	0.056	0.048	0.054	0.051	0.054	0.054	0.050
18 "	0.057	0.051	0.055	0.047	0.054	0.050	0.048
24 "	0.058	0.051	0.056	0.053	0.054	0.051	0.047
				Potassium (K)			
At planting	0.228	0.226	0.226	0.224	0.228	0.231	0.226
6 months	0.224	0.218	0.228	0.226	0.226	0.226	0.220
12 "	0.225	0.216	0.228	0.226	0.270	0.224	0.221
18 "	0.221	0.221	0.231	0.230	0.224	0.228	0.218
24 "	0.220	0.224	0.224	0.220	0.220	0.224	0.223

Table 40. Ca, Mg and S content (%) of the soil at half-yearly intervals

Months after planting	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
			Calcium (ca)				
At planting	0.061	0.058	0.056	0.058	0.062	0.060	0.064
6 months	0.068	0.058	0.056	0.050	0.063	0.063	0.054
12 "	0.063	0.054	0.055	0.061	0.061	0.062	0.053
18 "	0.059	0.054	0.054	0.051	0.058	0.058	0.053
24 "	0.054	0.055	0.054	0.058	0.054	0.058	0.056
			Magnesium (Mg)				
At planting	0.244	0.248	0.238	0.243	0.244	0.245	0.244
6 months	0.228	0.234	0.233	0.243	0.243	0.246	0.240
12 "	0.234	0.232	0.234	0.243	0.245	0.244	0.238
18 "	0.224	0.221	0.234	0.243	0.241	0.242	0.240
24 "	0.230	0.225	0.220	0.238	0.245	0.243	0.236
			Sulphur (S)				
At planting	0.108	0.110	0.110	0.108	0.114	0.104	0.106
6 months	0.114	0.112	0.108	0.114	0.108	0.107	0.102
12 "	0.104	0.104	0.111	0.108	0.111	0.104	0.094
18 "	0.114	0.100	0.104	0.109	0.104	0.108	0.101
24 "	0.106	0.098	0.101	0.100	0.114	0.104	0.094

The contents of secondary nutrients viz. Ca, Mg and S were not influenced by the treatments at different stages of observation. However, a slight decreasing trend was noticed towards the end.

Consultation of the above tables reveals relatively smaller changes in the total nutrient contents over the stages and between treatments. The total nutrient content of a soil is a more or less inherent feature, primarily dependent on its minerology and textural composition (Hsu and Jackson, 1960). The soil of the experimental area comes under the Vellanikkara series (Soil Survey Report, 1976). Description of pedon of the experimental site (Item 1.3.1 of Materials and Methods) shows that A horizon is having a thickness of 25 cm. Since the surface horizon of a soil series usually reveals a more or less uniform chemical composition, the relatively smaller variations in the total nutrient contents as observed during the period of study is explainable. But the slight decrease in nutrient contents observed towards the end, is indicative of the probable nutrient depletion that may manifest after several years of continuous and hazardous methods of cultivation (Mithrachaly and Koshy, 1967 and Kamprath, 1977).

7.3 Soil pH:

pH also did not reveal a noticeable change or a definite trend in its variations during the experimental period (Table 41). In general, it centered around the value 5.80.

pH remained unaffected probably due to lack of sufficient time for the treatment effects to bring about any notable change.

7.4 Cation exchange capacity (CEC):

Table 41 reveals that CEC showed an almost similar trend as that of organic carbon. At the end, T_2 gave the lowest value preceded by T_7. It was also noticed that T_5 and T_6 gave values of 12.73 and 12.38 per cent, respectively, which were higher than the initial values (Table 1).

The CEC of a soil is an inherent property obviously affected by the nature and amount of minerals and organic fractions (Tisdale et al. 1985). The textural composition of the soil being more or less identical (Table 37), changes in CEC between treatments can well be related to that of the organic carbon content. This is clearly manifested in T_5 and T_6 where higher organic carbon contents have been observed. A reverse trend is also noticed in T_2 and T_7 which recorded correspondingly lower organic carbon levels.

Table 41. pH, CEC and organic carbon content of the soil at half-yearly intervals

Months after planting	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
				pH			
At planting	5.85	5.78	5.85	5.80	5.78	5.78	5.84
6 months	6.01	5.81	5.80	5.75	5.85	5.81	5.81
12 "	5.90	5.85	6.05	5.81	5.80	5.83	5.83
18 "	5.80	5.89	5.85	5.84	5.85	5.88	5.84
24 "	5.85	5.91	6.05	5.80	5.89	5.85	5.91
				CEC (meq/100 g)			
At planting	12.40	12.48	12.34	12.41	12.48	12.36	12.38
6 months	12.04	12.30	12.36	12.40	12.51	12.33	12.33
12 "	11.48	11.38	12.15	12.31	12.49	12.18	11.47
18 "	12.38	11.04	12.36	11.48	12.65	12.44	11.36
24 "	12.05	10.48	12.33	12.00	12.73	12.38	11.58
				Organic carbon (%)			
At planting	1.64	1.64	1.61	1.63	1.61	1.61	1.59
6 months	1.64	1.60	1.60	1.59	1.60	1.58	1.48
12 "	1.58	1.60	1.55	1.48	1.62	1.60	1.47
18 "	1.64	1.58	1.56	1.53	1.64	1.59	1.51
24 "	1.58	1.54	1.58	1.53	1.65	1.60	1.50

7.5 Organic carbon content:

Over the stages, a slight reduction in organic carbon content was recorded by all the treatments except T_5, where an increase was observed. T_7 showed the lowest value of 1.47 per cent at the end of first year and thereafter exhibited sign of improvement. T_2 and T_4 also recorded lower values, especially towards the end.

The change in organic carbon content of each treatment parallels almost to the trend of soil loss (Table 11). T_7 eroded the maximum quantity of soil followed by T_2 and T_4. T_5 was the least erosive treatment. Consequently, T_7 registered the lowest organic carbon content, preceded by T_4 and T_2, while T_5 gave the highest value of 1.64 per cent higher than even the initial status of the soil (Table 1). As the surface soil is fairly rich in organic carbon and it remains to be the most erosive, the above observed variations are understandable. Coupled with this, the organic matter build up due to possible root and stem decay will, to a large extent, reflect the increased organic carbon content of grassed plot. Slight improvement in rice grown plot is also attributed to this.

8. Protective ability of treatments:

The protective ability against soil, run-off and nutrient losses as influenced by total canopy cover, soil binding ability of roots and earthworm activity of different treatments are discussed below.

8.1 Canopy cover index:

Total canopy cover index (combined canopies of all the species) are given in the Tables 42 a, 42 b and Fig. 21.

In 1984, all the treatments differed significantly. T_5 recorded the highest value and T_1 the lowest. Other treatments followed the order T_6, T_2, T_3 and T_4. Over the months also, this was almost the same trend. T_5 and T_6 registered sharp increase in the early stages reaching higher peaks in August. Subsequently, there was a sudden decline. In T_2, T_3 and T_4 a gradual increase over the months and subsequent reduction towards the end was observed. T_1 showed only a slight increase but never reached the value one.

Second year also exhibited an almost same trend as that of the first year.

Peak values of canopy cover index of grassed plot (T_5) in both years are indicative of the dense nature of land cover that could offer about eight times protection than that of the bare ground. Even in the first month, it could cover the land to the extent of 1.42 times and in

Table 42 a. Total canopy cover index in 1984

Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
June	0.01	0.10	0.08	0.03	1.42	1.72	-	0.56
July	0.04	0.57	0.48	0.15	3.21	3.91	-	1.40
August	0.38	0.92	0.81	0.41	7.82	5.14	-	2.58
September	0.49	1.23	1.06	0.63	4.63	4.57	-	2.10
October	0.57	1.48	1.39	0.77	3.86	0.22	-	1.38
November	0.65	1.53	1.45	0.81	3.36	0.33	-	1.35
December	0.67	1.07	1.00	0.72	2.06	0.35	-	0.98
Mean	0.40	0.99	0.90	0.50	3.77	2.32	-	
CD (0.05)	a = 0.08		b = 0.02		c = 0.07		d = 0.06	

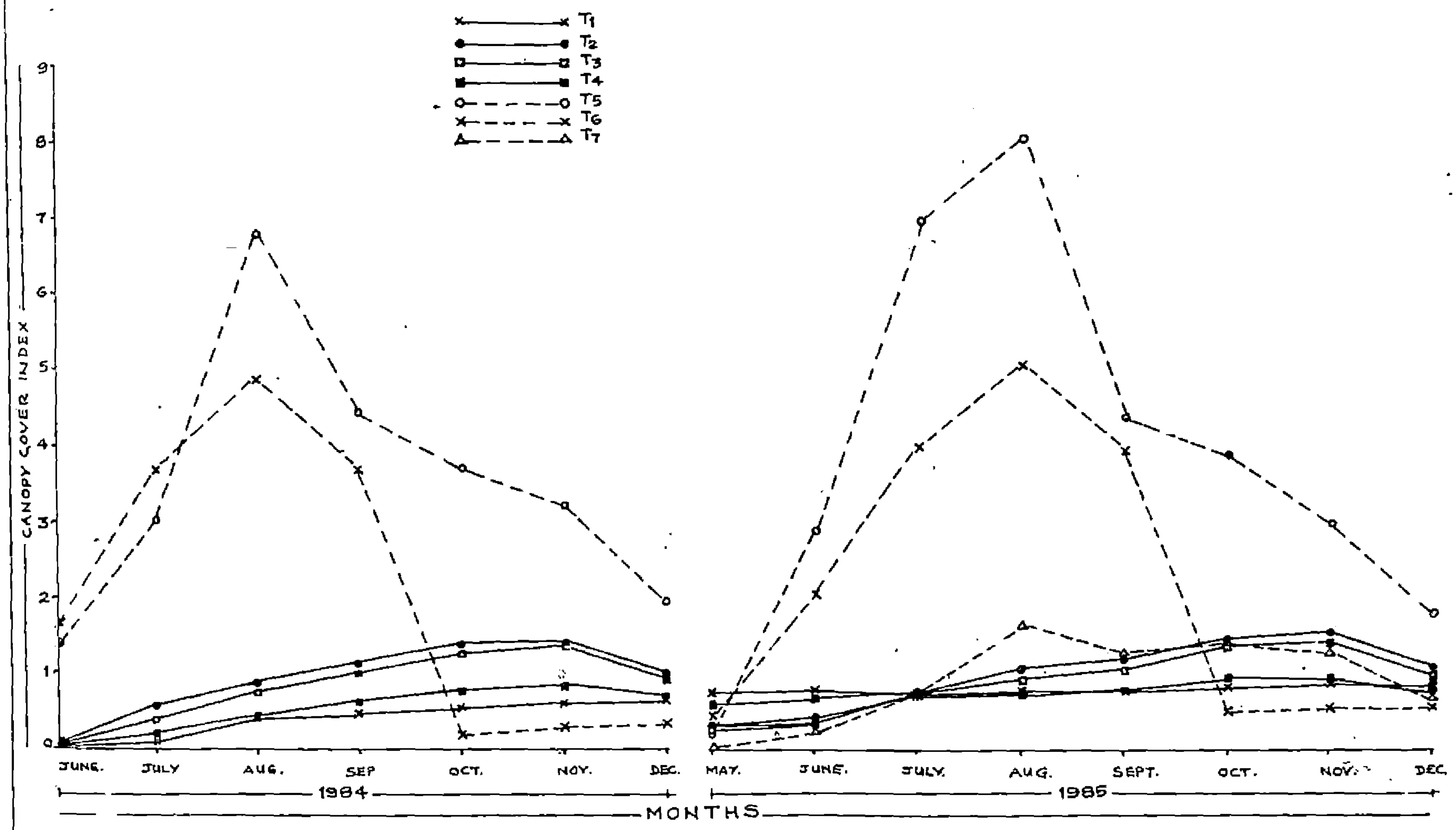
a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 42 b. Total canopy cover index in 1985

Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
May	0.82	0.40	0.40	0.67	0.34	0.48	0.00	0.44
June	0.86	0.50	0.48	0.70	3.08	2.18	0.28	1.16
July	0.87	0.93	0.84	0.79	7.37	4.23	0.90	2.28
August	0.88	1.24	1.00	0.89	8.48	5.44	1.75	2.81
September	0.92	1.30	1.15	0.94	4.73	4.91	1.36	2.19
October	0.94	1.60	1.46	1.02	4.18	0.60	1.49	1.61
November	0.97	1.67	1.54	1.05	3.20	0.61	1.45	1.50
December	0.98	1.18	1.11	0.96	1.98	0.63	0.86	1.10
Mean	0.90	1.10	1.00	0.88	4.17	2.38	1.01	
CD (0.05)	a = 0.05		b = 0.02		c = 0.08		d = 0.06	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

FIG. 21 - TOTAL CANOPY COVER INDEX DURING RAINY MONTHS.



all the erosive months land surface was effectively covered. In T_6 also, crop canopy was denser enough to cover the land surface, almost five times than the bare ground during the peak period. All other treatments were having comparatively open canopy indicating lesser protection against the falling raindrops especially during the initial months. Even in T_2, where five times cassava than that of T_4 was accommodated, land surface was practically open in the initial months of south-west monsoon.

8.2 Rainfall interception:

That portion of rainfall retained by the crop canopy refers to the intercepted rainfall. Influenced by the extent and density of ground cover, interception details help to explain the run-off and soil loss experienced by each treatment. Tables 43 a and 43 b contain the interception details.

As evident from the results, in the first year, all the treatments differed significantly barring T_2 and T_3. T_5 recorded the highest annual value of 35.23 per cent and T_1 the lowest, 8.50 per cent. T_2 and T_3 continued to be on par throughout and T_1 remained the lowest except in October. T_5 and T_6 registered higher values, almost throughout the first year.

Table 43-a. Rainfall interception (%) in 1984

Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
May	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
June	0.65	4.57	3.24	1.16	17.04	18.36	-	7.50
July	2.81	18.82	17.04	7.32	35.25	28.96	-	18.37
August	9.06	24.56	23.49	15.55	39.86	40.75	-	25.55
September	13.93	26.73	25.98	18.13	39.61	33.60	-	26.33
October	16.03	31.16	30.27	21.57	44.39	9.40	-	25.47
Mean	8.50	21.17	20.00	12.75	35.23	26.22	-	
CD (0.05)	a = 1.73		b = 1.44		c = 3.52		d = 3.51	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 43 b. Rainfall interception (%) in 1985

Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
May	23.18	14.47	13.05	14.09	12.82	14.71	0.00	13.19
June	25.52	23.63	22.83	24.66	34.41	39.00	15.36	26.49
July	26.00	32.00	34.96	30.20	41.39	45.85	31.03	37.65
August	32.67	42.03	40.10	40.71	56.42	50.85	33.09	42.27
September	35.70	48.58	40.63	41.17	39.12	29.05	36.43	38.67
October	31.37	41.20	39.89	34.18	34.93	18.90	33.89	33.48
November	20.87	30.67	29.76	28.82	16.41	16.58	28.97	24.58
Mean	27.90	33.22	31.59	30.54	33.64	30.71	25.54	

CD (0.05) a = 1.14 b = 1.18 c = 3.08 d = 3.12

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

In the second year, T_5 and T_6 maintained increased interception abilities upto August and thereafter a decrease. More than 50 per cent of the rainfall was intercepted in T_5 and T_6 in August. In T_2, the increase was gradual upto September and it maintained superiority over the rest of the treatments upto the end. T_3 also showed more or less same trend as T_2. In the last two months there was a reduction in interception in all the treatments.

8.2.1 Rainfall interception as influenced by its characteristics:

The interception of rainfall is influenced by its characteristics also. The daily rainfall characteristics and percentage interception in each treatment are provided in Appendix-II. The particulars in respect of July 1985 were selected so as to have enough erosive rainfall and canopy to intercept in all the treatments.

In general, an increase in rainfall interception with increase in canopy cover was the feature observed in all the treatments. When canopy cover (X) was regressed with corresponding rainfall interception (Y) a strong linear relationship ($r = 0.910^{**}$) with regression equation $Y = -0.050X + 6.07$ was obtained. The observed increase in rainfall interception in all the treatments over the period is hence conceivable. Linear increase in rainfall interception with increase in canopy cover was noticed by other workers also (Wischmeier, 1975; Hussein and Laflen, 1982 and Morgan, 1985). More than 50 per cent interception noticed in both grassed and riced plots (T_5 and T_6) when they offered maximum land cover and comparatively lower interception in T_1 throughout, further lend support to the above finding. A very sharp decrease in the interception values noticed in T_6 in both years during October is indicative of the sudden decrease in total canopy cover consequent to rice harvest.

The reversing trend observed in all other treatments during October and November 1985 warrented further analysis. Table 44 revealed that rainfall interception was negatively correlated with all the rainfall characteristics except duration. Among the negatively correlated characteristics, kinetic energy and EI_{15} were the highly correlated ones. Amount of rainfall was significant only next to them. This is suggestive of the fact that when canopy cover is almost uniform, interception is more influenced by the hitting power of the rainfall as decided by its kinetic energy or EI_{15}. Perusal of the Appendix-II further revealed that rainfall amounts of almost same level had given rise to quite different interception percentages. For example, storms of 11 mm and 11.25 mm on 24-7-1985 and 25-7-1985 had EI_{15} values of 4.02 and 6.91 respectively. Eventhough the amounts of these rainfall were almost same,

Table 44. Correlation between percentage interception (Y) and rainfall characteristics (X)

(No. of observations = 22)

Rainfall characteristics	r	Regression equation
1. Rainfall amount (mm)	- 0.572*	Y = 66.663 - 0.314 X
2. Duration (hr)	+ 0.324*	Y = 63.735 + 0.028 X
3. Kinetic energy (mt/ha cm)	- 0.603*	Y = 66.780 - 0.014 X
4. EI_{15}	- 0.582*	Y = 62.754 - 0.177 X
5. EI_{30}	- 0.565*	Y = 62.832 - 0.263 X
6. AI_m	- 0.560*	Y = 63.656 - 0.407 X

* Significant at 5% level

when the dense grass canopy could intercept 82.91 per cent of the first rain, it was only 54.91 per cent for the second one. Similar interception percentages were seen with rainfall of strikingly different amounts too. Rainfall of 8.25 mm and 13.25 mm occurred on 13-7-85 and 17-7-85, recorded interception percentages of 68.96 and 68.16, respectively. But these rainfall had almost uniform EI_{15} values of 4.79 and 4.99, respectively. This reiterates that when canopy cover is almost same, interception is more influenced by energy characteristics of the rainfall; the more the erosivity, the lesser will be the interception.

8.3 Splash erosion:

Splash erosion is a measure of soil detachability by the impact of raindrops. Tables 45 a and 45 b provide the details of splash erosion as influenced by different treatments. Table 46 contains the correlation coefficients between rainfall characteristics and splash erosion in each treatment.

In the first year, T_7 recorded significantly the highest value and T_5 the lowest. Other treatments were in between. T_3 and T_4 were on par. Over the months too, this was almost the same trend with some eceptions. Except

Table 45 a. Splash erosion (g/m^2) in 1984

Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
May	10.46	11.94	13.49	11.19	10.96	9.84	12.49	11.48
June	60.63	66.92	69.61	60.52	23.29	21.63	65.52	52.59
July	49.66	62.67	72.15	64.07	4.33	8.79	72.19	47.69
August	11.23	15.42	15.08	18.18	0.18	0.84	18.91	11.41
September	11.96	7.84	13.87	19.57	0.41	2.91	27.64	12.03
October	14.79	8.75	10.46	15.20	1.46	9.00	27.41	12.44
Mean	26.46	28.92	32.44	31.45	6.77	8.83	37.36	
CD (0.05)	a = 1.78		b = 1.32		c = 3.55		d = 3.48	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 45 b. Splash erosion (g/m^2) in 1985

Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
May	6.22	10.27	7.76	10.16	1.48	6.81	10.99	7.67
June	65.60	83.34	95.47	81.35	10.53	18.60	83.29	62.59
July	24.97	29.88	39.80	42.73	1.43	2.21	30.99	24.57
August	8.60	9.16	12.01	15.14	0.11	0.48	9.00	7.79
September	0.30	0.21	0.20	0.18	0.00	0.00	0.18	0.15
October	4.86	5.21	8.82	10.11	0.21	4.82	4.75	5.54
December	1.07	0.87	1.10	2.10	0.00	0.81	0.91	0.98
Mean	15.95	19.85	23.59	23.11	1.97	4.82	20.01	

CD (0.05) a = 0.93 b = 0.69 c = 1.91 d = 1.84

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

the initial two months, T_7 and T_5 continued to record the highest and lowest values, respectively. In the first two months T_3 gave the highest value and T_6, the lowest.

T_5 became significantly lower to all other treatments in the second year. Further, as compared to the first year, all the treatments recorded lower values and T_5 the lowest. T_3 gave the highest value and was on par with T_4. T_6 was slightly preceded by T_5. Over the months the cassava intercropped plots viz. T_4, T_3, T_2 and T_7 recorded higher values than others.

The highest splash erosion observed in T_7 of the first year was due to the uninterrupted raindrop impact on the cultivated bare fallow, where there was no protective cover to rob off the energy of the falling rain drops. (Mutchler and Young, 1975 and Hudson, 1984). When important rainfall characteristics were correlated with corresponding splash erosion, higher positive relations were seen with AI_m ($r = 0.932^{**}$) and EI_{15} ($r = 0.923^{**}$) (Table 46). This, coupled with the observed reduction of splash erosion in other treatments with varying levels of vegetal cover, explains the increased splash and soil erosion of the cultivated bare fallow plot.

Barring T_3, the variations seen in other treatments were to a great extent, proportionate to the amount of canopy cover (Tables 42 a & b). In general, splash erosion decreased with increase in crop canopy cover in a linear way. High correlation coefficients observed with grass ($r = 0.963^{**}$) and rice ($r = 0.914^{**}$) intercropped plots were indicative of their better protective abilities compared to other treatments. Comparatively weaker correlation coefficients between splash erosion and rainfall characteristics (Table 46) observed in treatments with vegetation further explain the energy dissipating power of vegetal cover as corroborated by Hudson (1971); Meyer et al. (1975) and Hussein and Laflen (1982). The weakest correlation observed in T_5, wherein the lowest splash erosion was seen, further support this view.

The variations seen in cassava intercropped treatments are, to a great extent, proportionate to the amount of canopy cover except in T_3. The reduced rate of splash erosion seen in T_2 towards the end as compared to T_4 substantiates this. But, all the cassava treated plots gave significantly higher values almost throughout, no matter whether the minimum number of cassava as in T_4 or the maximum possible number as in the T_2 was accommodated. The initial slow growth of cassava, severe soil disturbance due to mound planting, larger exposed area and the possibly high energy of leaf drips (Noble and Morgan, 1983 and

Table 46. Correlation coefficients (r) between rainfall characteristics and splash erosion in each treatment

Rainfall characteristics	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
<u>1 9 8 4</u> (No. of observations - 16)							
1. Rainfall (mm)	0.893**	0.860**	0.815**	0.822**	0.671*	0.749**	0.891**
2. Kinetic energy (mt/ha cm)	0.909**	0.863**	0.832**	0.860**	0.593*	0.694*	0.908**
3. EI_{15}	0.842**	0.788**	0.775**	0.854**	0.467	0.611*	0.923**
4. AI_m	0.815**	0.822**	0.847**	0.888**	0.426	0.553	0.932**
<u>1 9 8 5</u> (No. of observations - 20)							
1. Rainfall (mm)	0.770**	0.715**	0.780**	0.813**	0.481	0.442	0.795**
2. Kinetic energy (mt/ha cm)	0.748**	0.694**	0.756**	0.793**	0.456	0.418	0.768**
3. EI_{15}	0.471	0.407	0.474	0.474	0.322	0.343	0.467
4. AI_m	0.629*	0.566*	0.650*	0.674**	0.333	0.384	0.638**

* Significant at 5% level
** Significant at 1% level

Finney, 1984) are the possible reasons for this.

Higher values seen in T_3 when compared to T_2 might be due to the accidental flow of run-off into the splash collection assembly because of trenching. In-spite of the lesser canopy cover, lower values recorded in T_1 can be attributed to the undisturbed nature of the soil as well as the allowed weed growth during the second year. Comparatively lower values seen in T_7 towards the end of second year are indicative of the protective ability of grass stripping.

8.4 Soil binding ability (F):

Soil binding ability (F) is the ratio of total volume of roots to its thickness expressed as radius (Bhimaya, 1950). Data on F and root characters of both grass and rice during the rainy months are furnished in Tables 47 and 48,respectively.

With advancement of time, soil binding ability of grass showed a rapid increase and reached a peak value by the end of the first year. This was more or less maintained around 300 in the second year. Table 47 showed that there was only a slight increase in the mean radius of the roots from beginning to the end of the experiment whereas, the volume of roots was conspicouslyincreasing.

Table 47. Root characters and soil binding ability of grass

Year/Month	Volume of roots/m^2 (ml)	Mean radius (mm)	Soil binding ability (F)
1 9 8 4			
June	41.8	0.33	124.79
July	81.71	0.41	199.29
August	114.15	0.42	271.79
September	126.71	0.44	286.36
October	138.47	0.47	293.61
November	143.19	0.48	298.31
December	146.45	0.49	298.87
1 9 8 5			
May	133.18	0.46	300.39
June	144.45	0.47	307.34
July	158.18	0.51	310.16
August	159.91	0.51	313.55
September	164.16	0.52	315.69
October	157.15	0.51	308.13
November	156.00	0.52	300.14
December	154.50	0.52	297.12

Table 48. Root characters and soil binding ability of rice

Year/Month	Volume of roots/m^2 (ml)	Mean radius (mm)	Soil binding ability (F)
1 9 8 4			
June	36.18	0.31	116.71
July	76.18	0.38	200.47
August	90.76	0.41	221.37
September	89.48	0.41	218.24
1 9 8 5			
June	38.18	0.30	127.27
July	70.18	0.39	179.95
August	93.10	0.40	232.75
September	91.76	0.41	223.80

This was reflected in the soil binding ability. In both years, rice gave a trend of initial low value and a high final value towards maturity. As in the case of grass, here also, the volume of roots was directly responsible for soil binding ability.

Soil binding ability also indicates the ramifying effect of fibrous roots which prevents the soil particles from being detached and transported by falling raindrops. This is one of the main reasons for the reduced soil and splash erosion in grass and rice cropped plots (Table 11 and 45 a & b) as explained previously.

8.5 Earthworm activity:

Data on wormcast, a measure of earthworm activity, are reported in Tables 49 a & b.

In both years, T_5 registered the highest activity and T_3 the lowest. T_6 was also superior to all but only next to T_5. This was almost the same trend over the months except the first two months of the first year. T_1, T_2, T_4 and T_7 were more or less comparable to each other throughout.

High earthworm activity observed in T_5 and T_6 indicates the physical fitness of soil of these treatments. Dense vegetal cover, increased root activity and

Table 49 a. Amount of worm cast (g/m^2) in 1984

Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
May	8.22	7.27	9.16	7.16	7.17	7.86	6.67	7.64
June	16.35	18.95	18.19	18.79	17.89	19.29	16.29	17.97
July	32.29	26.79	16.50	26.29	56.32	46.25	22.73	32.46
August	42.66	25.96	5.02	33.82	77.41	52.57	23.20	37.23
September	59.10	36.66	8.59	38.91	120.89	76.22	23.16	51.93
October	36.94	29.83	14.01	44.69	119.10	85.09	20.50	50.02
November	17.93	9.82	8.68	15.63	102.66	32.02	11.14	28.27
December	3.73	2.89	0.72	1.61	42.79	24.18	2.59	11.22
Mean	27.15	19.77	10.11	23.36	68.03	42.93	15.79	

CD (0.05) a = 4.11 b = 3.46 c = 9.37 d = 9.15

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 49 b. Amount of worm cast (g/m^2) in 1985

Month	Treatments							Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	
May	12.38	8.82	2.99	7.27	20.64	7.15	5.09	9.19
June	17.69	13.62	4.23	17.00	30.57	21.02	14.44	16.94
July	24.95	40.42	10.24	30.80	81.61	49.04	22.99	37.15
August	44.58	41.23	7.66	50.54	116.09	99.93	39.88	57.13
September	41.60	45.06	3.59	41.55	129.82	100.31	48.05	58.57
October	39.56	33.00	4.33	32.48	137.14	66.01	34.96	49.64
November	21.26	9.98	7.25	9.93	43.82	13.11	11.36	16.67
December	4.72	1.38	0.81	1.25	27.01	9.58	1.16	6.56
Mean	25.84	24.19	5.13	23.85	73.34	45.77	22.24	

CD (0.05 a = 2.84 b = 2.73 c = 7.23 d 7.22

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

comparatively lesser soil impoverishment consequent to erosion may explain the high earthworm activity observed. The increased porosity (Table 32), infiltration rate (Table 36) and stability indices (Table 34) exhibited by these treatments as already explained might have been influenced partly by the earthworm activity. Tubular pores made by earthworms will be beneficial in terms of movement of water, soil air or roots (Douglas et al. 1980). The kinetic energy of falling raindrops required to disrupt wormcast, was 5 - 54 times greater than that required to disrupt natural soil aggregates (Vleeschauwer and Lal, 1981). These observations may also help explain the lesser run-off, low soil dispersion as exhibited by the suspended sediment load of run-off and very low to zero soil loss seen in these treatments. In T_3, the lowest earthworm activity was noticed due to soil compaction consequent to treatment effect as already explained.

8.6 Crop management factor (C):

It is the ratio of soil loss from land having specified crop management to that from continuous cultivated fallow with identical soil, slope and rainfall. It reflects the effect of vegetal cover, crop sequence, length of growing seasons and tillage practices on soil erosion and is designated as the combined protective ability of each crop management practice (Hudson, 1984). The monthly and total C values for each treatment are furnished in Table 50.

In the first year, the highest monthly and total C values were recorded by T_2 and the lowest, by T_3. From July onwards, T_3 recorded zero values. T_4, though recorded higher values in the initial months than T_1, with regard to the total, T_1 gave higher value. T_5 was always lower to T_6 and started registering zero values from August onwards.

In the second year, May and November recorded zero values since rainfall was not sufficient enough to cause erosion. All the treatments registered substantial reduction in C values in this year. Total C value was the highest in T_7 followed by T_2 and T_4. Throughout the year, values were zero in T_5 and T_3 except June in the latter.

The trend of changes in C values of each treatment in both years will precisely fit to that of the soil loss explained previously (Item 2.3). The highest total value of 0.731 recorded by T_2 illustrates the vulnerability of cassava cultivation in accelerating soil erosion. Drastic reduction of this value to 0.216 in the second year emphasises the sustainability potential of trees in hill slope farming. However, the very low C value of T_1 in the second

Table 50. Crop management factor (c)

Year/Month	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
May	0.072	0.075	0.004	0.075	0.054	0.061	-
June	0.216	0.254	0.009	0.226	0.109	0.127	-
July	0.165	0.226	0.000	0.218	0.053	0.093	-
August	0.040	0.051	0.000	0.050	0.000	0.004	-
September	0.119	0.080	0.000	0.099	0.000	0.001	-
October	0.084	0.045	0.000	0.074	0.000	0.006	-
Total	0.696	0.731	0.013	0.668	0.216	0.292	-
1985							
May	0.000	0.000	0.000	0.000	0.000	0.000	0.000
June	0.019	0.053	0.001	0.046	0.000	0.026	0.086
July	0.027	0.131	0.000	0.120	0.000	0.024	0.190
August	0.003	0.021	0.000	0.021	0.000	0.001	0.032
September	0.000	0.000	0.000	0.000	0.000	0.000	0.000
October	0.004	0.011	0.000	0.015	0.000	0.000	0.006
Total	0.053	0.216	0.001	0.202	0.000	0.051	0.310

year, can mainly be attributed to the undisturbed nature of the soil. The very high soil protective ability of grass is manifested in T_5, both in the first and second year. T_3 also recorded practically zero values because of the complete control of soil erosion effected by mechanical bunding across the slope. Taungya cultivation as followed in T_4 also reduced the C factor but not to a satisfactory level. This is attributed to the continued disturbance in the second year. T_6, inspite of the soil disturbance, gave comparable values to that of grass especially towards the end of second year. This is due to the soil protective ability of rice crop which makes rice taungya preferable than cassava. T_7 in the second year is an improvement of T_2. This treatment should have recorded at least the same value of T_2 of the first year. But gave only 0.310. Moreover, the value was approaching zero by November. This is attributed to the considerable reduction in soil loss due to grass stripping.

9. Growth of Eucalyptus:

Growth of Eucalyptus as influenced by different treatments is discussed below.

Height, canopy spread, collar girth and girth at breast height over bark (GBHOB) are provided in Tables

51, 52, 53 and 54 respectively.

9.1 Height:

The main effects and interaction effects were significant. T_1 plants were the tallest and were superior to all other treatments throughout. At the end of the experiment, T_2 plants were the shortest and were on par with T_5 plants. T_6 plants, though slightly inferior to many other treatments especially in the initial months, reached statistical parity with T_1 at the 24th month of planting. T_4 plants were on par with T_6 and T_3 with T_5 at this month. Over the stages and especially towards the end, treatment effects became insignificant and some initially inferior treatments even overtook others. For example plants in T_6 were significantly inferior to all other treatments except T_5 upto 12th month of planting. Later on, it overtook others except T_1 and even became comparable to the most tallest plants of T_1 at the end. In T_5, trees were inferior even to T_2 upto 18th month and thereafter, showed signs of improvement. Among the cassava cropped plots, viz. T_2, T_3, and T_4, stagewise differences were mainly insignificant upto the 15th month and later on, T_4 maintained significant superiority over others.

Table 51. Height (m) of Eucalyptus

Month after planting	Treatments T_1	T_2	T_3	T_4	T_5	T_6	Mean
At planting	0.35	0.36	0.34	0.37	0.37	0.34	0.35
3	1.65	1.30	1.30	1.35	1.24	1.52	1.46
6	3.47	3.31	3.31	3.24	1.84	2.50	2.98
9	4.60	3.90	3.90	3.91	2.26	3.16	3.62
12	5.64	4.42	4.42	4.56	2.96	3.81	4.29
15	6.79	4.85	4.85	5.16	3.99	5.73	5.24
18	7.60	5.62	5.65	6.21	4.86	7.05	6.17
21	8.79	7.02	7.43	8.23	7.00	8.63	7.85
24	9.69	7.75	8.34	9.14	7.90	9.36	8.62
Mean	5.39	4.28	4.45	4.69	3.62	4.67	

CD (0.05) a = 0.19 b = 0.14 c = 0.50 d = 0.35

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 52. Mean canopy spread (m) of Eucalyptus

Month after	Treatments						Mean
	T_1	T_2	T_3	T_4	T_5	T_6	
At planting	-	-	-	-	-	-	-
3	1.38	0.83	0.89	1.07	0.77	0.60	0.92
6	1.82	1.28	1.33	1.61	1.11	1.29	1.41
9	1.93	1.37	1.40	1.74	1.20	1.45	1.52
12	2.01	1.43	1.43	1.84	1.31	1.56	1.55
15	2.11	1.52	1.51	1.91	1.45	1.70	1.70
18	2.22	1.58	1.60	1.98	1.56	1.77	1.78
21	2.25	1.64	1.67	2.04	1.68	1.84	1.85
24	2.32	1.70	1.73	2.12	1.79	2.00	1.94
Mean	1.97	1.42	1.40	1.74	1.36	1.53	
CD (0.05)	a = 0.10	b = 0.08		c = 0.21		d = 0.20	

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

Table 53. Collar girth (cm) of Eucalyptus

Month after planting	Treatments						Mean
	T_1	T_2	T_3	T_4	T_5	T_6	
At planting	0.35	0.32	0.34	0.31	0.39	0.31	0.34
3	1.49	1.33	1.26	1.40	0.74	1.18	1.23
6	3.81	2.42	2.40	3.23	1.77	2.22	2.64
9	5.70	2.76	3.25	4.15	2.66	3.61	3.69
12	6.68	3.35	4.22	5.29	3.70	4.77	4.67
15	7.56	4.18	5.19	6.53	4.52	5.71	5.61
18	8.38	5.27	6.16	6.95	5.84	7.12	6.62
21	9.42	6.21	7.07	7.73	7.17	8.13	7.62
24	10.14	7.41	7.94	9.14	8.35	9.06	8.68
Mean	5.95	3.69	4.20	4.97	3.91	4.68	

CD (0.05) a = 0.22 b = 0.10 c = 0.33 d = 0.24

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

9.2 Canopy spread:

Main effects showed that treatments were significant except T_2 and T_3 which were on par. T_1 recorded the highest canopy spread of 2.32 m and T_2, the lowest of 1.70 m at the end. T_4 and T_6 plants closely followed T_1. Differences were also significant in the early stages and showed an almost comparable trend as that of height. In T_2 and T_5, throughout the period, the canopy spread was significantly lower to T_1. In T_4, the stagewise differences were significantly inferior to T_1 upto the 9th month of planting and thereafter the differences were, in general, insignificant. T_6 attained comparable values with that of T_4 from 15th month onwards.

9.3 Collar girth:

Treatment differences were significant. T_1 produced the thickest plants and T_2, the thinnest. Other treatments were in-between. Though the thinnest plants were seen in the grassed plot (T_5) upto the 9th month, towards the end it maintained significant superiority over the cassava cropped plots except T_4. T_6 and T_4 were comparable at the end.

9.4 GBHOB:

GBHOB, an important growth parameter and a reliable

Table 54. Girth at breast height over bark (GBHOB) in cm of Eucalyptus

Month after planting	Treatments						Mean
	T_1	T_2	T_3	T_4	T_5	T_6	
At planting	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
6	2.07	1.62	1.81	1.98	0.64	1.55	1.61
9	3.28	2.02	2.29	2.53	1.47	2.37	2.33
12	4.16	2.32	2.81	3.34	2.43	3.39	3.08
15	5.43	2.96	3.64	4.28	3.04	4.38	3.96
18	6.69	3.80	4.66	5.23	3.91	5.98	5.05
21	7.37	4.33	5.12	5.97	4.56	6.43	5.63
24	8.46	5.29	6.18	6.96	5.90	7.35	6.69
Mean	5.35	3.19	3.78	4.33	3.13	4.49	

CD (0.05) a = 0.13 b = 0.05 c = 0.17 d = 0.13

a = CD for treatments
b = CD for months
c = CD for months between treatments
d = CD for months within the treatment

yardstick to measure the growth rate, showed an almost similar trend as that of collar girth. T_1 was significantly superior to all treatments with a final value of 8.46 cm, and maintained superiority in all the stages of observations. With increase in time, T_2 recorded comparatively lesser values than T_1. At the 24th month, it recorded only 5.29 cm and was significantly inferior to all other treatments.

Fig. 22 illustrates the rate of increase of above growth parameters at different stages of observations.

In general, canopy spread showed a high initial growth rate followed by a steep decrease and subsequent stabilization over the stages in all the treatments. For other parameters, the initial increase and subsequent decrease were still more steeper in T_1, T_2, T_3 and T_4. The growth rates of these parameters were generally less during 9 - 18 months. In T_5 and T_6, the initial growth rates were comparatively less with pronounced peaks for height and collar girth during 18 - 24th months.

Morphological expressions mentioned above will indicate that trees were very robust in T_1 and very weak in T_2 and T_5 (Fig. 23 and Plates XIX - XXIV). As there was no competition for space and energy between the trees and intercrops as in other treatments, the increased

FIG. 22 - RATE OF INCREASE IN GROWTH PARAMETERS OF EUCALYPTUS.

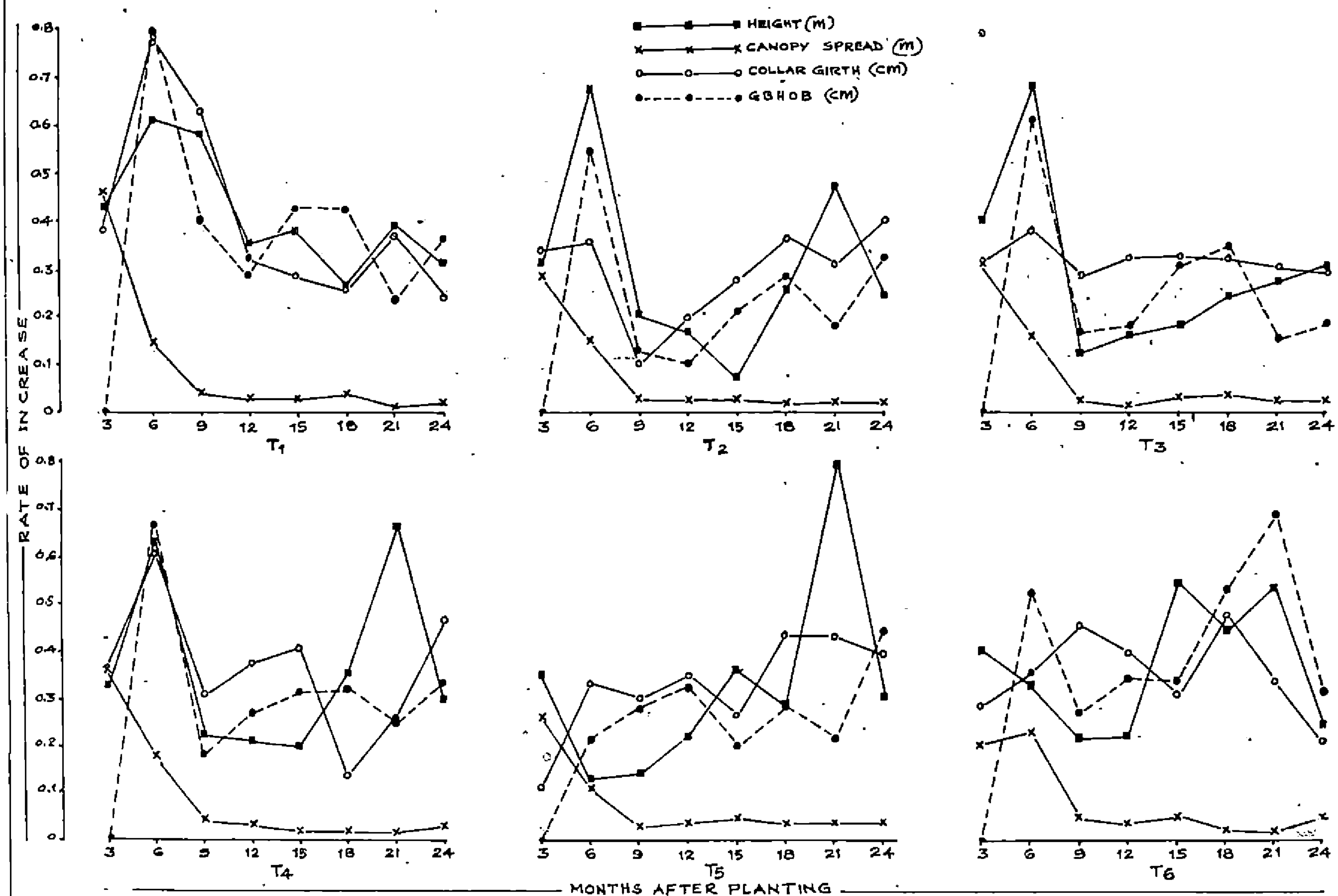
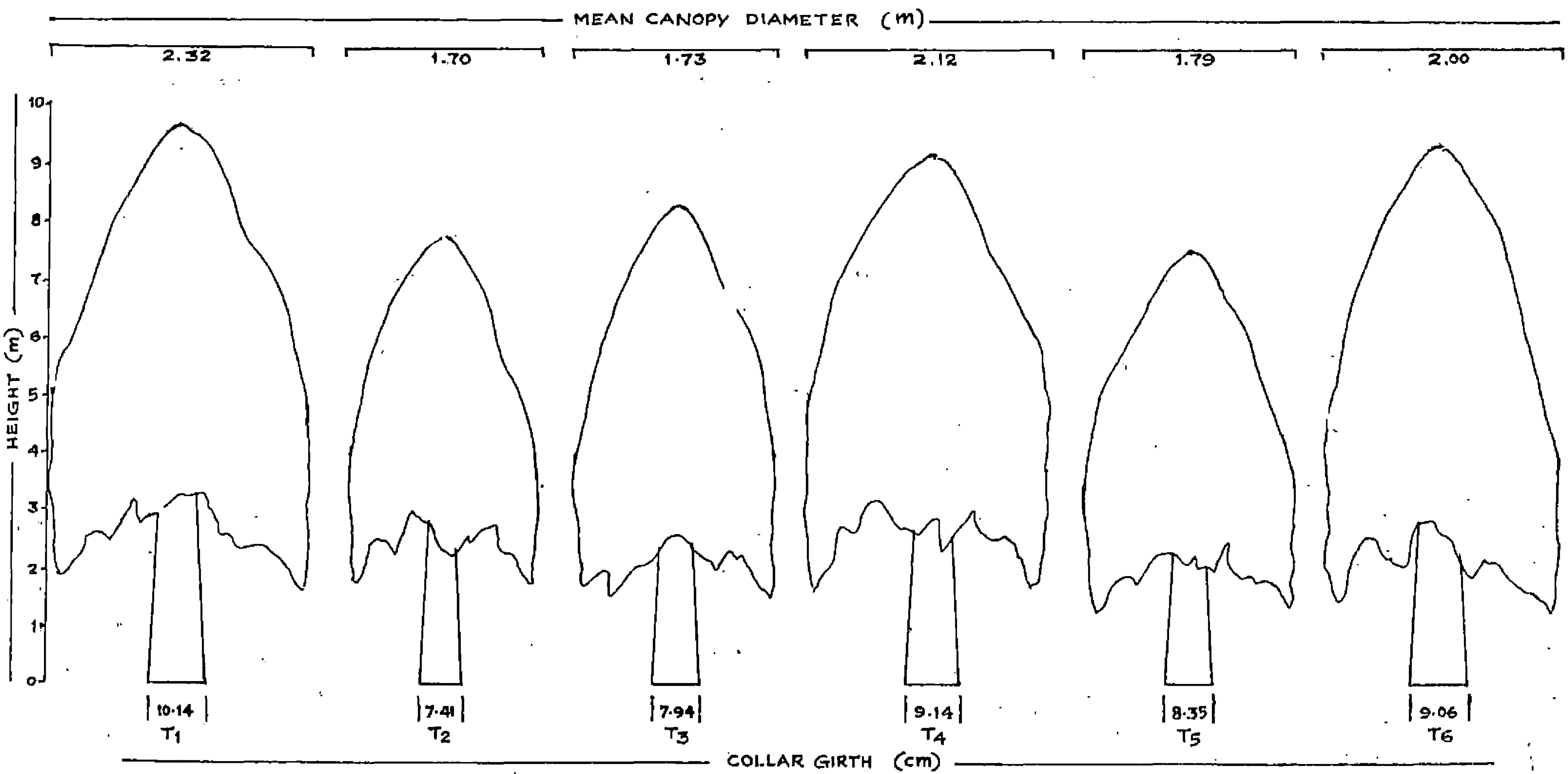
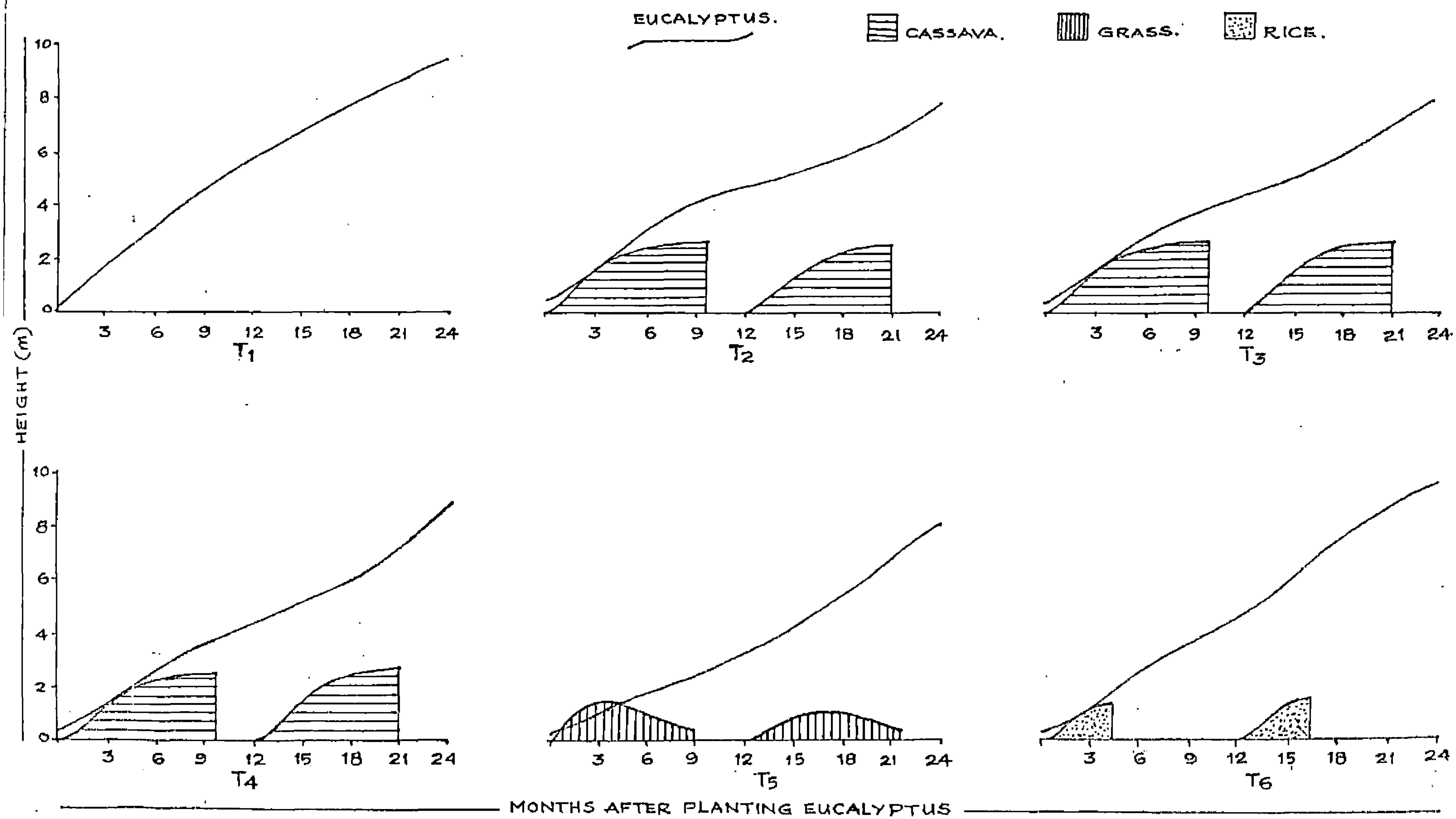


FIG. 23 - GROWTH OF EUCALYPTUS AT THE END OF EXPERIMENT



growth and growth rates of T_1 plants were expected. General weakness and low growth rates of trees in T_2 further explain this. As evident from Fig. 24, height of cassava in all the cassava intercropped plots viz. T_2, T_3 and T_4 never exceeded that of eucalyptus. Even then, the lowest growth rate of eucalyptus was observed in T_2 followed by T_3 and T_4. Since T_2 accommodated five times cassava and T_3, four times than that of T_4, this can mainly be attributed to the increased competition for space and nutrients corresponding to cassava population. Further, very severe soil loss (Table 11) and consequent nutrient drain (Table 31) in T_2 might have also aggravated the external stress on tree growth. Though there was substantial soil loss in T_4 and practically no loss in T_3, trees were comparatively robust in T_4. This is indicative of the fact that tree-crop competition is more decisive in determining the initial growth than soil and nutrient losses. This is more evident in T_5, the grassed plot. Here the tree growth was suppressed and that they were inferior as those of T_2. Fig. 24 illustrates that trees were continuously overtopped by the dense grass canopy upto the fourth months of planting. The canopy competition coupled with severe root competition of grass might have deprived T_5 plants of sufficient sunlight and nutrients. Riced plot (T_6), when compared to T_4 remained inferior in

FIG. 24 _ CANOPY HEIGHT OF EUCALYPTUS AND INTERCROPS AT MONTHLY INTERVAL



many of the growth parameters upto the end of the first year and later on regained superiority and even became comparable to T_1, in the case of height, at the end. This is because of the much less competition offered by rice, compared to grass.

In the second year, because of the difference in tree crop canopy orientation, influence of the intercrops on trees was not that much adverse as that of first year (Fig. 24). The initial retardation of growth and subsequent improvement towards the end in many of the intercropped treatments are indicative of this.

10. Economics:

Destructive sampling was not envisaged, in the experiment and hence, the yield of eucalyptus (wood volume) of each treatment was worked out by the formula suggested by Chaturvedi (1973). To have a strictly realistic approach, total income was arrived at based on the lowest probable price of each commodity. Table 55 provides the economics of each treatment and Fig. 25 illustrates the net income and percentage contribution of eucalyptus to total income.

In the first year, the highest net income of Rs. 3.70 thousand was recorded by T_2, closely followed by

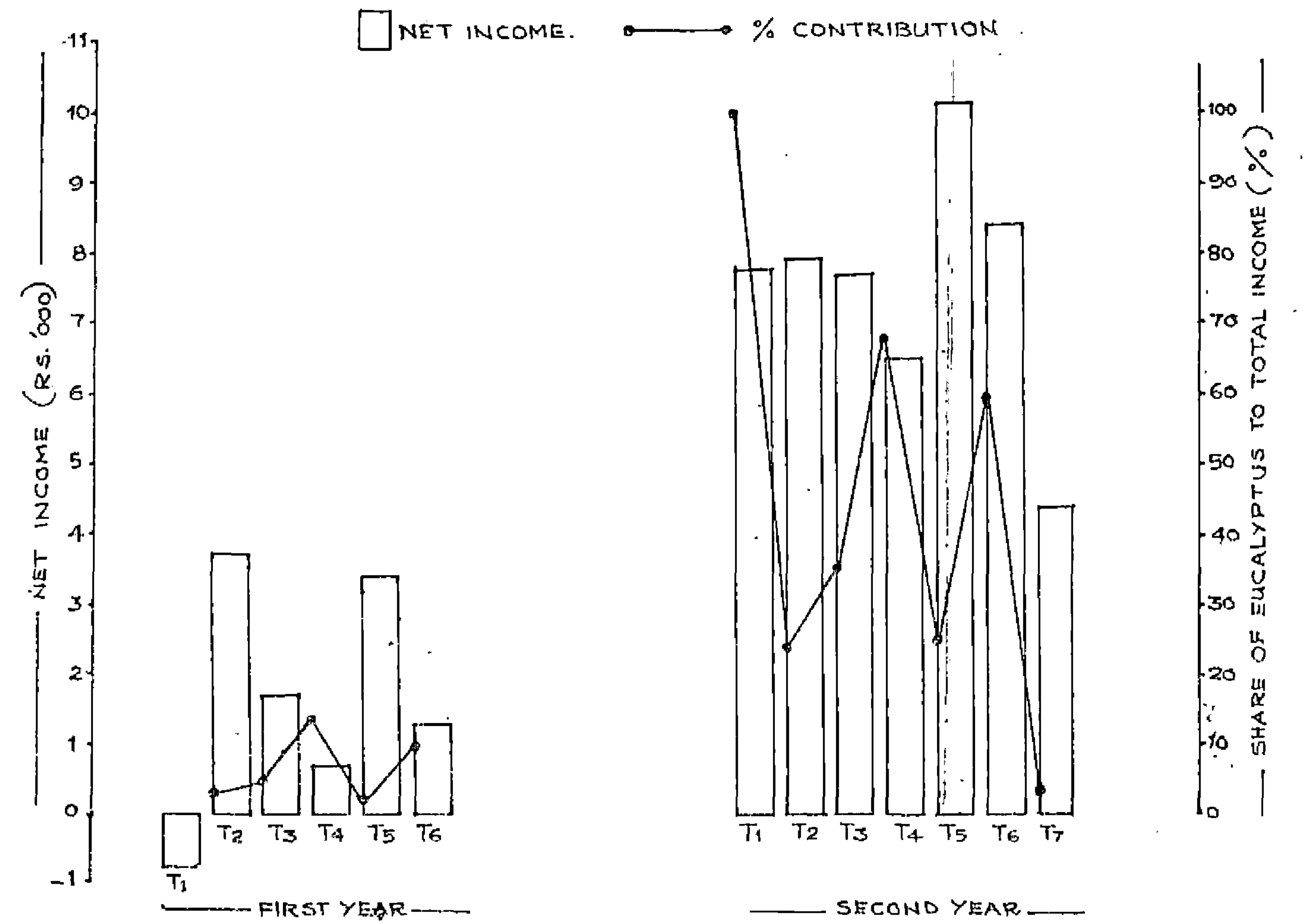
Table 55. Gross income, expenditure and net income ('000 Rs/ha) of each treatment

No.	Item	First year T_1	T_2	T_3	T_4	T_5	T_6	Second year T_1	T_2	T_3	T_4	T_5	T_6	T_7
I.	GROSS INCOME													
1.	Eucalyptus wood (@ Rs 150/m^3)	1.10 (7.34)	0.24 (1.60)	0.37 (2.44)	0.56 (3.70)	0.16 (1.09)	0.47 (3.16)	8.06 (53.74)	2.50 (16.63)	3.68 (24.55)	5.05 (33.63)	3.17 (21.16)	5.87 (39.11)	0.26 (1.71)
2.	Cassava													
	i) Tuber (@ Rs 500/t)	-	7.09 (14.18)	6.16 (12.31)	2.24 (4.48)	-	-	-	6.69 (13.38)	5.59 (11.90)	2.20 (4.40)	-	-	6.09 (12.18)
	ii) Marketable stems (@ Rs 100/1000 Nos)	-	1.10 (11.01)	0.90 (9.00)	0.23 (2.30)	-	-	-	1.06 (10.60)	0.91 (9.10)	0.23 (2.31)	-	-	0.93 (9.28)
3.	Grass (@ Rs 150/t)	-	-	-	-	9.42 (62.80)	-	-	-	-	-	9.80 (65.33)	-	1.09 (7.24)
4.	Rice													
	i) Grain (@ Rs 1500/t)	-	-	-	-	-	2.48 (1.65)	-	-	-	-	-	2.45 (1.63)	-
	ii) Straw (@ Rs 500/t)	-	-	-	-	-	1.69 (3.38)	-	-	-	-	-	1.62 (3.24)	-
	Total	1.10	8.43	7.43	3.03	9.58	4.64	8.06	10.25	10.54	7.48	12.97	9.93	8.36
II.	EXPENDITURE													
1.	Labour	1.55	4.10	5.20	2.05	4.85	2.50	0.25	2.40	2.80	1.00	2.85	1.58	3.95
2.	Inputs	0.25	0.63	0.55	0.33	1.35	0.81	-	0.38	0.30	0.08	0.87	0.56	0.66
	Total	1.80	4.73	5.77	2.38	6.20	3.31	0.25	2.78	3.10	1.08	3.72	2.14	4.61
III.	NET INCOME	-0.70	3.70	1.66	0.65	3.38	1.33	7.81	7.85	7.74	6.48	10.12	8.35	4.41

Note: Figures in parenthesis denote the quantity of economic produce in the units given for gross income calculation. Labour charge was calculated @ Rs 30/- per man and Rs.28/- per woman.

Cost of N in the form of Urea (45%) - Rs 5.11/kg
Cost of P in the form of SSP (18%) - Rs 12.92/kg
Cost of K in the form of MOP (60%) - Rs 2.61/kg

FIG. 25 - NET INCOME AND % CONTRIBUTION OF EUCALYPTUS TO TOTAL INCOME IN EACH TREATMENT.



T_3 with a value of Rs. 3.38 thousand. The lowest profit of Rs. 0.65 thousand was registered by T_4 and T_1 gave a net loss of Rs. 0.70 thousand.

Substantial increase in net income was observed in the second year in all the treatments. T_5, which was slightly inferior to T_2 in the first year, overtook all other treatments with the highest net income of Rs. 10.12 thousand. T_6 came next to this with a value of Rs. 8.35 thousand, though it was inferior to many treatments, in the first year. All the cassava intercropped treatments became inferior to these two. T_1, which showed a net loss in the first year, became profitable in the second year with a net income of Rs. 7.81 thousand, a value which can closely be compared with that of T_2. T_7 of the second year produced a profit of Rs. 4.41 thousand.

The comparatively low and non-repeated cost of cultivation and high growth rate, over the years, have brought about an increase in the net income share of eucalyptus. This is clearly evidenced by T_1 (eucalyptus alone) which produced a net loss of Rs. 0.70 thousand in the first year and a net profit of Rs. 7.81 thousand in the second year. Here, while the cost of cultivation through labour and inputs was Rs. 1.80 thousand in the first year, it was just Rs. 0.25 thousand in the second year. But yield of eucalyptus, showed the highest value of 53.74 m^3/ha, a seven times increase over the first year. Similarly, in rice cropped plot (T_6) about 60 per cent of the net income was contributed by eucalyptus resulting in a total of Rs. 8.35 thousand. All the cassava intercropped treatments too, registered substantial increase in net income in the second year, irrespective of the fact that cassava population remained constant during both years. This was clearly due to the increased percentage contribution of eucalyptus to total income as evidenced from Fig. 25. But, even when the tree crop contribution to total income was more than 67 per cent as in T_4 of the second year, total net income was always higher in other cassava intercropped treatments for increased population of cassava. T_5, the grass cropped plot, became the most profitable in the second year, though the income contributed by tree crop was only about 25 per cent. This can be attributed to the very high grass yield which alone accounted for Rs. 9.80 thousand out of Rs.10.12 thousand profit. Though the grass yield of first year was comparable to that of the second year, net income was far less than the second year for the initial high expenses through labour and inputs.

This income-expenditure analysis based on the quantity of economic produce *per se* will be misleading especially when the sustainability and acceptability of a production system is concerned. For example, by accommodating maximum possible number of cassava as in T_2, an income of Rs. 3.70 thousand/ha can be expected in the first year. But T_2 method of cassava cultivation can erode as high as 300 t of top soil/ha/yr which is equivalent to about 1.5 cm depth of soil (Table 11). This much soil will amount to the loss of major mineral nutrients worth no less than Rs. 5.39 thousand (Appendix-III) and convert the above profit of Rs. 3.70 thousand, to a net loss of Rs. 1.66 thousand/ha/yr. Further, at this alarming rate of soil loss, the whole A horizon can disappear within 16 years and make the soil unproductive and barren. On the other hand, grass farming can control the erosion completely and make a net income of Rs. 10.12 thousand in the second year. But the lack of a subsidiary food crop may make this treatment unacceptable by the hill slope farmers who practice subsistence farming. It can be seen that, T_7 of the second year was profitable to the extent of Rs. 4.41 thousand/yr. Further, this treatment could reduce the soil erosion by about 41 per cent as compared to T_2, a most erosive treatment, by one year time. Convinced from the results of grass farming, it can be concluded that, grass strips once established can control soil erosion satisfactorily and make T_7 of the second year an economically and ecologically preferable one.

Plate XIX Tree growth in eucalyptus alone treatment at 24th month.

Plate XX Tree growth in eucalyptus + five cassava on mounds at 24th month.

Plate XIX

Plate XX

Plate XIX

Plate XX

Plate XXI Tree growth in eucalyptus + four cassava on ridges across the slope at 24th month.

Plate XXII Tree growth in eucalyptus + one cassava on mound at 24th month.

Plate XXI

Plate XXII

Plate XXIII Tree growth in grass cropped plot at 24th month.

Plate XXIV Tree growth in rice cropped treatment at 24th month.

Plate XXIII

Plate XXIV

Summary

SUMMARY

An experiment was conducted at the Instructional Farm, College of Horticulture, Vellanikkara, for a period of two years from May 1984 to April 1986 to study the effect of agrotechniques for soil conservation in taungya systems on a 25 per cent sloppy land. Eucalyptus, the main tree component was intercropped with the usually cultivated taungya crops of cassava and rice. The efficiency of cassava planting on ridges, grass farming and grass stripping was also investigated. Run-off and soil loss were quantified by installing multi-slot device consisting of 47 slots and brick masonry settling tank specifically designed for the project. The salient results of the experiment are summarised below.

1. To explain and interpret the run-off and soil loss, some of the basic relations relevant to the experimental situation had been worked out. It was found that, run-off was highly correlated with the amount of rainfall ($r = 0.930^{**}$) closely followed by kinetic energy ($r = 0.912^{**}$) and AI_m ($r = 0.848^{**}$). Soil loss showed the maximum correlation with EI_{15} ($r = 0.977^{**}$) followed by EI_{30} ($r = 0.941^{**}$) and AI_m ($r = 0.931^{**}$). Soil loss was less correlated with run-off and indicated that erosion was more influenced by rainfall characteristics than run-off. Eventhough, the depth of rainfall was highly correlated

with all its characteristics studied, stronger correlations were observed with kinetic energy ($r = 0.975^{**}$) AI_m (0.909^{**}) and EI_{15} ($r = 0.859^{**}$).

2. Cultivated fallow plot produced the highest run-off of 1259 mm (53 per cent of the total rain). Eucalyptus + cassava on bunds across the slope produced very little run-off as compared to other cassava intercropped treatments. Eucalyptus + grass became most efficient in controlling run-off by accepting more than 96 per cent of total rain in the second year.

3. Cultivated fallow plot had eroded the highest quantity of 352 t of soil per ha per yr. Mound method of cassava cultivation, irrespective of its population, was more erosive than intercropping rice. Grass treatment could completely control the soil loss and was better than eucalyptus + cassava on bunds across the slope. Replacing 10 per cent of the cassava population with grass strips could reduce the soil erosion by 41 per cent within one year than the full cassava cropped plot. Tree planting alone could reduce the soil erosion by 87 per cent in the second year.

4. Eroded soil was, in general, more clayey than the soil matrix, especially in the initial months. In grass and rice intercropped plots, the loss of finer soil particles was comparatively less.

5. The total contents of primary and secondary nutrients in eroded soil were higher in the initial months. Majority of these nutrients recorded higher percentages than their respective inherent soil contents. Concentrations of dissolved N, K and Ca in run-off were higher than other nutrients. Contrary to the higher Mg content of soil compared to Ca, dissolved Mg was only 1/5th to that of Ca. Among the primary nutrients, dissolved P was the lowest. S content in run-off remained undetectable throughout. In general, all the intercropped treatments, consistently recorded higher concentrations of dissolved nutrients in both years.

6. Cultivated fallow plot had lost 416, 116 and 680 kg/ha of N, P and K respectively. Such losses were 395, 120 and 697 kg/ha respectively in eucalyptus + five cassava on mounds. Grass farming, irrespective of high fertilizer application, effectively reduced the primary nutrients losses to 4.0, 0.40 and 4.0 kg/ha respectively in the second year. Ridging was also comparable to grass farming in controlling nutrient drain. Regarding the losses of secondary nutrients, the highest quantity of 242, 878 and 299 kg/ha of Ca, Mg and S respectively were eroded by cultivated fallow plot closely followed by eucalyptus + five cassava on mounds. By eroding only

2.0, 0.70 and 0.10 kg/ha respectively, grass cultivation followed by cassava on ridges were effective in controlling the losses of secondary nutrients also.

7. Bulk density and total porosity were affected by continuous tilling and cassava cultivation. Grass inter-cropping followed by rice, improved the total porosity and maintained the desirable void ratio. Regarding the soil structural stability and permeability characteristics also, grass and rice cropped plots remained superior to others.

8. The influence of various treatments on soil texture was negligible and the proportions of sand, silt and clay remained constant around 50, 15 and 30 per cent respectively throughout the experiment. Water holding capacity at 0.3 and 15 bars also did not exhibit any noticeable change between treatments.

9. Total contents of both primary and secondary nutrients showed relatively smaller changes over the stages and between treatments. pH did not reveal a notable change and it centered around 5.80 always. There was a slight reduction in CEC towards the end in all treatments except grassed plot, where, an increase was observed. Organic carbon content also revealed an almost similar trend as that of CEC.

10. In grass and rice intercropped treatments, the combined canopy cover was denser enough to provide five to eight times protection than that of the bare ground. An increase in rainfall interception with a corresponding increase in canopy cover was observed resulting in more than 50 per cent of interception in these treatments. The highest splash erosion was observed in cultivated fallow plot. The extent of splash erosion seen in other treatments was almost proportionate to their combined canopy cover.

11. The peak soil binding ability of grass remained around 300 and that of rice around 200.

12. Measured in terms of wormcast, the earthworm activity was maximum in grassed plot (73.34 g/m^2) followed by riced plot (45.77 g/m^2) in the second year. Cassava on bunds across the slope produced the lowest wormcast (5.13 g/m^2).

13. Eucalyptus + grass and eucalyptus + cassava on ridges across the slope gave lower C values approaching zero and indicated their effectiveness in controlling soil erosion. Maximum C value of 0.731 was observed in eucalyptus + five cassava on mounds. The protective ability of grass stripping was reflected by the lower C value of 0.310.

14. The robust trees were observed in eucalyptus alone treatment. Eucalyptus + rice and eucalyptus + one cassava on mounds were less harmful to tree growth. The weakest trees were seen in eucalyptus + five cassava on mounds. In grass cropped plot, the vigour of the trees was less in the first year but it improved in the second year.

15. The highest net income of Rs. 10.12 thousand/ha was produced by eucalyptus + grass followed by eucalyptus + rice with a net profit of Rs.8.35 thousand/ha in the second year. Eucalyptus alone produced a profit of Rs.7.34 thousand/ha. Eucalyptus + five times cassava than taungya contract regulation eventhough had produced a net income of Rs. 7.81 thousand/ha it resulted in very severe soil and nutrient loss. Eucalyptus + cassava + 10 per cent grass strips gave a net profit of Rs. 4.31 thousand/ha within one year. When acceptability, sustainability and profitability are taken into account, this treatment seems to be better.

FUTURE LINES OF WORK

The following future lines of work are suggested.

1. Similar experiments may be conducted on different agroclimatic zones of the state on varying slopes.

2. Instead of grass strips, strips of other economic crops such as pineapple, sweet potato and medicinal plants can be attempted.

3. Possibilities of providing live mulch by close growing leguminous crops to dissipate rainfall erosivity and reduce splash and wash erosion, especially in the initial months of cassava cultivation, can be tried.

4. Tailoring of crop and planting geometry so as to have maximum canopy cover by way of crop improvement and agronomic measures can be investigated.

References

REFERENCES

Abujamin, S.A., Abdurachman, A. and Suwardjo (1985). Contour grass strips as a low cost conservation practice. ASPAC Extn. Bull. No.221 : pp. 1-8.

Adams, J.E., Richardson, E.W. and Burnett, E. (1978). Influence of row spacing of grain sorghum on ground cover run-off and erosion. Soil Sci. Soc. Am. J. 42(6): 956-962.

Aina, P.O., Lal, R. and Taylor, G.S. (1977). Soil and crop management in relation to soil erosion in the rainforest of Western Nigeria. In Soil Conservation and Management in the Humid Tropics. (Eds. Greenland, D.J. and Lal, R.). John Wiley and Sons, New York. pp. 75-82.

Alberts, E.E., Moldenhauer, W.C. and Foster, G.R. (1977). Soil aggregates and primary particles transported in rill and interrill erosion. Agron. Abstr. p. 174.

Alberts, E.E., Spomer, R.G. (1985). Dissolved nitrogen and phosphorus in run-off from watersheds in conservation and conventional tillage. J. Soil Wat. Conserv. 40(1): 153-156.

Alberts, E.E., Wendt, R.C., Piest, R.F. (1983). Physical and chemical properties of eroded soil aggregates. Trans. ASAE. 26(2) : 465-471.

Alexander, T.G., Sobhana, K., Balagopalan, M. and Mary, M.V. (1980). Taungya in relation to soil properties, soil erosion and soil management. Research report No.4, KFRI, Peechi, Kerala, India, pp. 24.

Alexander, T.G. and Thomas, P. Thomas (1981). Cultural practices for managing soil erosion in forest plantations. A state of knowledge report. Research Report No.14, KFRI, Peechi, Kerala, India. pp. 17.

AOAC (1980). Official methods of analysis of the Association of Official Analytical Chemists. (Ed. William Horwitz). Association of Official Analytical Chemists, Washington, 13th Edn. pp.561-562.

Balasubramanian, G. and Sivanappan, R.K. (1981). Effect of degree of slope and rainfall erosivity on soil erosion and the influence of mulching on run-off and soil loss. In Proceedings of the South-East Asian Regional Symposium on Problems of Soil Erosion and Sedimentation. (Eds. Tingsanchali, T. and Eggers, H.). pp. 167-171.

Barisan, S.G., Baker, J.L., Johnson, H.P. and Laflen, J.M. (1978). Effect of tillage systems on run-off losses of nutrients, a rainfall simulation study. Trans. ASAE, 21(5) : 893-897.

Barnet, A.P. (1958). How intense rainfall affects run-off and soil erosion. Agric. Engng. 39 : 703-711.

Barnet, A.P., Carreker, J.R., Abruna, F., Jackrow, W.A., Dooley, A.E. and Holladay, J.A. (1972). Soil and nutrient losses in run-off with selected cropping treatments on tropical soils. Agron. J. (3) : 391-396.

Baruah, P.C. (1973). An investigation of drop size distribution of rainfall in Thailand. M.S. Thesis, Asian Institute of Technology, Bankok. pp. 52.

Battawar, H.B. and Rao, Y.P. (1969). Effectiveness of crop cover for reducing run-off and soil loss. J. Soil Wat. Conserv. India. 17(3 & 4) : 39-50.

Baver, L.D. (1972). Soil erosion - water erosion. In Soil Physics. John Wiley & Sons, Inc., New York. pp. 446-469.

*Bertoni, J., Lombardi Neto, F., and Benatti, K. Jr. (1975). Bol. Techn. Inst. Agron. (Campinas, Braz.) 21 : 1-25.

*Bhatia, K. (1980). Conservation farming practices Krishi Samachar. 2(1/6) : 179-181.

Bhimaya, C.P., Reye, N.D. and Sivaraman, V. (1956). Preliminary studies on the role of grasses in soil conservation in the Nilgiris. J. Soil Wat. Conserv. 4 : 113-117.

Bhola, S.N., Khybri, M.L. and Dayal, R. (1975). Run-off and soil loss studies under different cropping pattern. J. Indian Soc. Soil Sci. 23 : 298-301.

Black, C.A. (1965). Methods of Soil Analysis. Part-I (Ed. Black, C.A.). American Society of Agronomy, Inc. Publishers, Madison, Wiscosin, U.S.A. pp. 770.

*Blanford, H.R. (1958); Highlights of one hundred years of forestry in Burma. Emp. For. Rev. 37(91) : 33-42.

Carter, C.E., Greer, J.D., Braud, H.J., and Floyd, J.M. (1974). Raindrop characteristics in South Central United States. Trans. ASAE. 17(6): 1033-1037.

Celestino, A.F. (1984). Farming systems approach to soil erosion control and management. In Soil Erosion Management (Eds. Craswell, E.T., Remenyi, J.V. and Nallana, L.G.) ACIR Proc. Series No. 6. pp. 64-70.

Chaturvedi, A.N. (1973). General standard volume table for eucalyptus hybrid. Indian Forest Rec. 12(14): 10.

Chin, C.C. (1981). Conservation measures on the cultivated slope lands of Taiwan. Food and Fert. Tech. Centre Extn. Bull. No. 157. p. 17.

*Colbrone, G.J.N. and Staines, S.J. (1985). Soil erosion in South Somerset. J. Agric. Sci. U.K. 104(1): 107-112.

*Colting, (1981). Effects of vegetative cover on run-off and soil loss in Benguet. M.S. thesis. UPLB, Los Banos, Laguna, Phillipines pp. 78.

Cornforth, J.S. (1970). Leaf fall in tropical forest. J. Appl. Ecol. 7 : 602-680.

Costin, A.B. (1980). Run-off and soil losses from an improved pasture at Ginnindera, Southern Thailand, New South Wales. Australian J. Agric. Res. 31(3) : 533-546.

Das, D.C., Raghunath, B. and Purnachandran, G. (1967). Rainfall intensity, energy and erosion index - Part III. J. Indian Soc. Agric. Engng. 4 : 69-80.

Douglas, J.I., Goss, M.J. and Hill, D. (1980). Measurement of pore characteristics in a clay soil under ploughing and direct drilling including use of a radioactive tracer (^{144}Ca) Technique. Soil & Tillage Research 1: (1980/1981) : 11-18.

Egashira, K., Kaetsu, Y. and Takuma, K.K. (1983). Aggregate stability as an index of erodibility of Ando Soils. Soil Sci. Pl. Nut., 29(4) : 478-481.

Ekern, P.C. (1951). Raindrops impact as the force initiating soil erosion. Proc. Soil Sci. Soc. Am. 15 : 7-10.

*Ellison, W.D. (1944). Studies of raindrop erosion. Agric. Engng. 25 : 131-136, 181-182.

El-Swaify, S.A. and Dangler, E.W. (1982). Rainfall erosion in tropics. A state of the area. In Soil erosion and conservation in the tropics. ASAE special publication No.43 pp.1-25.

Finney, H.J. (1984). The effect of crop covers on rainfall and splash detachment. J. Agric. Engng. Res. 29 : 337-343.

Foster, G.R. (1982). Modeling the erosion process. In Hydrologic modeling of small watersheds (Eds. Hann, C.T., Johnson, H.P. and Brakensiek, D.L.). ASAE Monograph No.5 : 297-380.

Foster, G.R., Lane, L.J., Nowlin, J.D., Laflen, J.M. and Young, R.A. (1981). Estimating erosion and sediment yield on field-sized areas. Trans. ASAE 24 : 1253-1263.

Free, G.R. (1960). Erosion characteristics of rain-fall. Agric. Engng. 41(7): 447-449, 455.

Ghidey, F., Gregory, J.M. Mc Carty, T.R. and Alberts, E.E. (1985). Residue decay evaluation and prediction. Trans. ASAE 28(1): 102-105.

Gomez, K.A. (1972). Techniques for Field Experiments with Rice. The International Rice Research Institute, Los Banus, Laguna, Philippines, p. 37.

Goswami, N.W. and Sarkar, M.C. (1975). Review on soil erosion and nutrient losses. In Proc. of FAI-FAO Seminar 1974 on optimising agricultural production under limited availability of fertilizers pp.212-223.

Gumbs, F.A. and Lindsay, J.I. (1982). Run-off and soil loss in Trinidad under different crops and soil management. Soil Sci. Soc. Am. J. 46(5): 1284-1266.

Hamilton, G.H. (1977). The assessment of soil erodibility. J. Soil Conserv. Serv. N.S.W. 3(3): 106-107.

Hart, G.E. (1984). Erosion from simulated rainfall on mountain range land in Utah. J. Soil Wat. Conserv. 39: 330-334.

Hillel, D. (1971). Infiltration-entry of water into soil. In soil and water physical principles and processes. Academic Press, New York, San Francisco, London, pp. 131-152.

Hsu, P. and Jackson, M.L. (1960). Inorganic phosphate transformations by chemical weathering in soils as influenced by pH. Soil Sci. 90 : 16-24.

Hudson, N.W. (1957). Erosion control research, progress report on experiments at Henderson Research Station, 1953-1956. Rhodesia Agric. J. 54(4): 297-323.

Hudson, N.W. (1971). Crop management for cover. In Soil Conservation. Cornell University Press, Ithaca, New York pp. 220-228.

Hudson, N.W. (1977). The factors determining extent of soil erosion. In Soil Conservation and Management in Humid tropics (Eds. Greenland, D.J. and Lal, R.) John Wiley and Sons, New York pp. 11-17.

Hudson, N.W. (1984). Mechanics of erosion. In Soil Conservation. Bastford Academic and Educational London. pp. 34-38.

Hurni, H., Nuntapong, S. (1983). Agroforestry improvement for shifting cultivation systems: Soil conservation research in northern Thailand. Mount. Res. Devpt. 3(4): 338-345.

Hussein, M.H. and Laflen, J.M. (1982). Effects of crop canopy and residue on rill and interrill soil erosion. Trans. ASAE 25: 1310-1315.

IITA (1980). Influence of cassava on soil structure. Research Highlights for 1980. International Institute for Tropical Agriculture, Ibadan, Nigeria, pp. 10-12.

Jackson, M.L. (1958). Soil Chemical Analysis. Prentice Hall of India,Pvt. Ltd., New Delhi, 2nd Edn. pp.498.

Jayaram, N.S., Chittaranjam, S., Rama, M.S. and Mohan Rao (1984). Run-off and soil loss studies under different vegetative covers on 2 per cent slope. Soil conservation Annual Report, C.S. & W.C.R. & T.I., Dehra Dun, UP, India.

*Jenny, H. (1961). "Reflection on the soil acidity merry-go-round". SSSA Proc. 25 : 428.

Johnson, C.B., Mannering, J.W. and Moldenhauer, W.C. (1979). Influence of surface roughness and soil size and stability on soil and water loss. Soil Sci. Soc. Am. J. 43(4): 772-777.

Johnson, C.W. and Moldenhauer, W.C. (1976). Effect of chisel versus mouldboard ploughing on soil erosion by water. Soil Sci. Soc. Am. J. 43(1): 177-179.

Kamprath, E.J. (1977). Soil acidity in response to liming. International Soil Testing Tech. Bull. 4, North Carolina, Agric. Exp. Station., Raleigh, N.C. pp. 238-239.

Kanwar, J.S. (1972 a). Soil and water-looking ahed. J. Indian Soc. Soil Sci. 20(3): 199-206.

Kanwar, J.S. (1972 b). Are fertilizers pollutants? An apprisal with reference to Indian conditions. Fertil. News 17(10): 17-22.

Kanwar, J.S. (1972 c). Twenty-five years of research in soil, fertilizer and water Management in India. Indian Fmg. 22(5): 16-26.

Kanwar, J.S. (1976). Calcium, megnesium and sulphur. In soil fertility: Theory and Practice. Indian Council of Agricultural Research, New Delhi, India. pp. 202-207.

Kanwar, J.S. (1982). Managing soil resources to meet the challenges to mankinds presidential address. 12th International Congress of Soil Science, New Delhi, India pp. 1-12.

Karmer, L.A. (1984). Seasonal run-off and soil loss from conventional and conservation tilled corn. Paper Am. Soc. Agric. Engnrs. No. 84. USDA, ARS, Columbia, USA: pp. 20.

KAU (1982). Package of Practices Recommendations. Directorate of Extension Education, KAU, Mannuthy, Trichur, Kerala, India. pp. 199.

Kemper, B. and Derpchi, R. (1981). Results of studies made in 1978 and 1979 to control erosion by cover crops and no tillage techniques in Parana, Brazil. Soil & Tillage Res. 1(3): 253-267.

King, K.F.S. (1979). Agroforestry and the utilization of fragile ecosystems. Forest Ecology and Management, 2 : 161-168.

*Knisel, W.G. (Ed.) (1980) Creams: a field scale model for chemicals, run-off and erosion from agricultural management systems. In USDA Conservation Research Report No. 26. pp. 143-149.

*Kovda, V.A. (1974). Presidential address, 10th International Congress of Soil Science, Moscow, USSR pp. 1-14.

Kowal, J.M. and Kassam, A.H. (1977). Energy load and instantaneous intensity of rainstorms at Samaru, Northern Nigeria. In Soil Conservation and Management in Humid Tropics (Eds. Greenland, D.J. and Lal, R.) John Wiley & Sons, Chichester pp. 57-70.

Krishnarajah, P. (1985). Soil erosion control measures for Tea land in Sri Lanka. ASPAC Extn. Bull. No. 219 : 10-19.

Krishnaswami, R.S., Vinayarai and Srinivasan, V.M.(1982). Sapling growth of Eucalyptus teriticornis under various edapho-climatic regions, Tamil Nadu. Indian J. For. 5(1): 21-23.

Laflen, J.M., Tabatabu, M.A. (1984). Nitrogen and phosphorus losses from corn-soybean nutritions as affected by tillage practices. Trans. ASAE 27(1): 58-63.

Lal, R. (1974). Soil erosion and shifting agriculture. In Shifting cultivation and soil conservation in Africa, FAO Soil Bul. No. 24, Rome; FAO pp. 48-71.

*Lal, R. (1976 a). Soil erosion on Alfisols in Western Nigeria I. Effect of slope, crop rotation, and residue management. Geoderma, 16, 363-375.

*Lal, R. (1976 b). Soil erosion on Alfisols in Western Nigeria. II. Effect of mulch rate. Geoderma, 16. 377-387.

Lal, R. (1976 c). Soil erosion on Alfisols in Western Nigeria, Monograph No.1 IITA, Ibadan, Nigeria pp. 21.

*Lal, R. (1980). Soil erosion as a constraint to crop production: Priorities for alleviating soil - related constraints to food production. IRRI and New York, College of Agric. and life Sci. Cornell University, Los Banos, Phillipines.

Lal, R. (1982 a). Effective conservation farming systems for the humid tropics. In Soil conservation in the tropics. ASAE special Pub. No. 43: 55-76.

Lal, R. (1982 b). No tillage effect on soil properties under different crops in Western Nigeria. Soil Sci. Soc. Am. J. 40(5): 762-768.

Lal, R. (1984). Soil erosion from tropical arable lands and its control. In Advances in Agronomy. 34 (Ed. Brady, N.C.). Academic Press, INC. London. pp. 183-240.

Lang, R.D. (1979). The effect of ground cover on surface run-off from experimental plots. J. Soil Conserv. Serv. N.S.W. 35. No.2 : 48-53.

*Lang, P.M. and Mallett, J.B. (1984). Effect of the amount of surface maize residue on infiltration and soil loss from aclay loam soil. S. Afr. J. Pl. Soil 1(3): 97-98.

Laskar, S. and Govindarajan, S.V. (1980). Erodibility of the soils of Thripura. Indian J. Agric. Sci. 50(2): 161-167.

Lately, J. (1985). Relationship between soil physical properties and crop production. In Advances in soil science. (Ed. STEWART, B.A.) Springer Verlag, New York, Berlin Heidelberg, Tokyo. pp. 277-293.

Loch, R.J. and Donnollan, T.E. (1983). Field rainfall simulator studies on two clay soils of the Darling Dows Queensland-II. Aggregate breakdown, sediment properties and soil erodibility. Aust. J. Soil Res. 21(1): 47-58.

*Lundgren, B. (1978). Soil conditions and nutrient cycling under natural and plantation forests in Tanzanian Highlands. In Reports in Forest Ecology and Forest Soils No.31. Swedish Univ. Agric. Sci. Uppsala, Sweden pp. 426.

*Luk, S.H. (1983). Effect of aggregate size and micro-topography on rainwash and rainsplash erosion. Zeitschrift fur Geomorphologic, 27(3): 283-295.

Mc Coll, R. (1983). Farm run-off: the mechanisms and moderating factors. Soil Wat. 3: 31-35.

Mc Dowell, L.L. and Mc Gregor, K.C. (1980). Nitrogen and phosphorus losses in run-off from no-till soybeans. Trans. ASAE, 23(3): 643-648.

Megahan, W.F. (1978). Erosion processes on steep granite road fells in central Idaho. Soil sci. Soc. Am. J. 42: 350-357.

Menon, T.M. (1984). Farm trials as a component of an integrated research programme - A general theoretical model. Paper presented in the workshop on Farm Trials, Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

Meyer, L.D. (1981). How rain intensity affects interrill erosion? Winter Meeting ASAE, December 1980, paper 80. p. 2503.

Meyer, L.D., Foster, G.R. and Nilkolov, S. (1975). Effect of flow rate and canopy on rill erosion. Trans. ASAE. 18: 905-911.

Meyer, L.D. and Harmon, W.C. (1984). Susceptability of agricultural soils to interrill erosion. Soil Sci. Soc. Am. J. 48(5): 1152-1157.

Misra, S.M., Patil, D.B., Pathak, P.S. (1982). Comparative differences in soil properties as a result of growing different grass legumes and tree combinations. Indian J. Range Mgmt. 3(1/2): 71-74.

Mithrachaly, J.I. and Koshy, M.M. (1967). Studies on the effect of deforestation on organic carbon, nitrogen and potash status of some forest soils of Kerala. Agric. Res. J. Kerala 5(1,2): 45-53.

Moldenhauer, W.C., Wischmeier, W.H. and Parker, D.T. (1967). The influence of crop management on run-off, erosion and soil properties of a marshall silty clay loam. Proc. Soil Soc. of Am. 31(4): 541-546.

Monke, E.J., Marelli, H.J., Meyer, L.D. and Jong, J.F. (1977). Run-off, erosion and nutrient movement from interrill areas. Trans. ASAE. 20 : 58-61.

Morgan, R.P.C. (1985 a). Priorities for technical research in soil conservation. ASPAC Extn. Bull. No. 218:1-9.

Morgan, R.P.C. (1985 b). International workshop on soil erosion and its countermeasures: Conclusions and recommendations. ASPAC Extn. Bull. No. 28: 10-12.

Morgan, R.P.C., Morgan, D.D.V. and Finney, H.J. (1982). Stability of agricultural ecosystem. Documentation of a simple model for soil erosion assessment. Collaborative paper series. 1. IIASA, Laxenburg, Austria, pp.28.

Mutchler, C.K., Mc Dowell, L.L. and Greer, J.D. (1985). Soil loss from cotton with conservation tillage. Trans. ASAE 28(1): 160-163.

Mutchler, C.K. and Young, R.A. (1975). Soil detachment by raindrops. In present and prospective technology for predicting sediment yields and sources. Proc. Sediment yield workshop, USDA sediment Lab; Oxford, Miss., U.S. Agric. Res. Serv. (Rep) ARS-S. 40. pp. 113-117.

Nair, P.K.R. (1979). Agroforestry research: a retrospective and prospective apprisal. In Conference on International Co-operation in Agroforestry, Nairobi, Kenya. (Eds. Chandel, T.Y. and Spurgeon, D.) ICRAF, Nairobi, Kenya, pp. 275-296.

Nair, P.K.R. (1984). The taungya system. In Soil Productivity Aspects of Agroforestry, ICRAF Science and practice of Agroforestry series No.1. pp. 12-18.

Narain, P., Verma, B. and Rao, D.H. (1982). Prediction of rainfall erosion potential and some parameters of universal soil loss equation at Kota. Indian J. Soil Conserv. 10(2, 3): 60-69.

Nema, J.P., Verma, B. and Patel, A.P. (1978). Predicting some universal soil loss parameters. Indian J. Soil Conserv. 6(2): 75-79.

*Noble, C.A. and Morgan, R.P.C. (1983). Rainfall interception and splash detachment with a brussels sprout plant: a laboratory simulation. Earth Surf. Proc. Landf. 8: 569-577.

Nwoboshi, L.C. (1981). Soil productivity aspects of agri-silviculture in the West African rain forest zone. Agro-Ecosystem 4 : 31-49.

Ojeniyi, S.O. and Agbede, O.O. (1980). Effects of single crop agri-silviculture on soil analysis. Expl. Agric. 16 : 371-375.

Ojeniyi, S.O., Agbede, O.O. and Fagbenro, J.A. (1980). Increasing food production in Nigeria: 1. Effects of agri-silviculture on soil chemical properties. Soil Sci. 130: 76-81.

*Orr, W. (1970). Run-off and erosion control by seeded and native vegetation on a forest born rocky mountain. Forest and Range Experiment Station Report. Fort Collins, Colarado. pp. 78.

*Orsi, S. (1984). Herbage crops and soil conservation. Rivista di Agromia. 18(3/4): 175-181.

Palis, R.C. (1977). Soil erosion under different cover crops. M.S. Thesis. UPLB Los Banos Laguna Phillipines. pp. 96.

Piper, C.S. (1967). Soil and Plant Analysis. Asian reprints. Ham Publishers, Bombay. pp. 252.

Quanasa, C. (1981). The effect of soil type, slope, rain intensity and their interactions on splash detachment and transport. J. Soil Sci. 32(2): 215-224.

Quinn, N.W. and Laflen, J.M. (1983). Characteristics of raindrop throughfall under corn canopy. Trans. ASAE, 26(5): 1445-1450.

*Ramaiah, R. and Sreenivas, G.N. (1975). Rainfall intensity and soil erosion. Mysore J. Agric. Sci. 9 : 448-453.

Rambabu, Gupta, S.K., Tejwani, R.G. and Rawat (1969). Correlation of daily, monthly and annual rainfall with energy intensity product (Presented at the 7th annual meeting, Indian Soc. Agric. Engnrs. Pantnagar, U.P. India).

*Rao, Y.P. (1984). Evaluation of cropping management factor in USLE under natural rainfall conditions of Kharagpur, India. In proceedings of the South-East Asian Symposium on Problems of soil erosion and sedimentation (Eds. Tngsanchali, T., and Eggers, H.)

Requier, J. (1982). A World assessment of soil degradation. Nature and Resources. XVIII(2): 18-21.

Robinson, C.S. (1979). Soil conservation in the Northern Territory. J. soil conserv. serv. N.S.W. 34(2): 101-105.

*Roose, E.J. (1971). Project de hutte Contre L' erosion Hydrique sor le Plateau Mossi (Haute Volta) ORSTOM Centre d' Adiopotoume, Abidjan, Ivory Cost.

Rose, C.W. (1960). Soil detachment caused by rainfall. Soil Sci. 89(1): 28-35.

Rose, C.W. (1984). Progress in research on soil conservation process and a basis for soil conservation practices. In Soil Erosion Management. ACIAR Proc. Series No.6. pp. 32-44.

Russel, E.W. (1973). Soil atmosphere. In Soil conditions and plant growth. Longmans, London, 10th Edn. pp. 247-258.

Sanchez, P.A. (1976). Soil physical properties. In Properties and management of soils in the tropics. John Wiley and Sons, Inc., New York, pp. 96-135.

*Saraiva, O.F., Cogo, N.P. and Mielniczuk, J. (1982). Erosion by rainfall and erosion losses under different soil management system and plant cover. Pesquisa Agro-pceuaria Brasileria. 16(1): 121-128.

Sekhon, J.S. and Ghosh, A.B. (1982). Potassium. In Review of Soil Research in India. 12th International Congress of Soil Science, New Delhi. pp. 331-339.

Sharma, S.G., Gupta, R.N., Panwar, K.S. (1976). Concept of crop protection factor evaluation in soil erosion. Indian J. Agric. Res. 10(3): 145-152.

Shaxson, T.F. (1981). Reconciling social and technical needs in conservation work on village farm lands. In soil conservation : Problems and prospects (Ed. Morgan, R.P.C.) Wiley, Chichester, England, pp. 148-164.

Sheng, T.C. (1982). Erosion problem associated with cultivation in humid tropical hilly region. In Soil erosion and conservation in the tropics: ASAE special publication No. 43. pp. 39.

Singer, M.J., Matsuda, Y. and Blackary, J. (1981). Effect of mulch rate on soil loss by raindrop splash. Soil Sci. Soc. Am. J. 45(1): 107-110.

Singer, M.J., Blackard, J. and Huntindon, G.L. (1980). Plant cover helps control range land soil erosion. Calif. Agric. 34(10): 8-10.

Singh, R. and Biswas, B.C. (1982). Fertilizer use and environmental quality in the tropics and subtropics. In Whither Soil Research. Transactions of the 12th International Congress of Soil Science, New Delhi, India. 227-247.

Singh, R.B. (1984). Plant performance and future prospects of cassava production in Asia and the Pacific Region. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. pp. 22.

Singh, R.S. (1980). Soil Physical Analysis. Kalyani Publishers, New Delhi pp. 52-61.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical Methods. Oxford and IBH Publishing Co., New Delhi, 6th Edn. pp. 593.

Soil Survey Report (1976). Soil Survey Report of main campus of Kerala Agricultural University, Trichur. Report No. 37. Department of Agriculture (Soil Conservation Unit) Kerala. pp. 20.

Subhashchandra and Rao, D.H. (1984 a). Studies on effect of degree of slope on soil loss from run-off plots. In Soil Conservation Annual Report, 1984 C.S. & W.C.R. & T.I. Dehra Dun, India. p. 147.

Subashchandra, and Rao, D.H. (1984 b). Studies on effect of slope and run-off and soil loss from run-off plots of 2 per cent slope. In Soil Conservation Annual Report, 1984. C.S. & W.C.R. & T.I., Dehra Dun, India. pp. 146-147.

*Teje, L.K. and Agu, A.N. (1982). Run-off and soil loss from erosion prediction plots in the Ife area of south western Nigeria. Geo. Eco. Trop. 6(3): 161-181.

Tejwani, K.G. (1979). Soil fertility status, maintenance and conservation for agroforestry systems on wasted lands in India. In Soil Research in Agroforestry. (Eds. Mongi, H.O. and Huxley, P.A.), ICRAF, Nairobi, Kenya, pp. 141-174.

Tisdale, S.L., Nelson, W.L. and Beaton, J.D. (1985). Basic soil-plant relationships. In Soil Fertility and Fertilizers. Macmillan Publishing Co., New York 4th Edn., pp. 95-109.

Turner, A.K., Mc Mohan, T.A. and Srikanthan, R. (1984). Rainfall intensity and overland flow in relation to soil erosion studies for tropical lands. In Soil Erosion Management (Eds. Crasswell, E.T., Remeny, J.V. and Nallana, L.G.) ACIAR Proceedings Series No. 6: pp. 24-31.

Ugner, P.W. (1982). Soil Physical properties after 36 years of cropping to winter wheat. Proc. Soil. Sci. Soc. Am. 11. 543-548.

Ulasker, L.G. and Onstad, C.A. (1984). Relating rainfall erosivity factors to soil loss in Kenya. Soil Sci. Soc. Am. J. 48(4): 891-896.

Uriyo, A.P. (1979). Monitoring soils in agroforestry. Physical properties. In Expert consultation in soil Research in Agroforestry, Nairobi, Kenya, 1979 Proceedings (Eds. Mongi, H.O and Huxley, P.A.) ICRAF, Nairobi, Kenya, pp. 413-437.

Van Doren, C.A. and Baver, F.C. (1946). Effects of crops on soil treatment on yield and erosion. Proc. Soil Sci. Soc. Am. 11: 543-548.

Vanelslande, A., Lal, R. and Gabriels, D. (1983). Soil erodibility. Annual Report, IITA, Ibadan, Nigeria, pp. 125.

Venkataraman, S. (1978). Use and requirements of agro-meterological data for quantifying crop-moisture stress and needs. In Proceedings Agroclimatological Research Needs of the Semi-Arid Tropics (Eds. Shaw, R.H., Sivakumar, M.V.K. and Virmany, S.M.) pp.170-181.

Venugopal, V.K. and Koshy, M.M. (1976). Exchangeable cations of some important soil profiles of Kerala. Agric. Res. J. Kerala. 14(1): 37-42.

Verma, B. (1984). Determination of erosion and parameters of universal soil loss equation with run-off plots. Extension Bulletin, C.S. & W.C.R. & T.I., Research Centre, Kota, India. pp. 15.

Viswambharan, K. (1980). Effect of agrotechniques on soil loss, surface run-off and soil moisture storage in hill slopes. M.Sc. (Ag.) thesis Department of Agronomy, College of Horticulture, Vellanikkara, Trichur, Kerala, India, pp. 117.

Vleeschauwer, D.De and Lal, R. (1981). Properties of worm-casts under secondary tropical forest growth. Soil Sci. 132(2): 175-181.

Williams, R.J.B. (1963). A new method for measuring soil stability. Chemistry and industry No.25: 1032-1033.

*Wischmeier, W.H. (1955). Punch cards record run-off and soil loss data. Agric. Engng. 36: 664-666.

Wischmeier, W.H. (1966). Relation of field plot run-off to management and physical factors. Proc. Soil Sci. Soc. Am. 30: 272-277.

Wischmeier, W.H. (1975). Estimating the soil loss equations, cover and management factor for undisturbed areas: In present and prospective technology for predicting sediment yields and sources, USDA Agric. Res. serv. Pub. ARS-8-40: 118-124.

Wischmeier, W.H., Johnson, C.B. and Cross, B.V. (1971). A soil erodibility nomograph for farmland and conservation sites. J. Soil Wat. Conserv. 25(5): 189-192.

Wischmeier, W.H. and Smith, D.D. (1958). Rainfall energy and its relationship to soil loss. Trans. Am. Geophys. Union 39: 285-291.

Wischmeier, W.H. and Smith, D.D. (1960). Rainfall energy and its relationship to soil loss. Trans. Am. Geophys. Union., 39, 285-291.

*Wischmeir, W.H. and Smith, D.D. (1978). Predicting rainfall erosion loss. United States Dept. of Agriculture, Agricultural Handbook pp. 537.

Wood, H.B. (1977). Hydrological differences between selected forested and agricultural soils in Hawai. Soil Sci. Soc. Am. J. 41: 132-136.

*Xiaoliang Experimental and Extension Station of Soil Conservation (1977). Effect of artificial vegetation on soil conservation of littoral hilly slopes. In Xiaoliang Experimental and Extension station of soil conservation report 1977. Diambai country, Kwangtung, China, pp. 127-138.

Yadav, U. (1961). Role of raindrops in soil erosion. J. Soil. Wat. Conserv. India. 9: 180-187.

Yodder, K.E. (1936). A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. J. Am. Soc. Agron. 28: 337-351.

Young, R.A., Mutchler, C.K. (1977). Erodibility of some Minnesota soils. J. Soil Wat. Conserv., 32(4):180-182.

Young, R.A. and Wiersma, J.L. (1973). The role of raindrop impact on soil detachment and transport. Wat. Resour. Res. 9: 1629-1636.

*Zein, I.A., Shawky, M.E., and Zaghloul, K.E. (1980). A comparative study on the effect of plant systems on some physical properties of soil desert calcareous soil. In Research Bulletin No.1243, Faculty of Agriculture, Ain Shams University. pp. 1-22.

Zingh, K., Agnihotri, Y. and Mishra, P.R. (1983). Role of Crassica in moderating rainfall erosivity. _Indian J. Soil Conserv._ 11(2): 73-76.

* Originals not seen

Appendices

Appendix I. Month-wise important meteorological data during the experimental period

Month	Maximum temperature (°C)	Highest maximum temperature (°C)	Minimum temperature (°C)	Lowest minimum temperature (°C)	Relative humidity (%)	Sunshine (hr)	Rainfall (mm)
1984							
May	34.50	37.00	25.80	22.80	55.00	247.10	243.90
June	29.00	33.00	22.70	21.00	82.00	42.30	709.35
July	28.60	30.80	22.90	21.00	78.00	78.40	627.75
August	29.30	30.50	22.20	21.50	74.00	155.40	237.70
September	30.40	32.60	23.20	22.00	68.00	194.50	152.55
October	29.90	33.00	22.10	16.00	68.00	187.50	350.50
November	32.10	33.80	23.10	20.00	54.00	219.00	7.80
December	31.90	35.00	20.80	16.50	46.00	277.90	16.40
1985							
January	32.60	35.00	22.60	18.60	52.00	278.20	14.70
February	34.70	37.00	22.80	18.60	40.00	248.40	0.00
March	36.10	40.00	24.60	22.50	45.00	279.30	2.00
April	35.50	37.00	25.10	21.90	53.00	246.90	20.10
May	34.10	37.00	21.30	21.60	60.00	209.40	205.90
June	28.30	31.00	22.10	21.80	84.00	64.60	829.25
July	28.50	30.50	22.70	21.50	77.00	84.10	709.50
August	28.80	30.20	22.70	20.50	79.00	89.30	294.50
September	30.50	34.00	23.00	21.50	69.00	59.30	53.00
October	31.10	33.00	22.50	21.10	66.00	201.70	321.05
November	31.80	36.00	22.30	19.00	59.00	211.70	13.40
December	32.20	34.00	22.90	18.60	45.00	272.50	56.80
1986							
January	32.50	34.00	22.40	20.00	45.00	279.78	1.20
February	34.20	35.50	22.10	19.50	40.00	248.70	1.20
March	36.20	40.30	24.30	22.80	42.00	261.80	9.95
April	36.00	39.00	25.20	22.00	67.00	251.00	20.10

Appendix-II. Daily rainfall characteristics and interception (%) of July 1985

Date	Rainfall characteristics					Rainfall interception (%)						
	Amount (mm)	Duration (hr)	Kinetic energy (mt/ha cm)	EI_{15}	AI_m	T_1	T_2	T_3	T_4	T_5	T_6	T_7
	(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(Y_1)	(Y_2)	(Y_3)	(Y_4)	(Y_5)	(Y_6)	(Y_7)
1-7-85	31.00	4.80	627.10	10.66	13.02	41.76	48.71	44.76	49.18	50.76	52.16	46.10
2-7-85	97.50	9.57	2221.02	106.61	54.89	26.18	37.16	36.38	36.01	39.41	38.16	35.04
3-7-85	17.25	0.53	437.61	10.30	8.80	44.71	49.76	49.78	44.16	54.96	53.10	43.90
5-7-85	24.50	4.63	562.20	15.74	9.92	40.78	46.10	44.19	40.08	57.16	58.46	46.16
6-7-85	27.50	1.57	667.30	18.68	9.63	30.16	38.16	40.16	49.90	42.00	43.19	37.18
7-7-85	9.00	0.43	217.52	6.53	2.70	28.96	33.96	30.79	31.64	62.07	60.11	32.81
8-7-85	9.50	2.00	213.08	4.69	2.09	36.39	41.76	42.34	40.11	61.16	58.19	40.76
9-7-85	90.00	8.38	2194.96	175.60	74.70	25.94	31.90	28.76	26.14	38.30	39.40	32.91
10-7-85	16.00	6.63	283.88	3.41	9.08	50.76	63.18	61.51	60.59	69.17	60.76	61.84
12-7-85	10.00	0.50	237.10	6.16	2.60	28.98	36.18	35.34	37.18	43.74	42.64	34.04
13-7-85	8.25	0.47	119.85	4.79	2.48	36.38	42.78	40.96	37.11	68.96	67.40	40.10
15-7-85	19.50	1.45	365.15	11.32	9.36	40.76	51.74	48.89	44.45	72.16	70.43	46.36
16-7-85	35.00	2.62	713.88	25.70	12.60	19.78	32.76	30.30	30.17	48.46	46.49	28.34
17-7-85	13.25	2.75	248.37	4.99	1.50	47.18	46.73	57.90	50.14	68.16	64.01	63.01
18-7-85	14.50	1.02	365.61	12.01	8.70	26.94	33.71	30.33	30.11	39.79	37.39	29.16
20-7-85	12.25	4.43	485.74	6.42	2.08	31.89	47.10	48.00	45.14	64.18	60.19	41.01
22-7-85	9.25	1.88	189.63	3.79	1.85	36.39	43.81	40.31	42.91	72.18	64.16	40.98
23-7-85	18.25	2.65	394.81	5.53	6.59	40.76	49.01	46.79	44.11	76.16	70.23	41.71
24-7-85	11.00	1.67	201.54	4.02	2.20	42.18	50.16	51.73	50.73	82.91	80.10	50.10
25-7-85	11.25	1.82	384.18	6.91	2.03	21.24	37.56	38.31	37.73	54.91	54.46	38.34
30-7-85	14.50	0.75	358.30	6.45	6.53	39.36	48.14	47.11	40.96	64.78	63.91	41.76
31-7-85	22.00	1.73	493.07	11.83	5.28	30.98	41.10	42.10	40.11	68.10	66.00	43.81

Appendix-III. Quantity and corresponding price of major eroded nutrients

	Quantity of major nutrient loss (kg/ha)			Equivalent amount of fertilizers (kg)			Corresponding price in Rs			
	N	P	K	Urea (45% N)	OSP (18% P_2O_5)	MOP (60% K_2O)	Urea	OSP	MOP	Total
1984										
T_1	330	92	570	733	1189	1145	1686	1189	1489	4364
T_2	395	120	697	878	1550	1400	2019	1550	1820	5389
T_3	14	8	18	31	181	36	71	181	47	299
T_4	345	101	563	767	1305	1131	1764	1305	1470	4539
T_5	173	49	321	384	633	645	883	633	839	2355
T_6	200	54	344	444	698	691	1021	698	898	2617
T_7	416	116	680	924	1499	1365	2125	1499	1775	5399
1985										
T_1	52	11	68	116	142	137	267	142	178	587
T_2	174	42	272	387	542	546	890	542	710	2142
T_3	4	1	7	9	13	14	21	13	18	52
T_4	139	31	203	309	401	408	711	401	530	1642
T_5	4	0	4	9	0	8	21	0	10	31
T_6	57	14	96	127	181	193	292	181	251	724
T_7	248	58	384	551	749	771	1267	749	1002	3018

Note: Cost of N in the form of Urea (45%) - Rs. 5.11/kg
Cost of P in the form of OSP (18%) - Rs. 12.92/kg
Cost of K in the form of MOP (60%) - Rs. 2.61/kg

AGROTECHNIQUES FOR SOIL CONSERVATION IN TAUNGYA SYSTEMS

By

R. GOPINATHAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Doctor of Philosophy in Agronomy

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
Kerala - India

1986

ABSTRACT

An experiment on 'Agrotechniques for soil conservation in taungya systems' was conducted at the Instructional Farm, College of Horticulture, Vellanikkara for a period of two years from May 1984 to April 1986. The main objectives of the experiment were to assess the run-off, soil and nutrient losses as influenced by the important taungya practices and to evolve economically and ecologically viable agro-forestry measures for soil conservation.

Eucalyptus, the main tree component, was intercropped with the usually cultivated taungya crops of cassava and rice. The efficiency of cassava planting on ridges, grass farming and grass stripping was also investigated. There were seven treatments replicated thrice in RBD. Daily run-off and soil loss were quantified by installing multi-slot device consisting of 47 slots and brick masonry settling tank specifically designed for the project.

Various rainfall characteristics were related vis-a-vis run-off and soil loss. It was found that run-off was highly correlated with the amount of rainfall ($r = 0.930^{**}$) closely followed by kinetic energy ($r = 0.912^{**}$) and AI_m ($r = 0.848^{**}$). Soil loss showed

maximum correlation with EI_{15} (r = 0.977**). A comparatively lesser correlation of run-off with soil loss (r = 0.790**) indicated that erosion was more influenced by rainfall characteristics than run-off.

Cultivated fallow plot produced the highest run-off of 1259 mm (53 per cent of the total rain) and soil loss of 352 t/ha/yr. Mound planting was very much deleterious irrespective of the cassava population. Rice taungya was comparatively harmless. Grass farming was more efficient than ridging in controlling soil erosion and run-off. It accepted more than 96 per cent of the rain and eroded only 0.40 t/ha of soil in the second year. Replacing 10 per cent of the cassava population with grass strips reduced soil erosion by 41 per cent than the maximum cassava treated plot within one year. Tree planting alone could reduce the soil erosion by 87 per cent in the second year.

The eroded soil was, in general, more clayey and contained more nutrients than the soil matrix especially during the initial months. Cultivated fallow plot had lost 416, 116, 680, 242, 878 and 299 kg/ha of N, P, K, Ca, Mg and S respectively. Such losses were 395, 120, 697, 183, 717 and 213 respectively in eucalyptus + five cassava on mounds, one of the most erosive treatments. Grass farming, irrespective of high fertilizer application, effectively reduced the above nutrient losses respectively to 4.0, 0.40, 4.0, 2.0, 0.70 and 0.10 kg/ha. Ridge planting of cassava was also comparable to grass farming in controlling nutrient drain.

Mound planting of cassava cultivation affected the soil physical characteristics. While grass, rice and zero cultivation improved them. Appreciable chemical changes were not manifested between treatments during the investigation period.

The most robust trees were observed in eucalyptus alone treatment. The weakest trees were seen with eucalyptus + five cassava on mounds. The highest net income of Rs. 10.12 thousand/ha produced by eucalyptus + grass combined with the complete control of soil erosion in the second year make this treatment the most ideal. However, the absence of a subsidiary food crop limits its adoption on a wider scale. When acceptability, profitability and sustainability are taken into account, the treatment eucalyptus + cassava + 10 per cent grass strips seems to be a better system.