EFFECT OF AGRO - TECHNIQUES ON SOIL LOSS, SURFACE RUNOFF AND SOIL MOISTURE STORAGE IN HILL SLOPES

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Effect of Agro-Techniques on soil loss, surface runoff and soil moisture storage in hill slopes" is a bonafide record of research work done by me during the course of research and 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.

(K.VISHWAMBHARAN)

Vellanikkara,
19th December 1980

C E R T I F I C A T E

Certified that this entitled "Effect of Agro-Techniques on soil loss, surface runoff and soil moisture storage in hill slopes" is a record of research work done independently by Shri.K.Viswambharan, under my guidance and supervison and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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C E R T I F I C A T E

We undersigned, members of the advisory committee of Shri. K.Viswambharan, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Effect of Agro-Techniques on soil loss, surface runoff and soil moisture storage in hill slopes " may be submitted by Shri.K.Viswambharan in partial fulfilment of the requirement for the degree.

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DEDICATED

to the memory of

Late Dr. U.P. BHASKARAN,

Former Director of Research,

Kerala Agricultural University

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Introduction

1. INTRODUCTION

Soil erosion is the greatest single menace facing Indian agriculture. Its effects are particularly noticed in areas where high rainfall intensities are experienced in short periods and where the terrain is undulating.

Although no systematic survey has been carried out in the country as a whole to determine the extent of erosion, some estimates have been made by some authorities which clearly indicate the gravity of the situation. In the first plan review it was observed that "about 200 million acres of land were exposed to the hazards of wind or water erosion and out of area actually under cultivation about 100 million acres are vulnerable to soil erosion" (Anon,1957). Mamoria (1976) reported that according to Mayedas no less than 123 million acres of land in India are in the process of either soil erosion or exhaustion caused by primitive methods of farming.

It has been estimated that the loss of soil through erosion of arable land is of the order of 6000 million tonnes a year with a total annual depletion of nitrogen of the order of 2.5 million tonnes valued Rs.1000 crores (Shenoi,1975). On an average about 10,000 hectares are being affected by erosion every year involving an average loss of about Rs.500 lakhs (Anon,1971).

Soil and water are two valuable gifts of nature which invariably determine the farm income. Loss of soil or water means loss of fertility which in turn is reflected in reduced yields. Conservation of these two vital sources will enable the farmer to utilise all the other production factors at the highest levels, thus ensuring a continuous higher level of production.

In Kerala it has been estimated that nearly 15 lakhs hectares are highly vulnerable to soil erosion hazards. Out of this only an area of about 70,000 hectares has so far been conserved under various soil conservation schemes. So the remaining 14.3 lakhs hectares require urgent soil conservation measures on a time bound programme (Anon,1980). According to an estimate by Balakrishna Pillai (1978) at least one third to one half of 19.66 lakh hectares are highly vulnerable to soil erosion hazards. The need for taking adequate steps to prevent erosion and to conserve the soil is therefore of paramount importance.

It is no exaggeration to say that about 50% of cultivation in Kerala is done on slopes which in most parts of the world would be considered unsuitable for cultivation. The worst form of soil erosion is therefore seen in this State. To understand the seriousness of erosion it is highly necessary to have an idea of the lie of the land in Kerala. Kerala is a narrow strip of land lying between the Arabian sea and the Western ghats. The western ghat region has an average height of about 500 ft, but some of its peaks rise to more than 8000 ft. At no place the land is more than 60 miles in width, average being about 35 miles. Coastal planes are hardly 2 or 3 miles in width except in certain backwater areas where it is slightly broader. The land then rises abruptly towards the mountain. Within the distance of about 30 miles the land rises to 5000 to 6000 feet height. The rainfall is very heavy being about 90 to 120 inches, some areas getting even as much as 200 inches spread over 6 or 7 months of the year (Nair,1958). The land is very undulating consisting of steep hills and hillocks with deep valleys and ravines cut cris cross by innumerable streams and rivers.

Kerala is very densely populated and the available land per capita is only 0.30 acre which is the lowest in India (Balakrishna Pillai,1978). Owing to the increasing pressure of population and the growing demand for land, a very large part of this steep and undulating land has been put under crops, either permanent tree crops or seasonal crops or both. Soil itself being lateritic in origin has very little binding material. The situation has been still aggravated by the cultivation of tapioca in the hill slopes.

Tapioca is cultivated in an area of about 3.29 lakhs hectares and its production being 53.9 lakhs tonnes (Ramakrishna Bhat, 1978). The loose soil is heaped into small mounds or long ridges. Then ridges and mounds are generally made along the slope because it is said to be less laborious to make them along the slope than across the slope. The land between ridges or mounds are left bare without any kind of cover and this encourages runoff and soil loss. During heavy rains a substantial amount of loose soil that is heaped up is washed down. Under such conditions if the limited land resources available are not properly looked after and conserved with the help of best known methods, the consequences would be very serious for the agricultural economy of the State.

Studies revealed that by the adoption of proper agronomic practices man can control soil and water losses to a great extent (Reddi, 1960). The agronomic practices for soil and water conservation have four principal objectives viz. (1) prevention of loss of fertile top soil. (2) Conservation of moisture by safe control and storage during periods of excess rainfall. (3) The restoration and maintenance of soil fertility (4) Better utilisation of soil fertility and moisture for increasing crop production.

The above objectives are sought to be achieved by suitable agronomic practices like contour cultivation, strip cropping, crop rotation, cover cropping, increasing the organic matter content of soil and application of manures and fertilizers. Practices like strip cropping and rotation have only very limited scope (Nair,1958). The engineering practices alone when applied fail to give best results. Combination of mechanical and agronomic practices always give emcouraging results (Reddi,1960).

In our country too much emphasis is being placed on bunds as a measure to hold soil and water. However, sufficient attention is not given for increasing infiltration of water between these bunds. Bunding should always be supplemented with the best possible agronomic practices, because bunds themselves do not improve soil fertility and when used alone they fail to hold the soil adequately (Reddi,1960). The agronomic practices greatly increase the water intake of the soil between bunds and reduce the amount of rain that reaches the bunds.

Tapioca is an eight to ten months crop and is planted during the periods of abundant rainfall either during June-July or September-October in Kerala. The initial growth rate of the crop is comparatively slow and it generally takes 2½ to 3 months to develop the full canopy. Further, tapioca is planted at a spacing of 75 to 90 cm. on both ways leaving considerable area unutilised during the early part of the crop growth. The heavy rainfall coupled with faulty methods of cultivation results in severe soil loss from the cultivated area during the early part of the crop growth.

Intercropping is a term that is being widely used by the agricultural scientists in recent years. It is a practice of intensive use of land to take two or more crops simultaneously each year. The system involves growing together two or more species of crops with the assumption that the two species could exploit the environment better than one. Intercropping as a method of reducing soil loss was suggested by Bhola et al. (1975). Groundnut was used as an intercrop to resist soil erosion by Lakshminarayana and Reddy (1972). Thus it was felt reasonable to test the feasibility of groundnut intercropping in tapioca in order to check the soil loss during the early part of the crop growth which also provides additional income to the farmer. The present investigation was therefore conducted with the following main objectives.

1. To assess the effects of various Agro-Techniques on soil loss and surface runoff.

2. To study the effects of various Agro-Techniques on subsoil and surface soil moisture storages.

3. To estimate the loss of nutrients through erosion under various Agro-Techniques.

4. To estimate the amount of retentive rainfall during the period of crop growth under various Agro-Techniques.

5. To assess the yield of tapioca and groundnut under various Agro-Techniques.

Review Of Literature

2. REVIEW OF LITERATURE

A brief review of the research conducted on soil erosion and the effect of intercropping on soil, water and nutrient losses is presented below.

2.1. Soil Erosion.

2.1.1. Definition of erosion and runoff

According to Bennet (1939) the vastly accelerated process of soil removal brought about by human interference with the normal disequilibrium between soil building and soil removal is designated as soil erosion. It can best be described as the theft of soil by the natural elements and is the removal of soil particles either singly or in mass (Gorie,1946). Ellison (1947) defined soil erosion as the process of detachment and transportation of soil materials by erosive agents viz. wind or water. As against soil formation soil erosion is a destructive process.

Eggar E. Foster (1948) defined runoff as all water that drain from the land areas by surface channels into which the water collects from overland flow or subterranean passages. Runoff is therefore water remaining from precipitation after losses from evaporation transpiration and seepage into ground cover. Runoff constitutes the lowest part of the hydrologic cycle.

2.1.2. Factors influencing soil erosion

It has been mentioned by Hudson (1977) that erosion arises from the effects of rainfall on soil and is determined by,

a) Erosivity - Specifically and solely a property of rainfall which can be quantitatively evaluated as the potential capacity of rain to cause erosion under given circumstances.

b) Erodibility - Specifically and solely a property of the soil which can be quantitatively evaluated as the vulnerability of the soil to erosion under given circumstances.

c) Management - A wide term covering all factors directly under man's control such as choice of land use, choice of crop, method of crop production down to details like plant population and manurial practices and

d) Landform - Which includes the length and steepness of slope and their shape and uniformity of shape.

2.1.2.1. Erosivity

According to Neal (1938) the percentage of runoff increased as the rainfall intensity increased, but at a decreasing rate. It was also found that the soil loss from a saturated soil increased as the 2.2 power of the rainfall intensity. Duley (1939) reported that rain drops are responsible for sealing the surface which prevents infiltration and storage of soil moisture. When rain drops hit the soil they have a dispersive action (Ellison,1947 ; McIntyre,1958 ; Yadav, 1961.). Free (1952) found that splash losses from elevated pans of bare soil were 50 to 90 times the runoff losses. He found that the average soil loss per inch of rain amounted from 5 to 7 tons per acre. Hudson (1957) suggested that rain drop impact and splashes were the major factors responsible for the initiation of runoff and soil loss. According to Ballal and Deshpande (1960) runoff and soil loss in the saturated condition of soil were generally higher than those caused by rains from air dry soil. Udai Kumar Yadav (1961) calculated the total energy of rain drops as being equal to roughly 100 H.P. on an acre during a rainfall rate of 0.1 inch/hr and 250 H.P. at a rainfall rate of 2 inches/hr. The latter force is sufficient enough to lift 7 inches of top soil layer to a height of 3 feet 86 times during a period of one hour, equivalent to 518 million foot pounds of work. He pointed out that this might be 1000 to 10,000 times the kinetic energy of the shallow sheets of runoff water that results from the same storm. About 95% of the soil loss in erosion process is due to the raindrop. Splash erosion is responsible for sheet erosion, puddle and fertility erosion. Lyles et al.(1969) found that wind driven rain considerably increased soil loss. Das and Rao (1974) found that splash erosion is increased with increasing antecedent moisture condition under same compaction. As the time of exposure is increased, the splash loss increased while rate of splash losses decreased very gradually. Mutchler and Young (1975) reported that raindrop splash was the primary agent in soil detachment and transport from interrill areas. Monke et al.(1977) stated that inter rill erosion rates increased when overland flow increased.

Ellison (1944) stated that splash erosion increased as the 0.65 power of the rainfall rate. Ekern and Muckenhirn (1947) reported that for a constant drop size and time, the amount of sand transported was directly proportional to the intensity of precipitation.

Mookerjee (1950) found that there was a high correlation between rainfall intensity and the amount of eroded soil. Storm erosivity varied exponentially with rainfall intensity (Ekern,1954 ; Tamhane et al. 1959). Exponential relationship between rainfall intensity and soil erosion was observed by Tamhane et al.(1959) and Bisal (1960). Free (1960) reported that the relationship between splash erosion losses for both sand and soil with energy value for rainfall were exponential and parabolic type. Rose (1960) observed that the rate of soil detachment per unit area was influenced by the momentum than the kinetic energy of the storm per unit area and time.

Wischmeier (1955) reported that combination of rainfall energy and quantity of rainfall was the important variable in effecting soil erosion. Wischmeier and Smith (1958) showed a close relationship between rainfall intensity and the total kinetic energy. Wischmeier (1959) found that the erosion index is the most precise single estimate of rainfall erosion potential. Wischmeier (1961a) also found that the relationship of soil loss from a fallow plot to EI values was linear but for the slope of the regression line for any set of data dependent on soil type and land slope. Hudson (1971) reported from his work in Rhodesia that the cumulative kinetic energy of storms greater than one inch/hr (KE>1) was more significantly correlated with soil loss than EI_{30} index. Experiments in the tropics indicated a lower correlation coefficient between EI_{30} index and soil loss than was obtained for the original experiments in U.S.A (Ahmad and Breckner, 1974). However, Lal (1976) reported a better correlation with the product of total rainfall amount and peak storm intensity (AIm) than either EI_{30} or KE > 1 indices.

Many field experiments revealed that correlation of soil loss with amount of rain in individual storms as well as with maximum amount falling in 5, 15 or 30 minute intervals was poor. However, the product of kinetic energy and maximum 30 minute intensity was most significantly correlated with soil loss (Wischmeier et al. 1958). Wischmeier's EI_{30} index had subsequently been extensively used in predicting soil loss. Das et al. (1967) reported that the rainfall energy was linearly related to rainfall amount. He found that EI value estimated with 30 minute maximum rainfall intensity was the best correlation with soil erosion as compared to 5 , 15 or 60 minute intensity product. Rogers et al. (1967) observed that the kinetic energy of rainfall calculated from rainfall intensity using the equation, $KE = 210.3 + 89 \log I$ (metre tonnes/ha.cm) was satisfactory.

The importance of raindrop energy in governing the amount of soil loss under fallow conditions is well documented (Ellison,1952 ; Wischmeier and Smith,1958 ; Young and Wiersma, 1973). Barnett (1958) found that maximum 60 minute intensity was closely related to soil erosion. Das et al.(1967) found that the use of EI_5 min. has been recommended for Nilgiris. Rambabu et al.(1969) found that for Dehra Dun EI_{30} values were significantly correlated with daily and monthly rainfall values. But the annual rainfall values were not significantly correlated with annual EI_{30} values. However, Dangler and Swaify (1975) observed that for most soil little or no erosion occured during the first 30 minutes of the first storm even when the simulated rainfall intensity was 6.4cm/hr. Sharma, et al. (1976) reported that irrespective of the nature of the crop, Splash losses were better correlated with kinetic energy of the storm than its erosion index.

2.1.2.2. Erodibility

The different erosion of two soils under similar environment and management conditions is attributed to their inherent soil characteristics. This property of the soil is referred to as soil erodibility. Erodibility involves those soil properties that effect infiltration rate, permeability and the changes with time that occur in those soil properties and others that determine the effects of dispersion, splashing, abrasion and transporting forces of rainfall and runoff. Structure and structural stability are closely related to this soil property, but are different to define in such a way that they provide a measure of erodibility (Lal, 1977). The various properties which affect detachability and transportability of soil involve particle size distribution, organic matter content, presence of cementing materials like Fe and Al oxides, nature of clay minerals and balance of cations on the exchange complex and properties which are themselves dependent on these such as permeability, soil structure and strength (Lal, 1977). He also pointed out that some other properties such as entrapped air may also be important.

Middleton and Buoycos as described by Mehta et al. (1963) used dispersion ratio as a measure of soil erodibility. Wischmeier et al. (1969) developed a soil erodibility monogram based on soil properties. Studies conducted by Romkens et al. (1974) indicated that particle size and the percentage of citratebicarbonate-dithionite (CDB) extractable Fe, Al and Si were significant prediction parameters of subsoil erodibility on high clay subsoils studied. Subsequent analysis of subsoil data per se yielded a prediction equation with a coefficient of determination $r^2 = 0.95$. Singer et al. (1974) studied the relative erodibility of surface soil (0-15cm) from 10 soil series and found that the observed erodibility of the soils was in an order different from the order predicted by the Wischmeier et al. monograph. Two soils with high exchangeable sodium were much more erodible than the monograph predicated and two which had high dithionite extractable Fe content were less erodible than the monograph predicted. Further studies indicated that exchangeable sodium percentage, dithionite extractable Fe and Al were additional useful indices in predicting the erodibility of those soils. However, Bruce-Okine and Lal (1975) found that erodibility was to vary directly with sand and inversely with clay content. Flow characteristics significantly influence the transportability (Lal,1977). Singh and Verma (1978) reported that runoff and soil loss increased with increase in the fineness of soil texture. Nema et al. (1978) reported that the soil erodibility factor K in the universal soil loss equation for the soil and climatic conditions of Vasad comes out to be 0.0592 tonnes/ha/unit of rainfall factor.

2.1.2.3. Management

The principles are well known as they are the same for all climatic zones. The importance of mulch or crop cover, the need for controlled flow of surface water, the association between efficient farming and good erosion control etc. need due consideration (Hudson,1976). However, because of greater erosivity of the climate in the humid tropics the maintenance of a cover over the soil assumes greater importance (Hudson, 1977)

Baver (1961) classified the major effects of vegetation on runoff and erosion into 5 distinct categories. They are (1) interception of rainfall by vegetative cover (2) decreasing the velocity and cutting action of runoff water (3) root effect in increasing granulation and porosity (4) biological activities associated with vegetative growth and their influence on soil porosity and (5) transportation of water leading to subsequent drying out of the soil.

Ellison (1947) reported that the soil detachment hazard was inversely proportional to the resistance factor of surface covers and mulches in reducing runoff velocity. The basis of soil and water conservation is the cover that protects land from the direct impact of raindrops and runoff water (Speer,1960). He also pointed out that the protective cover can to a great extent be a by-product of a crop production programme that results in consistently high yields of grain and oil seeds crops. Udai Kumar Yadav

(1961) reported that the secret of preventing erosion is to remove the energy of rain drops by vegetative shield. Adams (1966) reported that surface cover of straw reduced runoff and essentially eliminated erosion. Singer and John Backard (1978) reported that runoff volume was significantly reduced by high mulch cover levels which protected the soil from sealing and helped to maintain high infiltration rate.

Mulching is an effective mean to protect the soil surface from sealing under the impact of rain drops (Harrold,1947 ; Scheller and Evans,1954). McAlister (1957) reported that due to mulch farming there would be reduced damage from wind or water erosion. Mannering and Meyer (1963) reported that mulch application of 1,2 and 4 tonnes per acre maintained very high infiltration resulting in essentially no erosion. Taylor, et al. (1964) found that a mulch of corn stover and barn yard manure gave excellent control of soil and water losses from corn after corn on a steeply sloping deep loose soil. Vasudevaiah et al.(1965) reported that both runoff and soil loss from grain crops seemed to be mostly dependent on soil condition where as that from grasses seemed to be directly influenced by the rainfall. Wischmeier (1966) found that improved soil and crop management reduced average plot runoff by about 40 per cent.

Mannering *et al*.(1966) reported that the surface mulch which covered more than 95% of the soil surface had striking effect on both infiltration and soil loss. Soil loss was reduced to zero when straw mulch was applied at 2.0 tons/acre on a deep pervious soil with 5 per cent slope (Smith,1968). Lyles *et al*. (1974) indicated that soil detachment decreased with increased amounts of mulch cover. Harrold and Edwards (1974) observed that mulch of about 0.5 ton per acre on the surface of the no-tilled system was effective in reducing erosion. Megahan (1978) stated that erosion was reduced on an average of 75% by straw mulching.

Smith (1946) reported that crop cover desipates the energy of falling rain drops and develop a soil condition that will resist erosion. He classified crops into two groups viz. erosion resisting and erosion permiting. Martson (1952) concluded that the amount of ground cover is the most important variable influencing runoff and erosion under nonarable conditions. Hudson (1957) concluded that ground cover is almost entirely responsible for reducing runoff and erosion from grassed areas and the same effect can be achieved by any cover such as a surface mulch, dense maize crops or a good early green manure crop. He suggested that the effect of ground cover is primarily to dissipate rain drop energy. Natural covers and grasses were found to be effective in checking soil erosion (Gupta et al. 1963 ; Vasudevaiah et al. 1965). Vasudevaiah et al. (1965) concluded that among the four cultivated crops tried viz.gora paddy, urid,maize and peanut, peanut recorded the lowest runoff and soil loss. Gurmel Singh et al. (1967a) reported that groundnut gave minimum water loss and the fallow gave the maximum water loss. They have attributed the reason that the fallow provide no cover and hence no obstruction to the flow of water and therefore rainfall received is lost as runoff. Water cannot flow through groundnut easily and there is more time for absorption of water in the soil as a result of which there is less water loss. Again, soil loss was maximum under fallow since it does not provide protection against falling raindrops. They have concluded that groundnut was the best, since it recorded the minimum soil and water losses . However, work conducted by Battawar and Rao (1969) revealed that cowpea was the best for controlling erosion. Among the six cropping patternsviz. bajra, mung, kodra, tursundhia jowar and bidi tobacco and two cover treatments tried by Verma et al.(1968) cover treatments yielded minimum runoff and soil loss while cropping patterns gave soil loss values less than 7.5 tonnes/ha.per year with the exception of bidi tobacco which gave higher values in the same year.

Soil loss under bidi tobaco could be reduced by cover-cum-green manuring with sannhemp and the yield of tobaco was also increased by 16.7%. It was recommended that bidi tobaco should invariably be green manured to reduce erosion and obtain higher yields. Crops putting on the maximum growth during the monsoon indicate yields negatively correlated with runoff and soil loss. Misra et al. (1969) devised soil conservation methods for creating such conditions that more rain water would be absorbed and preserved into the soil, surface runoff would be minimised and excessive runoff would flow at a harmless speed. The best results are achieved if the land was kept covered under vegetation. Hudson (1971) suggested that soil erosion is proportional to the fraction of soil surface exposed to direct raindrop impact. Suraj Bhan and Misra (1971) reported that cultivation of errect groundnut variety A.K.K-24 in rows of 45 x 60 cm.apart considerably reduced soil erosion losses. Soil losses were further reduced by strip cropping with permanent grasses and by application of mulch after harvesting groundnut. Among the different crops tried by Bhola et al. (1975) runoff and soil loss were highest under maize and lowest under C.tetragonoloba suggesting that maize on slopes should be intercropped with a legume. Meyer et al. (1975) reported that canopy to dissipate rain drop impact energy decreased rill erosion to less than that without canopy cover and effectively eliminated inter rill erosion. Sharma *et al.* (1976) related storm energy dissipated to the crop canopy and there was a high positive correlation between splash erosion and effective storm energy expended on bare plots. He termed the fraction of kinetic energy of rainfall dissipated by a crop during its growth period as crop protection factor and it can serve as a reliable index of the crop's capacity to protect soil against splash erosion. *Vigna mungo* and *Cajanus cajan* groundnut mixture were most effective in checking splash erosion. Bhardwaj *et al.* (1978) observed a definite reduction in soil and water losses by increasing inter row spacing from 45 to 90cm and decreasing the intra row spacing from 40 to 20cm in maize. Their data indicated that plant geometry could help in reducing soil and water losses from agricultural fields. Lang (1979) observed that ground cover was found to affect both the occurance and magnitude of runoff. Increased amounts of cover resulted in curvilinear decrease in the average frequency of runoff, storm runoff yield, event depth and total average annual run off. 75% ground cover was found to be critical above which runoff increased rapidly.

Logan (1960a) derived the following conclusions from his work in Australia. (1) Runoff in cropped land is considerably greater than that where the land is used for grazing. (2) Standing wheat is not effective in reducing runoff, but stubble is very effective. (3) Antecedent moisture and percentage of cover are the most important factors influencing runoff from crop and pasture. Subsequently, Logan (1960b) reported the following results. (1) The soil loss from cropped land has been far in excess of that from grazing land. It has been roughly 30 times that from land not cultivated at all and 6 or 7 times that from land fallowed and sown to lucerne. (2) The fallow land gave the highest soil loss. (3) There were high erosion from cropped lands before the crop gave sufficient protection. (4) Erosion predisposes to further erosion. (5) The amount of heavy rains (more than one inch/hr) and amount of cover play a large part in determining the seriousness of soil loss. (6) As the amount of runoff governs to a large degree the amount of soil loss, the factor which increases the runoff will also increase soil loss.

Battawar and Rao (1969) observed that the crop protection factor values were high in the initial stages due to poor cover. As vegetative cover increased C-factor values decreased and soil loss was reduced. Walkinson (1975) while experimenting with cowpea found that the actual soil loss was greater than the predicted soil loss by the universal soil loss equation in the early part of the season and much less during the crop maturity. Thus cropping management factor consisted of a complexity of components which exert varied dominance on soil erosion during the season. Nema et al. (1978) reported that the crop management factor for mung, groundnut and cowpea were 0.465, 0.374 and 0.317 respectively.

Bennet (1939) reported that contour tilled sorghum plots gave an average grain yield of 589 lb/acre as against an average of 461 lb/acre on straight row tilled fields. In another experiment Gupta et al. (1963) reported that maximum water loss occured under bare fallow plots where as maximum soil loss occured under bare ploughed plots in a 9% slopy field. Cultivated fallow gave the maximum runoff and soil loss (Gurmel Singh et al. 1967b). Agarwal and Indira Pati Singh (1970) revealed that cultivation of cane on contour can save 23.6 inches of rainfall and 21.32 tonnes of soil from moderately slopy fields succeptible to erosion. Yield of cane planted on contour trenches followed by earthing during rain was increased to the extent of about 27%. Rao and Satyanarayana (1972) found that resistance of soil increased with compaction as a direct linear function. Gupta et al. (1975) reported that for potato-potato combination grown under up and down cultivation on 25% slope, cropping management and supporting conservation practice factors affecting runoff and soil loss were 0.563 and 0.400 respectively revealing that the potato-potato up and down method of cultivation did not control soil loss. John M. Tromble (1975) reported that increased roughness in microtopography provided additional detention storage resulting in decreased runoff when compared to the control. Significant increases in runoff were associated with bare soil. Crown cover and erosion pavement were significant in reducing runoff. Muller et al.(1978) found that mean rate of infiltration was lowest for no till sites resulting in highest mean runoff volume. Although mean sediment concentration in runoff was lowest for no till sites in May, greatest losses of sediment occured at these sites due to the higher runoff volumes. Greatest sediment loss during July occured at conventionally tilled sites due to higher sediment concentration and reduced infiltration rates relative to those during May. Khybri, et al. (1978a) reported that strip tillage reduced soil loss from 52 tonnes/ha to 40 tonnes/ha.

Williamson and Kingsley (1974) reported that cultivation across slope decreased runoff and erosion and it also increased the yield of maize and oats in the two year rotation. However, work conducted by James et al.

(1978) revealed that inward gradient of bench terraces gave less runoff and soil loss than the outward gradient of bench terraces for potato crop. The effect of direction of cultivation on bench terraces did not show marked result to warrant any conclusion. Bonde <u>et al</u>. (1978) reported that ridges across slope considerably reduced the runoff and soil loss over flat sowing in tobaco and cotton.

2.1.2.4. Land form

Cook (1936) reported that among the landforms, degree and length of slope were important controlling variables of water erosion process. However, Neal (1938) reported that the percentage of slope had no apparent effect on the percentage of runoff for slopes above one percent. Soil losses from a saturated soil increased as the 0.7 power of the slope. Mathematically the relation is $E \propto S^a$ where E is erosion, S the slope and 'a' an exponent. Zingg (1940) analysed the results of laboratory and field experiments and found a value for 'a' as 1.49. It was stated that doubling the degree of slope increased the total soil loss in runoff by 2.61 times. Doubling the horizontal length of slope increased the total soil loss in runoff by 3.03 times. Increasing the degree of slope increased the total runoff. Musgrave

(1947) used a=1.35 in the slope practice equation. However, Wischmeier (1966) observed that under normal field conditions runoff from row crops averaged a 10% increase for each additional per cent slope. He observed that the relationship between runoff and slope was found to be logarithmic. Hudson (1977) reported that erosion generally increased exponentially with increase in slope, the exponent for tropical soils approached 2 though it has been reported to vary between 1.3 and 2.1. Length of slope has a similar effect on soil loss as degree of slope. The build up of the amount of surface runoff, its velocity and depth on longer slopes increased erosion hazard. However, the relationship between slope length and erosion is complicated by the shape of the slope,viz. whether convex, concave, complex or regular. He found that in the case of irregular slopes, it is the steepest section of slope which may dominate the erosion.

2.1.3. Universal soil loss equation

Development of equations and relationships as an aid to calculation of field soil loss has been attempted by many (Zingg,1940; Smith,1941, Smith and Whitt,1947). The relationships developed were mainly for local use. There have been efforts to develop an equation or a system that could be applied universally whenever rainfall caused significant sheet and rill erosion. Musgrave (1947) made an effort to reevaluate the factors for better determination of soil loss by using the soil loss data collected by various research stations in U.S.A upto 1946. Wischmeier (1959) made major contribution to the prediction of soil loss by his studies on rainfall erosion index and evaluation of crop management factor. In 1961 he came out with the universal soil loss equation (Anon, 1961).

Numerical assessment of soil loss by water under a particular management practice can be achieved with the help of universal soil loss equation as described by Wischmeier and Smith (1965). It is defined as

$A = RKLSCP$ where,

A = computed soil loss per unit area.

R = Rainfall factor, the number of erosion index units in a normal year's rainfall. The erosion index is a measure of erosive force of specific rainfall.

K = Soil erodibility factor is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow on a 9% slope of 72.6ft long.

L = The slope length factor is the ratio of the soil loss from field slope length to that from a 72.6ft length on the same soil type and gradient.

S = Slope gradient factor is the ratio of the soil loss from the field gradient to that from a 9% slope.

C = Cropping management factor is the ratio of the soil loss from a field with specified cropping and management to that from the fallow condition on which the factor K is evaluated.

P = Erosion control practice factor is the ratio of the soil loss with the specific practice to that with straight row farming up and down the slope.

The science of soil conservation has advanced much with the introduction of the universal soil loss equation. Walkinson (1975) suggested that a non canopy factor had to be introduced in addition to the soil exposure factor to adequately substitute for the cropping management factor in the universal soil loss equation.

2.1.4. Nutrient losses through erosion

Eroded soils are richer than the original soil in respect of nutrients (Middleton et al. 1934; Rogers, 1941). Bobko (1943) during his studies on loss of nutrients by erosion observed that the losses are considerable and in some cases exceeded the annual crop removal. Erosion is found to be a selective process which decreases soil fertility (Stalling,1951; Massey and Jackson,1952 ;

Staltenberg and White,1953). Goel et al. (1968) found that nutrient losses in general were increased on steeper and longer slopes but the concentration of nutrients in the runoff is thereby decreased. Bonde et al. (1979) reported that ridges across the slope considerably reduced nitrogen losses by 50.9% and 45.8% over flat sowing in tobacco and cotton respectively.

2.1.5. Mechanical composition of eroded sediment.

Eroded soils are richer than the original soil in respect of colloidal clay (Middleton et al. 1934; Rogers,1941). Tamhane et al. (1959) while studying the intensity of rainfall on soil loss and runoff observed that soil lost in runoff is much more clayey as compared to the original soil and that clay and silt were the main constituents carried away by runoff water. Alberts et al.(1977) found that the inter rill erosion produced aggregates that were considerably smaller than those produced by rill erosion. Only 13% of the inter rill aggregates were larger than 0.5mm while 36% of the rill aggregates were larger than 0.5mm. Added rill flow to the top of the plot at rates ranging from 4 to 60kg/minute had little effect on the size distribution of rill aggregates.

2.2. Intercropping as a practice to resist erosion

Mirchandani (1958) reported that blackgram was used as an intercrop in Damodar Valley area to reduce soil loss. In another experiment Jain and Jain (1971) reported the beneficial effects of cowpea as an intercrop with maize in reducing loss of soil, water,nitrogen and phosphorus in Udaipur. Groundnut was considered as a soil conserving crop since it provided a good canopy cover in short periods. Lakshminarayana and Reddy (1972) reported that groundnut helped to cover the soil and prevent runoff in slopes when grown with shallow rooted and low water requiring crops like jowar or bajra. Bhola et al. (1975) suggested that maize on the contour should be intercropped with a legume to reduce runoff and soil loss.

2.3. Intercropping in cassava.

The practice of intercropping in cassava has been reported from Brazil as early as 1935. Singh et al.(1969) reported that the tuber yield of tapioca was not much affected by growing legumes like groundnut and cowpea as intercrops, but on the other hand gave an additional income. Beets (1975) reviewed the intercropping practice with tapioca in Indonesia and noted the intercropping was profitable than monoculture. Katyal and Dutta (1976) found that growing of groundnut and cowpea in between tapioca rows did not affect the normal yield of the main crop and was found to be very profitable. Sintuprama (1976) reported the practice of intercropping in tapioca in Thailand and found it profitable without affecting the growth and yield of the main crop. Mohankumar (1978) obtained best results with peanut as intercrop in cassava giving 25% more return than cassava monoculture.

Several workers have reported the beneficial and harmful effects of intercropping in cassava. Singh and Mandal (1968) noted that growing groundnut as inter crop in cassava did not substantially affect the growth and yield of the latter, but on the contrary provided additional gross income of Rs.1150/ha. Several workers found that groundnut grown with cassava did not affect the latter much (Singh et al. 1969 ; Singh and Mandal, 1970 and Katyal and Dutta, 1976). Singh et al. (1969) reported that groundnut and cowpea as intercrops with tapioca enriched the soil fertility by adding nitrogen through the organic matter added to the soil. From the income point of view groundnut was found to be a more profitable intercrop for cassava (Singh et al.1969).

Contrary to this, several workers have reported that growth and yield of tapioca was reduced considerably when intercropped with crops including groundnut (Anon 1960 ,Thamburaj and Muthukrishnan,1976). Similarly, Mohankumar and Hrishi (1973) reported a significant reduction in the tuber yield of tapioca by intercropping with groundnut. But in their trial the groundnut intercropped fields recorded the maximum returns which was significantly superior to all other crops tried.

Materials and Methods

3. MATERIALS AND METHODS

A field experiment was conducted at the Instructional Farm, Vellanikkara to study the effects of various agro-techniques on soil loss, surface runoff and soil moisture storage in hill slopes.

3.1. Materials.

3.1.1. Site and Soil

The Instructional Farm, Vellanikkara is situated at 10° 32"N lattitude and 76°10" longitude at an altitude of 22.25 metres.

The soil of the experimental area is deep, well drained, moderately acidic, sandy clay loam of lateritic origin and fairly rich in organic matter. The area having a uniform slope of 15.32% facing northeast was selected for laying out the experiment. The physical and chemical characteristics of the soil profile are given below.

3.1.1.1. Physical characters.

Depth	Characters
0 to 20 cm.	- Colour dark reddish brown (5Yr3/4), crumb structure, sandy loam, non

calcareous, well drained, abundant roots, gravels few, diffused boundary.

20 to 40 cm - Colour reddish brown (5Yr 4/4), non calcareous, well drained, few roots concretions of diameter upto 5mm present, partially weathered granitic boulders of different sizes present, no distinct boundary.

40 to 60 cm - Colour yellowish red (5Yr 4/6), sandy loam, crumb structure, noncalcareous, well drained, few roots, gravels of diameter upto 4mm present, partially weathered granitic boulders of different sizes present, diffused boundary.

60 to 80 cm - Colour light reddish brown (5Yr 6/4), sandy loam, compact non calcareous moderately drained, few roots, very few concretions, boulders as in the previous layer, irregular and broken boundary.

80 to 130cm - Colour pink (5Yr 7/3 compact, non calcareous, moderately drained ,roots absent, granitic boulders present, boundary not clear.

3.1.1.2. Mechanical composition and other properties of the top soil (0-15cm.)

Coarse sand	-	29.35%
Fine sand	-	21.32%
Silt	-	14.56%
Clay	-	30.14%
Loss on ignition	-	4.63%
Field capacity (0.3 atmosphere pressure)	-	19.23%
Permenant wilting percentage (15 atmospheres pressure)	-	13.32%

3.1.1.3. Infiltration rate

The infiltration rate of the experimental area as measured by doubles cylinder infiltrometer is given in Table 1.

The basic infiltration rate was observed to to 14.95 cm./hr. and the accumulated infiltration was 103.5 cm. over a period of 290 minutes. The average initial moisture of the soil upto 50 cms. was observed to be 18.53% when the infiltration rate was measured.

Table 1

Infiltration measurement of the experimental area.

Elapsed time (minutes)	Depth of water in the infiltrometer: Before filling (cm)	Depth of water in the infiltrometer: After filling (cm)	Infiltration rate (cm/hr.)	Accumulated infiltration (cm.)
0	0	11.0	--	--
5	4.6	11.0	76.8	6.4
10	4.9	11.0	73.2	12.5
15	5.2	11.0	69.6	18.3
25	1.7	11.0	55.8	27.6
40	2.7	11.0	33.2	35.9
60	3.8	11.0	28.8	43.1
90	1.0	11.0	20.0	53.1
130	0.3	11.0	16.05	63.8
170	1.0	11.0	15.0	73.8
210	1.1	11.0	14.85	83.7
250	1.1	11.0	14.85	93.6
290	1.1	11.0	14.85	103.5

3.1.1.4. Chemical characteristics of the soil profile

The chemical characteristics of the soil profile were studied and given in Table 2.

3.1.2. Climate

The area enjoys a humid tropical climate. The weekly averages of daily maximum temperature showed small fluctuations, the range for the entire period being 28.9°c to 36.8°c. The weekly averages of daily minimum temperature also showed small fluctuations, the range being 19.4°c to 26.7°c during the entire cropping season. The relative humidity also varied from 69% to 95% in the forenoon and 27% to 82% in the afternoon. The total rainfall received during the cropping season is 716.05mm occured in 55 rainy days. Most of the rains (540.25mm) were received during the first 11 weeks after planting. After this there were practically no rains for a period of about 17 weeks. Rains again started from the 29th week after planting. During these later periods there were 175.8mm of rain in about 14 rainy days. The weekly average of bright sunshine hours/day recorded during the cropping season varied from 0 to 5.3 hours per day. The sunshine was poor during the later part of the cropping season. The meteorological data during the period are presented in Fig 1 and Appendix I.

Table 2. Chemical characteristics of the soil profile

Sl. No.	Characters	Depth					
		0-20 cm	20-40 cm	40-60 cm	60-80 cm	80-100cm	100-120cm
1.	Total Nitrogen (%)	0.1032	0.0932	0.0642	0.0483	0.0338	0.0299
2.	Total Phosphorus (%)	0.04	0.045	0.035	0.035	0.03	0.03
3.	Total Potassium (%)	0.1125	0.1263	0.1093	0.0983	0.1031	0.0855
4.	Total Calcium (%)	0.20	0.21	0.21	0.21	0.21	0.19
5.	Total Magnesium	Traces	Traces	Traces	Absent	Absent	Absent
6.	Iron & Aluminium (%)	29.0	21.69	20.5	14.62	17.44	19.74
7.	Acid Soluble Salts (%)	70.96	78.56	75.25	76.8[illegible]	61.56	80.73
8.	T.S.S. (%)	0.15	0.13	0.40	0.12	0.11	0.11
9.	Organic Carbon (%)	1.26	0.58	0.34	0.15	0.12	0.08
10.	Available Phosphorus (ppm)	1.35	1.03	0.93	0.91	0.64	0.53
11.	Available Potassium (ppm)	100.3	105.5	98.3	75.6	66.8	50.8
12.	Exchangeable Calcium (ppm)	250.3	266.7	159.6	160.6	150.8	140.3
13.	pH	5.8	5.8	5.9	6.1	6.1	6.1

3.1.3. Season.

The experiment was conducted during the period from 17th September 1979 to 21st May 1980.

3.1.4. Cropping history.

The area was under rubber plantation before being utilized for the experiment. It was cleared during 1975 and put under bulk crop of tapioca till 1976. Thereafter it was kept uncultivated and infested with heavy weeds.

3.1.5. Varieties.

Tapioca variety M-4 and groundnut variety TMV-2 were used for the experiment.

3.1.6. Fertilizers.

Ammonium sulphate (20% N), Super phosphate (16% P_2O_5) and Muriate of potash (60% K_2O) were used to supply the required quantities of nitrogen, phosphorus and potassium respectively. Calcium oxide was used as the liming material.

3.2. Methods.

The experiment was conducted in uniform field runoff plots having a length of 24.3 metres and width of 2.7 metres. The plot edgings were done with embedded polythene sheets. The runoff from each plot was collected directly into water proof polyethylene lined earthen tanks having length of 2.7 metres, width of 1 metre and depth of 1.3 metres.

3.2.1. Treatments.

There were five treatments consisting of four cultivation methods and one uncultivated control.

T_1 - Tapioca alone in mounds.

T_2 - Tapioca in mounds of with groundnut as intercrop.

T_3 - Tapioca alone in ridges across the slope.

T_4 - Tapioca in ridges across the slope with groundnut as intercrop.

T_5 - Uncultivated bare fallow (control)

3.2.2. Lay out of the experiment.

The experiment was laid out in Randomised Complete Block Design with four replications. The lay out plan is shown in Fig 2.

3.2.3. Runoff and soil loss collection.

After each rain the runoff collected in the tanks were recorded. In order to determine the soil loss the runoff water was stirred thoroughly and a sample of 500ml was quickly taken for sediment calculation Balasubramanian (1979). Sufficient amounts of runoff were collected to obtain enough soil samples for chemical analysis. Gravimetric method was followed to measure the sediment present. Runoff was calculated in terms of millimetres of rainfall and soil loss in terms of kilograms per ha.

3.2.4. Analysis of rainfall.

Only rainfalls exceeding 12.5mm was taken for the study as erosion was negligible under lower rains. Since a simple expression of relationship between rainfall and erosion was desired, only those characters which can be taken directly from a recording rainguage chart were considered. For this purpose an automatic recording rainguage was installed at the centre of the experimental site. The rainguage chart observations were checked with an 122mm ordinary rainguage. The recording rainguage chart was used for studying the following specific characters and factors of rainfall.

1. Amount of rainfall in centimeters.
2. Maximum rainfall intensites in cm./hr. for 5,15, 30 or 60 minutes intervals.
3. The total kinetic energy of rain storms was calculated as per the equation given by Wischmeier and Smith (1958). According to them, the kinetic energy is given by

   $E_k = 210.3 + 89 \log I$ where,

Ek is the kinetic energy in metre tonnes per ha.cm of rainfall and I is the rainfall intensity in cm/hr.

4. The kinetic energy thus obtained was multiplied by the maximum intensity recorded during 5,15,30 or 60 minutes intervals. The erosion indices thus obtained were termed EI_5 , EI_{15} , EI_{30} and EI_{60} respectively. Where E is the kinetic energy and I_5 , I_{15} , I_{30} and I_{60} were the rainfall intensities.

5. The cumulative kinetic energy of storms with intensities more than 2.5 cm/hr. (KE > 1) was recorded (Hudson,1971).

6. The product of total amount of rainfall and the peak storm intensity (AIm) was calculated for each storm (Lal,1976).

3.2.5. Surface and subsoil moisture storages

The soil moisture stored at depths of 5cm, 15cm, 30cm, 45cm, 60cm, 75cm, 90cm and 105 cm of the soil profile was measured at fortnightly intervals using neutron scattering probe. 0 to 22.5 cm layer was taken as surface soil and 22.5 to 112.5cm layer as subsoil. The moisture measured was converted to mm of water for determining the soil moisture storages.

3.2.6. Field culture

3.2.6.1. Preparation of main field

The field was tilled (except the control plot) with a spade and ridges and mounds were taken as per the treatments. Polyethelene lined earthen tanks were constructed at the lower end of each plot for the collection of runoff.

3.2.6.2. Liming and fertilizer application

Liming and fertilizer applications were done as per the package of practices recommendations of Kerala Agricultural University (Anon,1978.)

3.2.6.3. Planting and spacing

Tapioca and groundnut were planted in the appropriate plots on 17.9.79. The spacing used for tapioca was 90cm x 90cm and that for groundnut was 15cm x 15cm. In the ridges groundnut was planted on both sides of the ridges and in mounds it was planted around the mounds. The population of groundnut was maintained constant in both the cases.

3.2.6.4. Plant protection

Groundnut was given a prophylactic spraying with Dithane M-45 and malathion ~~30~~ 61 days after planting for controlling the pests and diseases. No plant protection measures were taken for tapioca as it was free from pests and diseases.

3.2.6.5. Weeding and earthing up.

Hand weeding and earthing up were done 30 days after planting.

3.2.6.6. Harvesting

Groundnut was harvested on 21.12.79 when it was 96 days old. Tapioca was harvested on 21.5.80 when it was 247 days old.

3.2.7. Observations

The following observations were recorded for tapioca and groundnut.

3.2.7.1. Observations for tapioca

Biometric observations of tapioca were recorded from a sample of 10 plants from each plot selected and tagged at random and their averages were determined for each character. Subsequent observations were taken from the same plants at monthly intervals.

a) Total number of leaves per plant

The total number of leaves produced by the plant at the time of observation was recorded.

b) Number of functional leaves per plant

The number of green leaves present in each plant at the time of observation was recorded.

c) Height of plant

The height of plant from the bottom to the terminal bud was recorded.

d) Canopy diameter of plant

The canopy diameter of the plant was determined as the average of the two measurements taken north-south and east-west.

e) Yield of tapioca tubers.

The fresh weight of tapioca tubers was recorded.

f) Yield of tops.

The fresh weight of tops was recorded. A sample was dried for determining the dry matter percentage and this was used for finding out the harvest index.

g) Harvest index.

The harvest index was calculated using the following equation.

$$\text{Harvest index (\%)} = \frac{\text{Dry weight of tuber}}{\text{Dry weight of tops+ tuber}} \times 100$$

3.2.7.2.. Observations of groundnut

Biometric observations of groundnut were taken from 25 plants selected and tagged at random from each plot and the averages were determined. Subsequent observation were taken from the same plants at monthly intervals. The following observations were taken

a) Height of plants

The height of the plants from the soil level to the highest point of plant was recorded.

b) Number of functional leaves per plant

The total number of green leaves present at the time of observation was noted.

c) Number of branches per plant

The number of branches present in each plant at the time of observation was recorded.

d) Number of pods per plant

The number of pods present in each plant at the time of harvest was recorded.

e) Number of pegs per plant

The number of pegs (including pods) at the time of harvest was recorded.

f) Yield of pods

The yield of pods from each plot was recorded after rejecting yields from the four outer rows.

g) Yield of bhusa

The yield of bhusa from each plot was recorded as above after rejecting four outer rows.

h) Harvest index

The harvest index was calculated using the following equation.

$$\text{Harvest index (\%)} = \frac{\text{Dry weight of pods}}{\text{Dry weight of pods + bhusa}} \times 100$$

3.2.9. Chemical analysis

The total nitrogen, total phosphorus and total potassium contents of runoff sediment was determined by methods given by Jackson (1958). The dissolved nitrogen in runoff was neglected as it was found to be very low. Total nitrogen content of sediment was determined by macrokjeldahl's method. The phosphorus content of runoff sediment was determined colorimetrically using vanedomolybdo phosphoric yellow colour method in nitric acid system. The Perkin-Elmer-UV-Vis microcomputor controlled spectrophotometer was used for reading the colour intensity. The potassium was determined flame photometrically using Corning - Eel flame photometer.

The available phosphorus through runoff was determined using the procedure suggested by Jackson (1958). The sum of water soluble and pH_3 extractible phosphorus was considered as available phosphorus in runoff.

The available potassium was also determined as per the method suggested by Jackson (1958). The sum of water soluble and neutral normal ammonium acetate extractible potassium was considered as available potassium in runoff.

The pH of the runoff sample was determined using systronics needle type pH meter. The electrical conductance of the runoff was determined using Elico digital conductivity bridge. The water samples were immediately used after collection for determination of pH and conductance.

3.2.9. Mechanical analysis.

Mechanical analysis of the runoff sediment was conducted by the pipette method as reported by Piper (1942).

3.2.10. Statistical analysis.

The data obtained were subjected to statistical analysis by the analysis of variance technique as suggested by Snedecor and Cochran (1967). Correlations and regressions were found out utilizing the data from the control plot for predicting soil loss under varying rainfall conditions.

Results and Discussion

4. RESULTS AND DISCUSSION

The results and discussion of the present investigation are presented in the following text with the help of suitable tables and figures.

4.1. Relationship of runoff and soil loss with various rainfall characteristics.

The data on runoff and soil loss were collected from uncultivated bare fallow runoff plots of 15.32% slope and size of 24.3M length and 2.7M width. Simple correlations and regressions were worked out between runoff/soil loss and various rainfall characteristics such as amount of rainfall, average intensity of rainfall, EI_5 index, EI_{15} index, EI_{30} index, EI_{60} index, total kinetic energy of rainfall, $KE > 1$ and AIm index. The data are presented in Table 3 and Fig 3 and 4. These relationships followed a pattern of $y = a + bx$.

In the case of runoff maximum correlation was obtained with AIm index ($r = 0.962$). This was closely followed by EI_5 index ($r = 0.960$). The correlation coefficient of runoff with various rainfall parameters were significant at one per cent level except the average intensity in which case it was not significant even at

Table 3. Relationship between rainfall characteristics and erosion.

Sl. No.	Relationship between: Independent variable (x)	Dependant variable (y)	Number of observations (n)	Coefficient of correlation (r)	Regression equation
1	2	3	4	5	6
1.	Amount of rainfall (mm)	Runoff (mm)	18	0.8590**	$y = 0.5649^{**}x - 6.0132$ ($r^2 = 0.738$)
2.	-do-	Soil loss (kg/ha.)	18	0.7250**	$y = 333.839^{**}x - 5139.15$ ($r^2 = 0.526$)
3.	Average Intensity (cm/hr.)	Runoff (mm.)	18	0.3052	..
4.	-do-	Soil loss (kg/ha)	18	0.3582	..
5.	EI_5 Index (metric units)	Runoff (mm)	18	0.9599**	$y = 0.23 x + 2.0348$ ($r^2 = 0.921$)
6.	-do-	Soil loss (kg/ha)	18	0.9399**	$y = 157.656^{**}x - 1130.398$ ($r^2 = 0.883$)

(Contd.)

Table 3. (contd.)

1	2	3	4	5	6
7.	EI_{15} Index (metric units)	Runoff (mm)	18	0.8956**	$y = 0.2498x + 2.6073$ ($r^2 = 0.794$)
8.	-do-	Soil loss(kg/ha)	18	0.9769**	$y = 192.972^{**}x - 1375.93$ ($r^2 = 0.954$)
9.	EI_{30} Index (metric units)	Runoff (mm)	18	0.8526**	$y = 0.2441^{**}x + 3.5049$ ($r^2 = 0.727$)
10.	-do-	Soil loss (kg/ha)	18	0.9761**	$y = 195.745^{**}x - 871.668$ ($r^2 = 0.953$)
11.	EI_{60} Index (metric units)	Runoff (mm)	18	0.9194**	$y = 0.4839^{**}x + 2.33$ ($r^2 = 0.845$)
12.	-do-	Soil loss (kg/ha)	18	0.9591**	$y = 353.518^{**}x - 1271.012$ ($r^2 = 0.92$)

(Contd.)

Table 3. (contd.)

1	2	3	4	5	6
13.	Total Kinetic Energy of rainfall (metre tonnes/ha)	Runoff (mm)	18	0.8829**	$y = 0.0208^{**}x - 4.326$ ($r^2 = 0.78$)
14.	-do-	Soil loss (kg/ha)	18	0.7639**	$y = 12.614^{**}x - 4352.82$ ($r^2 = 0.584$)
15.	KE 1 (metre tonnes/ha)	Runoff (mm)	18	0.8909**	$y = 0.0224^{**}x + 0.94$ ($r^2 = 0.794$)
16.	-do-	Soil loss (kg/ha)	18	0.9119**	$y = 16.07^{**}x - 2162.23$ ($r^2 = 0.832$)
17.	AIm (units)	Runoff (mm)	18	0.9617**	$y = 0.6297^{**}x + 1.2316$ ($r^2 = 0.925$)
18.	-do-	Soil loss (kg/ha)	18	0.9207**	$y = 422.145^{**}x - 1548.77$ ($r^2 = 0.848$)

** Significant at 1 per cent level.

5 per cent level. The prediction equations were also worked out under the existing conditions of length and gradient factors and presented in Table 3.

In the case of soil loss maximum correlation was obtained with EI_{15} index (r = 0.977). This was closely followed by EI_{30} index (r = 0.976). The correlation coefficient of soil loss with various rainfall characteristics were significant at one per cent level except average intensity. In the case of average intensity it was not significant even at 5 per cent level. Prediction equations of soil loss were also worked out and presented in Table 3.

According to Wischmeier (1959) erosion index value (EI_{30}) is the most precise single estimate of rainfall erosion potential. This was based on the data collected from various stations in U.S.A. Workers in India have found that in Dehra Dun EI_{30} explained 54% of variation in soil loss where as in Ootacamund EI_5 was found to be superior to EI_{30} index (Khybri <u>et al</u>. 1978). In the present study AIm index best explained the runoff closely followed by EI_5 index. But in case of soil loss EI_{15} best explained the soil loss closely followed by EI_{30} index. Such variations were also observed by earlier workers in other places (Wischmeier, 1959). This can be attributed to the peculiar characteristics of rain fall and soils occuring in these areas.

Soil loss was correlated with runoff (r=0.359) also. But the correlation coefficient was less than that of other erosion indices indicating thereby that runoff alone is not the single parameter determining soil loss. Detachment and transportation of soil particles are affected by various other factors also. Soil loss was found to be more correlated with erosion indices. Regression equation between soil loss (y) in kg/ha. and runoff (x) in mm was found to be as $y = 601.19\ x - 1694.95$. The relationship is shown in Fig.5

4.2. Runoff loss under different treatments

Runoff observed in different treatments during the occurence of different rainfalls are presented in Table 4. The total runoff observed are given in Table 6 and Fig 6. Sufficient rainfall did not occur upto one month after planting to assess the degree of runoff in the intercropped fields during the early periods. In all the rains maximum runoff was observed under uncultivated bare fallow runoff plots which was significantly higher over the other plots. This can be attributed to the direct impact of falling rain drops which puddle the soil surface and prevents infiltration thus promoting more runoff

Table 4. Surface runoff* as affected by different treatments and dates of rainfall (10^{-3} mm)

Dates of observation	26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Treatments	1	2	3	4	5	6	7	8	9
T_1	380.0 (2.575)	3747.5 (3.534)	7037.5 (3.847)	2965.0 (3.451)	1760.0 (3.245)	1870.0 (3.271)	2120.0 (3.321)	4612.5 (3.658)	1727.5 (3.233)
T_2	332.5 (2.495)	5302.5 (3.701)	5937.5 (3.768)	2170.0 (3.327)	965.0 (2.978)	525.0 (2.710)	380.0 (2.577)	1122.5 (3.048)	295.0 (1.515)
T_3	245.0 (2.374)	972.5 (2.982)	1682.5 (3.219)	852.5 (2.882)	1140.0 (3.053)	142.5 (2.067)	410.0 (2.606)	790.0 (2.897)	250.0 (2.018)
T_4	197.5 (2.243)	900.0 (2.947)	1060.0 (2.947)	462.5 (2.640)	562.5 (2.702)	47.5 (1.520)	280.0 (2.444)	260.0 (2.404)	10.0 (1.000)
T_5	352.5 (2.502)	6875.0 (3.544)	9405.0 (3.972)	4865.0 (3.686)	4260.0 (3.628)	4060.0 (3.605)	3552.5 (3.546)	7512.5 (3.888)	2902.5 (3.461)
SEm ±	(0.076)	(0.167)	(0.085)	(0.082)	(0.056)	(0.110)	(0.040)	(0.047)	(0.318)
CD.(0.05)	N.S.	(0.514)	(0.263)	(0.252)	(0.172)	(0.339)	(0.124)	(0.144)	(0.980)

(Contd.)

Table 4.(Contd.)

Dates of observation	16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Treatments	10	11	12	13	14	15	16	17	18
T_1	6910.0 (3.829)	2210.0 (3.317)	3932.5 (3.583)	7117.5 (3.844)	30702.5 (4.487)	6532.5 (3.814)	395.0 (2.593)	15575.0 (4.190)	937.5 (2.949)
T_2	3747.5 (3.548)	687.5 (2.670)	925.0 (2.935)	1862.5 (3.262)	13055.0 (4.110)	5390.0 (3.731)	347.5 (2.513)	10690.0 (4.029)	587.5 (2.708)
T_3	1832.5 (3.262)	287.5 (1.866)	997.5 (2.996)	1150.0 (3.046)	8375.0 (3.891)	2695.0 (3.429)	150.0 (2.036)	4722.5 (3.626)	130.0 (2.109)
T_4	1865.0 (3.267)	297.5 (1.830)	997.5 (2.993)	1050.0 (3.011)	4260.0 (3.606)	2502.5 (3.398)	202.5 (2.271)	2407.5 (3.344)	172.5 (2.191)
T_5	1535.0 (4.185)	12870.0 (4.096)	7847.5 (3.893)	12202.5 (4.084)	48190.0 (4.683)	7810.0 (3.891)	3525.0 (3.544)	36512.5 (4.562)	4525.0 (3.652)
SEm ±	(0.040)	(0.269)	(0.045)	(0.53)	(0.058)	(0.018)	(0.113)	(0.063)	(0.092)
C.D.(0.05)	(0.123)	(0.828)	(0.139)	(0.164)	(0.177)	(0.056)	(0.349)	(0.196)	(0.282)

* Figures in brackets are logarithms.

(Mamoria,1976).

On critical examination of individual rains it was observed that maximum runoff (48.19mm) in a single event had taken place in bare fallow runoff plots (T_5) under a rainfall of 76.5mm where as minimum runoff (0.01mm) in a single event was observed in treatment T_4 under a rainfall of 26.0mm. The percentage of runoff under individual rainfall events are given in Table 11. Maximum percentage of runoff from a single rainfall event occured in bare fallow runoff plots (63.3%) under a rainfall of 12.5mm. This plots again registered a runoff of 63% under rainfall of 76.5mm. Minimum pe¢centage of runoff in a single event (0.04%) was recorded in T_4 under a rainfall of 26mm. One month after planting the inter cropped plots (T_2 and T_4) recorded less runoff than the corresponding non intercropped plots (T_1 and T_3 respectively).

On examination of total runoff before the harvest of the intercrop it was observed that intercropped fields recorded significantly lower runoff than the corresponding non intercropped fields irrespective of ridge or mound method of cultivation. Similarly, after the harvest of intercrop also intercropped fields recorded significantly lower runoff than the corresponding non intercropped fields.

The maximum total runoff during the entire cropping season was observed in bare fallow runoff plots (193.02mm) which was significantly higher over the other plots. This was followed by T_1 ie, tapioca in mounds without intercrop (100.43 mm) which was significantly higher over T_2 ,T_3 and T_4. Intercropped plots (T_2 and T_4) recorded less runoff than the corresponding non intercropped plots (T_1 and T_3). It is also revealed that ridges across the slope significantly reduced runoff than the mound method of cultivation. The reason for the less runoff in intercropped fields before the harvest of intercrop may be attributed to the following seasons. (1) Interception of rainfall by vegetative cover and thereby resisting the puddling action of rain drops. (2) Root effect in increasing granulation and porosity. (3) Biological activities associated with vegetative growth and their influence on soil porosity and (4) Transportation of water leading to subsequent drying out of the soil. All the above factors increase infiltration and reduce runoff (Baver,1961). Lang (1979) also found that ground cover affects both the occurence and magnitude of runoff and increased amounts of ground cover resulted in curvilinear decrease in runoff. In the present study the granulation and porosity effects brought about by the legume intercrop were sustained in the field even after the harvest of the intercrop resulting in high infiltration capacity of soil which had reflected in the low runoff in these plots even after the harvest of intercrop. Ridges across slope was effective in reducing runoff. The runoff were collected in between the ridges and the ridges prevented it from running away. It also prevented the build up of runoff. This resulted in low runoff from ridged plots. This is similar to the findings of Williamson and Kingsley (1974) who reported that cultivation across the slope decreased runoff and soil loss.

4.3. Soil loss under different treatments

The soil loss observed in different treatments under different rainfall during the period of investigation are presented in Table 5. The loss of soil before and after the harvest of the intercrop and total soil loss during the season are given in Table 6 and Fig 6. In T_1 (tapioca in mounds alone) the soil loss under different rainfall ranged from 75.0 to 12989.4 kg/ha, in T_2 (tapioca in mounds with groundnut) from 44.28 to 3973.63 kg/ha, in T_3 (tapioca alone in ridges across the slope) from 48.15 to 1500.78 kg/ha, in T_4 (tapioca in ridges across the slope with groundnut) from 33.5 to 1120.5 kg/ha. and in T_5 (uncultivated bare fallow) from 109.53 to 34413.59 kg/ha. It is also seen that during all the reins maximum soil loss

Table 5. Soil loss* (kg/ha.) as affected by different treatments and dates of rainfall.

Dates of observation	26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Treatments	1	2	3	4	5	6	7	8	9
T_1	100.38 (1.966)	352.45 (2.531)	572.43 (2.750)	677.23 (2.777)	207.63 (2.314)	94.28 (1.961)	277.18 (2.406)	1799.75 (3.079)	92.43 (1.923)
T_2	44.28 (1.603)	275.03 (2.417)	393.18 (2.574)	323.88 (2.509)	118.40 (2.054)	87.23 (1.917)	54.45 (1.717)	218.50 (2.333)	58.98 (1.730)
T_3	59.79 (1.607)	113.95 (2.049)	261.05 (2.410)	238.98 (2.363)	131.75 (2.115)	110.78 (2.025)	48.15 (1.665)	222.28 (2.286)	62.25 (1.791)
T_4	60.13 (1.708)	80.83 (1.893)	191.48 (2.268)	200.43 (2.286)	102.4 (2.009)	84.98 (1.907)	60.75 (1.745)	205.9 (2.304)	50.85 (1.680)
T_5	109.53 (2.037)	1215.65 (3.0537)	1482.93 (3.138)	871.40 (2.910)	733.50 (2.777)	319.05 (2.399)	699.33 (2.790)	4987.85 (3.676)	403.03 (2.559)
SEm ±	(0.155)	(0.078)	(0.0507)	(0.063)	(0.083)	(0.080)	(0.096)	(0.096)	(0.059)
C.D (0.05)	N.S.	(0.240)	(0.153)	(0.195)	(0.256)	(0.247)	(0.297)	(0.297)	(0.1827)

(contd.)

Table 5. (contd.)

Dates of observations	16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Treatments	10	11	12	13	14	15	16	17	18
T_1	1786.18 (3.091)	279.73 (2.246)	1126.23 (2.900)	3266.33 (3.437)	12889.4 (4.077)	195.75 (2.281)	75.00 (1.851)	8453.65 (3.845)	1908.05 (3.117)
T_2	114.5 (2.054)	59.35 (1.733)	80.50 (1.877)	102.28 (2.000)	713.90 (2.834)	105.93 (2.010)	63.40 (1.779)	3873.63 (3.474)	223.35 (2.342)
T_3	112.63 (2.031)	53.63 (1.687)	97.13 (1.967)	106.88 (2.012)	670.03 (2.813)	80.88 (1.905)	48.35 (1.627)	1500.78 (3.163)	231.73 (2.312)
T_4	71.50 (1.853)	80.33 (1.876)	68.48 (1.798)	108.63 (2.018)	379.75 (2.547)	68.95 (1.831)	33.50 (1.516)	1120.50 (3.033)	215.10 (2.330)
T_5	3249.45 (3.498)	794.2 (2.895)	1730.6 (3.183)	3759.70 (3.486)	19174.6 (4.266)	557.10 (2.743)	201.50 (2.301)	34413.58 (4.536)	2701.65 (3.403)
SEm ±	(0.097)	(0.093)	(0.078)	(0.068)	(0.033)	(0.042)	(0.091)	(0.102)	(0.109)
C.D.(0.05)	(0.300)	(0.287)	(0.240)	(0.209)	(0.102)	(0.129)	(0.281)	(0.315)	(0.336)

* Figures in brackets are logarithms.

occured under bare fallow runoff plots. This can be attributed to the direct effect of rain drop splashes. This is similar to the findings of Free (1952) who found that splash losses from elevated pans of bare soil were 50 to 90 times the runoff losses. The total soil loss during the season was also highest under bare fallow runoff plots which was significantly higher over the other treatments. This indicates clearly that vegetation decreases soil loss as it resists the direct impact of raindrops through their canopy effects. This is in agreement with the findings of Ellison (1947) who reported that soil detachment hazard was inversely proportional to the resistence factor of surface covers and mulches in reducing runoff velocity. In T_2 (tapioca in mounds with intercrop) the soil loss one month after planting was significantly lower than that of T_1 (tapioca in mounds alone). Similarly in T_4 (tapioca in ridges across the slope with intercrop) also soil losses in most of the cases were lower than that of T_3 (tapioca alone in ridges across the slope). This suggests that intercropping of groundnut significantly reduces soil loss irrespective of the method of cultivation. This may be partly due to its effects on decreasing on the amount of runoff and partly due to the effect of crop canopy which resists the action of raindrop splashes. This result is in agreement with the findings

Table 6. Runoff and soil loss as affected by different treatments before and after harvest of intercrop.

	Runoff (mm)*				Soil loss (kg/ha)**		
	Before harvesting intercrop	After harvesting intercrop	Total	% of Total rainfall	Before harvesting intercrop	After harvesting intercrop	Total
T_1	76.99 (4.895)	23.44 (4.370)	100.43 (5.001)	14.682	23521.6 (4.323)	10632.5 (3.950)	34154.1 (4.484)
T_2	37.31 (4.570)	17.02 (4.230)	54.32 (4.7347)	7.941	2644.5 (3.418)	4266.3 (3.545)	6910.8 (3.801)
T_3	19.13 (4.275)	7.69 (3.866)	26.82 (4.419)	3.921	2289.2 (3.348)	1861.9 (3.259)	4151.1 (3.609)
T_4	12.25 (4.082)	5.29 (3.714)	17.54 (4.238)	2.564	1746.4 (3.235)	1438.1 (3.146)	3184.5 (3.494)
T_5	140.65 (5.148)	52.37 (4.719)	193.02 (5.286)	29.217	39530.8 (4.578)	37873.3 (4.577)	77404.1 (4.882)
C.D.(0.05)	(0.075)	(0.110)	(0.079)	0.840	(0.127)	(0.274)	(0.157)
SEm ±	(0.024)	(0.036)	(0.026)	0.273	(0.041)	(0.089)	(0.051)

* Figures in brackets show values of 10^{-3}mm converted to logarithms for analysis.

** Figures in brackets show logarithms of soil loss in kg/ha.

of Speer (1960) who suggested that the basis of soil and water conservation is the cover that protects the land from the direct impact of raindrops and runoff water. Udai Kumar Yadav (1961) also reported that the secret of preventing erosion is to remove the energy of the falling rain drops by vegetative shield.

The data on soil losses before and after the harvest of intercrop are given in Table 6. It is seen that soil losses were significantly lower in the intercropped fields than the corresponding non intercropped fields before and after the harvest of intercrop. This may be due to the high infiltration occuring in these fields as a result of the intercrop. The effect of the intercrop in increasing granulation and porosity might have persisted even after the harvest of intercrop. This is in agreement with the findings of Baver (1961). Ridges across the slope were also effective in reducing soil loss. This may be due to its effect on reducing runoff as discussed earlier.

The total soil loss during the cropping season from uncultivated bare fallow was 77.4 tonnes/ha which was significantly higher than that of the other plots. Among the different cultivation techniques maximum soil loss was registered from T_1 (tapioca alone in mounds) being 34.15 tonnes/ha which was significantly higher than that of the other treatments. In the corresponding intercropped field (T_2) the soil loss was only 6.9 tonnes/ha. Similarly, while the treatment where tapioca was planted in ridges across the slope without intercrop (T_3) registered a soil loss of 4.15 tonnes/ha the corresponding intercropped field (T_4) registered a soil loss of only 3.18 tonnes/ha. The reasons for the lesser soil losses in intercropped fields were discussed earlier.

4.4. Mechanical composition of runoff sediment.

Mechanical composition of runoff sediment was found out for different treatments and periods of observation and the data are given in Table 7. The mechanical composition of sediment varied only slightly between different treatments. But the runoff during highly intensive rainfall contained more sand in the control plots (T_5) as well as in the plots where tapioca was cultivated in mounds. The amount of silt and clay were correspondingly low. All the other treatments were on par. The high amount of sand content may be attributed to the high sediment carrying capacity of runoff during heavy rains. The data on weighted mean percentage of sand, silt and clay pooled over different rainfalls are presented in Table 10. Maximum sand content (57.4%) was registered by T_5 (uncultivated bare fallow) followed by T_1 (tapioca in mounds without intercrop). All the other treatments were on par. As explained earlier the high content of sand in T_5 and T_1 may be due to high runoff observed resulting in high sediment carrying capacity.

4.5. Nutrient content and nutrient loss through erosion.

The data on total nitrogen, total phosphorus, total potassium contents of runoff sediments under different treatments and periods of observation are given in Table 7. The data indicated only small variations which were not consistent to explain. Hence their weighted mean percentage pooled over different periods of observation are presented in Table 10. Maximum nitrogen content was registered by T_5 and T_2 (0.14%) and minimum content by T_1 (0.128%). In the case of total phosphorus, maximum content was registered by T_3 (0.498%) and minimum by T_5 (0.369%). Potassium content was maximum in T_3 (0.1322%) and minimum in T_5 (0.1066%). Thus it is seen that the nutrient concentration of runoff sediment showed only slight variations suggesting that total nutrient contents of runoff sediment were unaffected by different treatments.

The data on available phosphorus and available potassium in runoff are given in Table 8 and Table 9

Table 7. Mechanical composition and nutrient losses through runoff sediment as affected by different treatments and dates of rainfall.

Dates of obser- vation	Treat- ment No	Mechanical composition of runoff sediment			Loss on ignition %	Nutrient content of runoff sediment			Total N loss kg/ha.	Total P loss kg/ha.	Total K loss kg/ha.
		Sand %	Silt %	Clay %		Total N %	Total P %	Total K %			
1	2	3	4	5	6	7	8	9	10	11	12
26.9.79	T_1	43.22	13.89	38.30	4.60	0.1301	0.0373	0.1100	0.133	0.0374	0.1104
	T_2	44.42	12.88	38.10	4.60	0.1425	0.0423	0.1263	0.062	0.0187	0.0559
	T_3	45.45	13.60	36.55	4.40	0.1394	0.0479	0.1463	0.088	0.0286	0.0875
	T_4	43.30	14.80	37.50	4.40	0.1332	0.0466	0.1188	0.080	0.0280	0.0714
	T_5	43.67	12.95	38.78	4.60	0.1426	0.0423	0.1220	0.157	0.0463	0.1336
29.9.79	T_1	47.35	10.67	37.18	4.80	0.1418	0.0410	0.1308	0.506	0.1445	0.4610
	T_2	48.25	14.17	33.38	4.20	0.1278	0.0540	0.1288	0.359	0.1403	0.3542
	T_3	43.22	12.15	39.73	4.90	0.1174	0.0479	0.1288	0.134	0.0546	0.1468
	T_4	42.75	13.00	39.85	4.40	0.1529	0.0479	0.1250	0.126	0.0387	0.1010
	T_5	50.33	13.05	35.52	4.10	0.1359	0.0523	0.1263	1.615	0.6359	1.5354

(contd.)

Table 7 (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
11.10.79	T_1	49.20	15.22	31.38	4.20	0.1407	0.0410	0.1288	0.800	0.2347	0.7373
	T_2	42.75	13.00	39.45	4.80	0.1458	0.0435	0.1388	0.586	0.1710	0.5457
	T_3	44.75	12.00	38.65	4.60	0.1454	0.0479	0.1263	0.375	0.1250	0.3297
	T_4	48.30	10.75	36.25	4.70	0.1202	0.0423	0.1158	0.238	0.0810	0.2217
	T_5	54.45	10.15	31.30	4.10	0.1301	0.0410	0.1025	1.918	0.6080	1.6238
15.10.79	T_1	46.55	12.20	36.85	4.40	0.1283	0.0479	0.1250	0.901	0.3244	0.8465
	T_2	43.22	12.15	39.83	4.80	0.1403	0.0479	0.1213	0.456	0.1552	0.3930
	T_3	43.30	14.80	37.00	4.50	0.1277	0.0466	0.1175	0.310	0.1114	0.2808
	T_4	43.22	13.88	38.30	4.60	0.1429	0.0373	0.1100	0.283	0.0748	0.2205
	T_5	47.30	10.75	37.25	4.70	0.1407	0.0498	0.1263	1.259	0.434	1.1006
27.10.79	T_1	41.65	17.35	36.80	4.20	0.1311	0.0473	0.1325	0.270	0.0982	0.2751
	T_2	45.00	13.40	37.20	4.40	0.1418	0.0498	0.1288	0.167	0.0590	0.1525
	T_3	46.55	12.20	36.85	4.40	0.1358	0.0479	0.1250	0.182	0.0631	0.1647
	T_4	47.35	8.92	38.83	4.90	0.1400	0.0410	0.1308	0.144	0.0420	0.1339
	T_5	48.97	6.50	39.83	4.80	0.1313	0.0410	0.1308	0.986	0.3007	0.9594

(Contd.)

Table 7. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
28.10.79	T_1	46.30	10.75	38.25	4.70	0.1234	0.0498	0.1293	0.116	0.0470	0.1214
	T_2	43.22	13.88	38.80	4.10	0.1368	0.0466	0.1198	0.122	0.0406	0.1036
	T_3	43.55	14.47	37.58	4.40	0.1383	0.0448	0.1325	0.156	0.0496	0.1468
	T_4	44.05	14.10	37.55	4.30	0.1367	0.0479	0.1213	0.115	0.0407	0.1031
	T_5	47.05	10.97	37.48	4.50	0.1487	0.0510	0.1363	0.454	0.1627	0.[illegible]349
30.10.79	T_1	45.45	13.40	36.75	4.40	0.1333	0.0479	0.1463	0.363	0.1328	0.4055
	T_2	47.05	10.97	37.48	4.50	0.1309	0.0498	0.1263	0.074	0.0271	0.0688
	T_3	42.20	13.42	39.48	4.90	0.1423	0.0598	0.1425	0.067	0.0288	0.0686
	T_4	46.55	10.20	38.85	4.40	0.1329	0.0479	0.1250	0.080	0.0291	0.0759
	T_5	49.20	15.12	31.48	4.20	0.1311	0.0510	0.1288	0.892	0.3567	0.9007
7.11.79	T_1	48.00	13.35	34.65	4.00	0.1307	0.0429	0.1013	2.339	0.7721	1.8231
	T_2	48.30	15.65	32.05	4.00	0.1429	0.0410	0.1095	0.299	0.0896	0.2393
	T_3	42.20	13.27	39.63	4.90	0.1283	0.0541	0.1388	0.279	0.1203	0.2974
	T_4	46.55	12.20	37.05	4.20	0.1283	0.0479	0.1263	0.264	0.0986	0.2601
	T_5	51.45	15.32	28.83	4.40	0.1316	0.0516	0.1188	4.325	2.5737	5.9256

(Contd.)

Table 7. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
13.11.79	T_1	43.07	12.55	39.78	4.60	0.1323	0.0423	0.1220	0.119	0.0391	0.1128
	T_2	50.32	13.05	32.63	4.00	0.1308	0.0466	0.1163	0.077	0.0275	0.0686
	T_3	40.62	11.58	42.50	5.30	0.1324	0.0554	0.1450	0.083	0.0345	0.0903
	T_4	43.55	14.47	37.78	4.20	0.1425	0.0448	0.1288	0.073	0.0228	0.0655
	T_5	47.52	12.00	36.18	4.30	0.1350	0.0423	0.1158	0.528	0.1705	0.4667
16.11.79	T_1	47.05	10.67	37.78	4.50	0.1219	0.0510	0.1363	2.082	0.9110	2.4346
	T_2	47.52	12.00	36.18	4.30	0.1376	0.0423	0.1158	0.159	0.0484	0.1326
	T_3	43.30	14.80	37.40	4.50	0.1327	0.0466	0.1175	0.148	0.0525	0.1323
	T_4	45.15	13.70	36.85	4.30	0.1377	0.0429	0.1288	0.098	0.0342	0.0921
	T_5	48.15	11.60	35.75	4.50	0.1344	0.0523	0.1325	1.419	1.6995	4.3055
19.11.79	T_1	44.05	14.10	37.55	4.30	0.1345	0.0479	0.1213	0.372	0.1340	0.3393
	T_2	50.32	13.05	32.53	4.10	0.1314	0.0466	0.1158	0.076	0.0277	0.0687
	T_3	41.65	17.35	36.80	4.20	0.1237	0.0473	0.1325	0.066	0.0254	0.0711
	T_4	43.62	13.48	38.30	4.60	0.1327	0.0448	0.1325	0.107	0.0360	0.1064
	T_5	48.30	13.65	34.65	4.00	0.1289	0.0429	0.0913	1.015	0.3407	0.7251

(Contd.)

Table 7. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
21.11.79	T_1	50.52	12.00	33.18	4.30	0.1257	0.0423	0.1163	1.428	0.4764	1.3098
	T_2	49.20	15.12	31.48	4.20	0.1298	0.0510	0.1263	0.103	0.0411	0.1017
	T_3	44.47	13.05	38.78	4.60	0.1326	0.0423	0.1263	0.131	0.0411	0.1227
	T_4	47.55	12.00	36.15	4.30	0.1286	0.0423	0.1158	0.087	0.0270	0.0793
	T_5	51.30	10.45	34.25	4.00	0.1360	0.0373	0.1013	2.440	0.6455	1.7531
23 .11.79	T_1	50.20	14.22	31.38	4.20	0.1353	0.0510	0.1263	4.227	1.6658	4.1254
	T_2	47.30	10.75	37.25	4.70	0.1347	0.0498	0.1263	0.139	0.0509	0.1292
	T_3	47.05	10.97	37.48	4.50	0.1370	0.0479	0.1250	0.147	0.0512	0.1336
	T_4	46.55	12.20	36.85	4.40	0.1289	0.0429	0.1188	0.140	0.0466	0.1291
	T_5	52.55	10.37	32.98	4.10	0.1348	0.0379	0.0988	5.212	1.4249	3.7146
28.11.79	T_1	54.45	10.15	31.30	4.10	0.1311	0.0410	0.1095	17.302	5.2847	14.1139
	T_2	47.35	8.92	38.83	4.90	0.1406	0.0398	0.1350	0.984	0.2841	0.9638
	T_3	45.45	14.4	35.75	4.40	0.1275	0.0479	0.1463	0.865	0.3209	0.9803
	T_4	47.05	11.97	36.48	4.50	[illegible]	[illegible]	[illegible]	0.530	0.1819	0.4747
	T_5	55.52	7.55	32.73	4.20	0.1447	0.0354	0.1063	27.382	6.7878	20.3826

(Contd.)

Table 7. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
7.4.80	T_1	51.45	15.32	28.83	4.40	0.1339	0.0516	0.1188	0.259	0.1010	0.2326
	T_2	44.45	14.40	36.75	4.40	0.1338	0.0479	0.1463	0.143	0.0507	0.1550
	T_3	42.20	13.27	39.83	4.70	0.1329	0.0523	0.1325	0.108	0.0423	0.1072
	T_4	44.05	14.10	37.55	4.30	0.1400	0.0479	0.1213	0.098	0.0330	0.0836
	T_5	54.72	7.95	33.03	4.30	0.1429	0.0466	0.1163	0.796	0.2596	0.6479
17.4.80	T_1	43.22	12.15	39.83	4.80	0.1310	0.0479	0.1213	0.098	0.0359	0.0910
	T_2	46.47	9.50	39.53	4.50	0.1410	0.0410	0.1308	0.091	0.0260	0.0829
	T_3	44.05	14.10	37.05	4.80	0.1340	0.0479	0.1188	0.067	0.0232	0.0574
	T_4	46.35	12.30	36.95	4.40	0.146	0.0466	0.1175	0.046	0.0156	0.0394
	T_5	47.35	8.92	38.83	4.90	0.124	0.0398	0.1350	0.249	0.0800	0.2714

(Contd.)

Table 7. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12
26.4.80	T_1	54.45	10.25	31.20	4.10	0.122	0.0416	0.1095	10.269	3.5167	9.2567
	T_2	44.05	14.10	37.55	4.30	0.139	0.0479	0.1213	5.473	1.8555	4.6987
	T_3	48.15	11.60	35.75	4.50	0.132	0.0523	0.1289	1.974	0.7849	1.933
	T_4	44.95	12.80	37.85	4.40	0.126	0.0479	0.1220	1.382	0.5367	1.3670
	T_5	63.05	8.90	24.25	3.80	0.140	0.0316	0.1013	47.894	10.9747	34.8610
20.5.80	T_1	47.05	10.57	37.68	4.70	0.124	0.0466	0.1175	2.340	0.8892	2.2420
	T_2	48.3	15.65	32.05	4.00	0.135	0.0410	0.1198	0.306	0.0916	0.2653
	T_3	45.45	14.40	35.85	4.30	0.151	0.0479	0.1463	0.350	0.1110	0.3390
	T_4	46.55	12.20	37.15	4.10	0.133	0.0448	0.1298	0.284	0.0964	0.2770
	T_5	51.30	10.25	34.35	4.10	0.135	0.0398	0.1013	3.701	1.0753	2.7368

respectively. Their weighted means under different treatments pooled over periods of observations are given in Table 10. It is seen from the data that definite relationship exists between the available nutrient content and the amount of soil contained in runoff. From the pooled means it is seen that maximum available phosphorus content was observed under T_5 (10.78 g/ha.cm of runoff) and minimum under T_2 (7.52 g/ha cm of runoff). In the loss of available potassium also similar differences were observed. Maximum available potassium content was observed under T_5 (626.88g/ha cm of runoff) and minimum under T_2 (351.62 g/ha cm of runoff). The high content of available potassium and available phosphorus observed in T_5 may be due to the high content of sediment in the runoff in this treatment.

The amount of total nutrients lost through eroded sediment under different treatments and periods of rainfall are given in Table 7. The total nutrient losses over the entire cropping season are given in Table 10. It is seen that maximum loss of nutrients viz.107.47 kg nitrogen, 28.476 kg phosphorus and 82.475 kg potassium were registered by T_5 (uncultivated bare fallow) and minimum loss of nutrients viz.4.17 kg nitrogen, 1.463kg phosphorus and 3.902 kg potassium by T_4 (tapioca in ridges

Table 8. Content of available Phosphorus as affected by different treatments and periods of rainfall (g/ha.cm)

Dates of observation	26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Treatments	1	2	3	4	5	6	7	8	9
T_1	46.04	7.49	6.49	9.73	7.52	6.58	6.91	12.42	5.68
T_2	41.87	6.91	7.68	8.61	6.38	8.13	7.17	8.68	56.98
T_3	44.02	8.08	7.76	11.65	5.66	20.33	6.68	10.01	30.95
T_4	49.77	7.58	9.67	12.38	8.57	47.09	7.64	19.50	77.36
T_5	51.81	8.06	7.52	7.95	7.43	7.81	7.94	15.66	5.87
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	19.505	N.S.	2.541	48.107
SEm ±	0.673	1.142	1.302	1.470	1.04	6.329	0.559	0.824	15.611

(Contd.)

Table 8 (contd.)

Dates of observation	16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Treatments	10	11	12	13	14	15	16	17	18
T_1	10.49	8.77	9.47	11.07	10.19	7.75	9.65	11.57	28.06
T_2	5.51	9.89	8.59	5.24	5.77	8.01	10.00	10.01	11.83
T_3	7.66	31.04	7.74	7.92	6.97	8.71	13.38	10.91	31.82
T_4	6.40	54.78	7.17	5.96	5.94	8.25	8.92	11.84	25.13
T_5	9.18	7.79	10.63	9.93	10.93	8.65	7.16	17.90	13.22
C.D.(0.05)	3.128	N.S.	N.S.	4.049	2.735	N.S	N.S	N.S	5.81
SEm ±	1.015	12.057	1.163	1.314	0.897	0.592	1.907	1.947	1.885

Table 9. Content of available potassium as affect by different treatments and periods of rainfall (g/ha.cm)

Dates of observation	26.9.79	29.9.79	10.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Treatments	1	2	3	4	5	6	7	8	9
T_1	538.32	309.37	285.15	528.20	402.37	209.00	300.8	629.51	198.90
T_2	385.15	219.69	352.56	482.61	457.64	370.31	315.49	424.15	4900.93
T_3	401.70	320.29	396.71	633.44	498.21	1231.66	274.97	484.25	2247.16
T_4	540.01	241.72	619.85	686.76	578.48	3605.63	431.09	1078.93	4045.25
T_5	550.12	414.91	430.84	361.31	431.83	298.31	409.60	1053.91	273.32
SEm ±	59.52	50.98	116.88	81.12	62.22	621.52	53.17	100.32	1391.06
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S	1915.28	N.S.	309.14	N.S

(Contd.)

Table 9. (Contd.)

Dates of observation	16.11.79	19.11.79	21.11.79	23.11.79	29.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Treatments	10	11	12	13	14	15	16	17	18
T_1	546.0	328.94	495.46	651.62	583.81	167.95	450.66	737.82	2141.98
T_2	133.48	410.29	194.83	212.82	225.39	150.39	492.72	701.62	786.74
T_3	183.30	2381.45	218.33	197.26	208.67	346.1	1021.69	643.06	2612.84
T_4	149.19	2616.22	166.80	207.87	243.34	184.32	455.36	974.49	1881.55
T_5	365.65	260.17	361.31	485.15	603.87	268.09	234.49	1266.37	806.30
SEm ±	109.03	749.28	48.28	82.36	38.88	80.37	199.43	166.03	392.12
C.D.(0.05)	N.S.	N.S.	148.76	253.79	119.96	N.S.	N.S.	N.S.	1203.35

across the slope with groundnut as intercrop). The amount of nutrients lost through erosion can be explained with reference to the soil losses observed.

The losses of available phosphorus and available potassium during the cropping season are given in Table 10 and Fig 7. The maximum loss of available phosphorus was recorded by T_5 (207.87g) and minimum by T_4 (14.39g). In the case of available potassium, the maximum loss was observed in T_5 (12.11kg.) and minimum in T_4 (0.71 kg.).

4.6. Sediment content of runoff.

The data on mean sediment content (weighted) of runoff under different treatments are given in Table 10. The maximum sediment content was observed in T_5 (4009.5 kg/ha cm of runoff) and minimum in T_2 (1303.2 kg/ha cm of runoff). It can be seen that the higher sediment content of runoff was observed in bare plots which had accumulated large volume of runoff. This may be partly due to the splash effect in detaching soil particles and partly due to the high sediment carrying capacity of runoff on those plots. The higher sediment content in the cropped field (T_1) can also be explained as due to the poor soil cover and build up of large volume of runoff resulting in high sediment carrying capacity.

Table 10. Mechanical composition* nutrient content* nutrient loss and sediment content* of runoff over the entire season as affected by different treatments

Treat-ments.	Mechanical composition of runoff sediment (%)			Loss on ignitions (%)	N content of runoff sediment (%)	P content of runoff sediment (%)	K content of runoff sediment (%)	Available P loss(g/ha.cm of runoff)
	Sand	Silt	Clay					
1	2	3	4	5	6	7	8	9
T_1	52.10	11.13	32.53	4.19	0.128	0.0435	0.1143	10.02
T_2	45.04	13.34	37.22	4.40	0.140	0.0464	0.1241	7.52
T_3	45.72	12.90	36.95	4.53	0.132	0.0498	0.1322	8.40
T_4	45.55	12.52	37.51	4.42	0.131	0.0459	0.1225	8.27
T_5	57.40	9.46	29.09	4.05	0.140	0.0368	0.1066	10.78

(Contd.)

Table 10. (Contd.)

Available K loss (g/ha.cm of runoff)	Total N loss during the season (kg./ha.)	Total P loss during the season (kg/ha.)	Total K loss during the season (Kg/ha.)	Seasonal available P loss (g/ha.)	Seasonal loss of available K (kg/ha.)	Sediment content of runoff (kg/ha.cm)
10	11	12	13	14	15	16
541.15	44.01	14.945	39.038	100.47	5.40	3423.7
351.62	9.70	3.205	8.580	40.56	1.89	1303.2
368.70	5.52	2.068	5.489	22.26	0.94	1632.3
404.78	4.17	1.463	3.902	14.39	0.71	1853.7
626.88	107.47	28.476	82.479	207.87	12.11	4009.5

Table 11. Percentage of runoff* during different rainfalls observed as affected by different treatments.

Dates of observations	26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79	16.11.79
Treatments	1	2	3	4	5	6	7	8	9	10
T_1	3.04 (10.01)	9.92 (17.96)	27.60 (31.69)	23.53 (28.75)	7.10 (15.45)	9.08 (17.52)	16.96 (24.26)	36.90 (37.34)	6.64 (14.90)	21.76 (27.76)
T_2	2.66 (9.24)	14.03 (21.73)	23.28 (28.78)	17.22 (24.41)	3.89 (11.33)	2.55 (9.13)	3.04 (10.02)	8.98 (17.42)	1.14 (3.85)	11.98 (19.97)
T_3	1.96 (8.01)	2.57 (9.20)	6.60 (14.83)	6.77 (14.71)	4.60 (12.35)	0.69 (4.54)	3.28 (10.39)	6.32 (14.56)	0.96 (4.74)	5.86 (14.00)
T_4	1.58 (7.03)	2.38 (8.84)	4.16 (11.33)	3.67 (10.90)	2.27 (8.45)	0.23 (2.55)	2.24 (8.59)	2.08 (8.24)	0.04 (1.15)	5.96 (14.10)
T_5	2.82 (9.42)	18.19 (24.75)	36.88 (37.38)	38.61 (38.40)	17.18 (24.47)	19.71 (26.32)	28.42 (32.15)	63.3 (52.93)	11.16 (19.50)	49.04 (44.45)
SEm ±	(0.711)	(1.88)	(1.29)	(1.97)	(0.578)	(0.759)	(0.942)	(2.220)	(1.60)	(1.19)
C.D.(0.05)	N.S.	(5.79)	(3.98)	(6.06)	(1.78)	(2.34)	(2.90)	(6.85)	(4.92)	(3.68)

(Contd.)

Table 11. (Contd.)

Dates of observation	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Treatments	11	12	13	14	15	16	17	18
T_1	4.07 (11.46)	29.57 (32.79)	27.91 (31.79)	40.13 (39.30)	28.40 (32.19)	3.16 (1022)	24.34 (29.53)	4.47 (12.04)
T_2	1.27 (6.02)	6.96 (15.05)	7.30 (15.61)	17.07 (24.34)	23.44 (28.95)	2.78 (9.45)	16.70 (24.12)	2.80 (9.31)
T_3	0.53 (3.30)	7.50 (15.87)	4.51 (12.16)	10.95 (18.89)	11.67 (19.97)	1.20 (5.86)	7.38 (15.36)	0.62 (4.48)
T_4	0.54 (3.37)	7.50 (15.94)	4.12 (11.64)	5.57 (13.47)	10.88 (19.25)	1.62 (7.18)	3.76 (10.96)	0.82 (5.05)
T_5	23.70 (28.97)	59.01 (50.22)	47.85 (43.76)	63.00 (52.54)	33.96 (35.62)	28.20 (32.04)	57.05 (49.06)	21.55 (27.61)
SEm ±	(1.36)	(1.098)	(1.29)	(1.226)	(0.728)	(0.821)	(1.110)	(1.12)
C.D.(0.05)	(4.18)	(3.38)	(3.96)	(3.78)	(2.24)	(2.53)	(3.42)	(3.44)

* Figures in brackets are angles.

4.7. Retentive Rainfall.

The data on the percentage of retentive rainfall under different treatments and periods of observation are given in Table 12. In T_1 the retentive rainfall percentages under different rains ranged from 59.87 to 96.96, in T_2 from 76.57 to 98.87, in T_3 from 88.33 to 99.47, in T_4 from 89.12 to 99.96 and in T_5 from 36.7 to 97.18. Considering the total rainfall and total runoff during the season, the total retentive rainfall and its percentage were determined for various treatments. In T_1 the total retentive rainfall during the season was 583.62mm (85.32%), in T_2 629.73mm (92.06%), in T_3 657.23 mm (96.08%), in T_4 666.5mm (97.44%) and in T_5 491.03 mm (71.78%). From the results it is seen that maximum retentive rainfall was recorded by T_4 and minimum by T_5. The retentive rainfall figures were inversely related to the amount of runoff occured in those plots. In T_5 the retentive rainfall was low because of high runoff and in T_4 the retentive rainfall was high because of low runoff (Table 6) occurred in these plots. The reasons for high runoff in T_5 and low runoff in T_4 were explained earlier.

4.8. pH and conductivity of runoff water.

The data on pH and conductivity of runoff water under different treatments and periods of observation are presented in Table 13 and Table 14 respectively.

Table 12. Percentage of retentive rainfall* during different rainfalls observed as affected by different treatments.

Dates of observation	26.9.79	29.9.79	10.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Treatments	1	2	3	4	5	6	7	8	9
T_1	96.96 (79.99)	90.08 (72.04)	72.4 (58.31)	76.47 (61.25)	92.90 (74.55)	90.92 (72.48)	83.04 (65.74)	63.10 (52.66)	93.36 (75.10)
T_2	97.34 (80.76)	85.97 (68.27)	76.72 (61.22)	82.78 (65.59)	96.11 (78.67)	97.45 (80.87)	96.96 (79.98)	91.02 (72.58)	98.87 (86.11)
T_3	98.04 (81.99)	97.43 (80.80)	93.40 (75.17)	93.24 (75.29)	95.40 (77.65)	99.31 (85.46)	96.72 (79.61)	93.68 (75.44)	99.04 (85.26)
T_4	98.42 (82.97)	97.62 (81.16)	95.85 (78.67)	96.33 (79.10)	97.73 (81.55)	99.77 (87.46)	97.76 (81.41)	97.92 (81.76)	99.96 (88.85)
T_5	97.18 (80.58)	81.91 (65.25)	63.12 (52.62)	61.39 (51.60)	82.82 (65.63)	80.29 (63.68)	71.58 (57.85)	36.70 (37.07)	88.84 (70.50)
SEm ±	(0.771)	(1.89)	(1.29)	(1.97)	(0.578)	(0.759)	(0.942)	(2.22)	(1.60)
C.D.(0.05)	N.S.	(5.79)	(3.98)	(6.06)	(1.78)	(2.34)	(2.90)	(6.85)	(4.92)

(contd.)

Table 12. (Contd.)

Dates of observation	16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Treatments	10	11	12	13	14	15	16	17	18
T_1	78.24 (62.24)	95.93 (78.54)	70.43 (57.21)	72.09 (58.21)	59.87 (50.70)	71.60 (57.81)	96.84 (79.78)	75.67 (60.47)	95.54 (77.96)
T_2	88.03 (70.03)	98.74 (83.99)	93.05 (74.95)	92.70 (74.39)	82.94 (65.66)	76.57 (61.05)	97.22 (80.55)	83.30 (65.88)	97.20 (80.69)
T_3	94.15 (76.00)	99.47 (86.70)	92.50 (74.13)	95.49 (77.84)	89.05 (71.11)	88.33 (70.03)	98.8 (84.14)	92.62 (74.64)	99.39 (85.52)
T_4	94.03 (75.89)	99.46 (86.63)	92.50 (74.16)	95.89 (78.36)	94.43 (76.53)	89.12 (70.75)	98.38 (82.82)	96.24 (79.04)	99.18 (84.95)
T_5	50.96 (45.55)	76.30 (61.04)	41.00 (39.78)	52.15 (46.24)	37.01 (37.46)	66.05 (54.38)	71.80 (57.96)	42.95 (40.94)	78.46 (62.39)
SEm ±	(1.19)	(1.36)	(1.098)	(1.29)	(1.226)	(0.728)	(0.821)	(1.11)	(1.12)
C.D.(0.05)	(3.68)	(4.18)	(3.38)	(3.96)	(3.78)	(2.24)	(2.53)	(3.42)	(3.44)

* Figures in brackets are angles.

Table 13. pH of runoff water as affected by different treatments and dates of rainfall.

Dates of observation	26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	29.10.79	30.10.79	7.11.79	13.11.79
Treatments	1	2	3	4	5	6	7	8	9
T_1	5.95	5.95	5.95	5.78	5.88	5.75	5.55	5.58	5.48
T_2	5.98	5.98	5.90	5.68	5.85	5.65	5.65	5.58	5.48
T_3	5.98	5.93	5.88	5.65	5.73	5.70	5.60	5.58	5.48
T_4	5.95	5.95	5.95	5.50	5.80	5.78	5.70	5.53	5.63
T_5	5.95	6.03	5.95	5.83	5.93	5.75	5.68	5.55	5.58
SEm ±	0.055	0.087	0.055	0.090	0.102	0.051	0.053	0.063	0.048
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.149

(Contd.)

Table 13. (Contd.)

Dates of observation	16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Treatments	10	11	12	13	14	15	16	17	18
T_1	5.43	5.40	5.38	5.38	5.40	5.93	5.55	5.90	5.75
T_2	5.58	5.40	5.43	5.45	5.40	5.98	5.63	5.65	5.73
T_3	5.50	5.48	5.35	5.48	5.33	5.95	5.53	5.78	5.78
T_4	5.48	5.40	5.45	5.48	5.45	5.95	5.53	5.70	5.65
T_5	5.35	5.50	5.45	5.50	5.50	5.83	5.65	5.68	5.78
SEm ±	0.080	0.072	0.085	0.070	0.093	0.060	0.078	0.079	0.086
C.D.(0.05)	N.S	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

It is seen from the data that pH of runoff water was not affected by different treatments except on 13.11.79 during which T_4 was significantly higher than that of T_1, T_2 and T_3. However, T_4 and T_5 were on par. T_1 , T_2 and T_3 were also on par. The high pH of T_4 may be because of low salt content of runoff in that plot (Firman E.Bear,1964). However, there was no significant difference between the treatments during all the other rains suggesting that the pH of runoff water was not affected by different treatments.

It is further revealed that conductivity of runoff water was not affected by different treatments except on 20.5.80 when T_5 recorded maximum conductivity of 49.35 micromhos/cm which was significantly higher than the other treatments which were on par. The high conductivity in T_5 may be because of high neutral salt content of runoff from that plot. However, the conductivity was not affected by different treatments during all the other rains, suggesting that the effect of different treatments in changing the conductivity of runoff is meagre.

4.9. Storage of soil moisture as affected by different treatments.

The data on surface soil moisture (0 to 22.5 cm layer) storage under different treatments and periods are

Table 14. Electrical conductance of runoff water as affected by different treatments and dates of rainfall (micromhos/cm.)

Dates of observation	26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Treatments	1	2	3	4	5	6	7	8	9
T_1	52.35	42.63	35.35	67.15	65.28	37.58	52.20	55.98	54.38
T_2	58.43	53.13	36.95	68.48	41.68	38.98	40.83	46.63	47.38
T_3	58.23	52.20	50.45	60.15	43.80	33.58	39.55	44.33	48.55
T_4	54.65	65.78	41.20	63.10	41.28	33.95	50.25	53.20	56.58
T_5	56.28	51.08	51.58	65.90	53.15	39.43	47.30	47.00	55.65
SEm $\pm$	5.10	7.16	5.67	2.85	8.32	4.10	5.03	3.96	8.50
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

(Contd.)

Table 14. (contd.)

Dates of observation	16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Treatments	10	11	12	13	14	15	16	17	18
T_1	48.13	48.55	49.73	42.90	46.23	39.03	45.85	36.28	36.38
T_2	44.65	39.73	42.43	35.45	43.48	40.20	48.85	36.75	38.18
T_3	38.68	37.83	44.45	46.23	44.35	39.38	44.78	34.23	35.10
T_4	44.00	37.40	40.23	40.93	46.68	40.50	45.73	37.00	37.98
T_5	42.93	47.75	41.73	47.25	49.45	48.83	48.00	42.38	49.35
SEm ±	5.19	5.69	4.67	4.60	4.73	3.57	3.59	2.85	2.98
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

given in Table 15 and Fig 9. It is seen from the data that surface soil moisture was lowest under T_5 and highest under T_3 during the initial periods of study at which there were frequent occurrence of rainfall. Surface soil moisture was lowest under T_5 because the land was bare and as such there was heavy evaporation loss from the upper soil layers. During the dry periods maximum surface soil moisture was recorded under T_3 and minimum under T_5. This is due to the fact that tapioca was responsible for depletion of moisture in T_3 with only small amounts of evaporation from surface since the land was kept under partial shade due to crop canopy where as in T_5 , the soil moisture was depleted through the direct effect of sunshine as the plot was bare fallow and consequent high rate of evaporation. In the course of study, there were frequent occurrences of rainfall during the later periods resulting in maximum storage of surface soil moisture in T_4 and minimum in T_5. The high moisture storage in T_4 may be because of the increase in storage capacity of soil brought about by the high retention of moisture in the inter ridge areas resulting in high infiltration capacity by the effect of intercropping.

The data on subsoil (22.5 to 112.5cm layer) moisture storage as affected by different treatments and

Table 15. Surface soil (0 to 22.5 cm.) moisture storage as affected by different treatments and periods of observations (mm)

Dates of observation	17.9.79	30.9.79	13.10.79	27.10.79	10.11.79	24.11.79	8.12.79	23.12.79	5.1.80	19.1.80
Treatments	1	2	3	4	5	6	7	8	9	10
T_1	60.38	55.71	50.78	55.42	54.90	60.78	35.93	24.90	20.27	20.68
T_2	62.04	52.79	53.56	52.89	55.11	65.64	34.57	23.44	22.26	20.49
T_3	61.96	59.24	55.13	59.39	58.76	67.24	37.31	26.85	23.77	23.29
T_4	62.92	57.26	51.42	57.60	58.31	64.65	35.54	26.41	24.19	23.03
T_5	57.78	52.03	46.82	52.84	51.53	58.71	35.39	25.71	22.83	21.24
SEm ±	0.693	1.376	1.169	1.436	1.397	1.574	2.065	1.333	0.775	1.280
C.D.(0.05)	2.14	4.24	3.60	4.43	4.30	4.85	N.S	N.S	2.389	N.S

(Contd.)

Table 15. (contd.)

Dates of observation	2.2.80	16.2.80	1.3.80	15.3.80	29.3.80	12.4.80	26.4.80	10.5.80	20.5.80
Treatments	11	12	13	14	15	16	17	18	19
T_1	19.47	19.17	18.52	19.25	17.86	30.53	43.22	34.29	31.01
T_2	18.86	18.41	16.91	16.25	15.56	30.49	48.05	31.29	27.83
T_3	22.51	22.42	21.06	21.03	20.47	32.75	51.55	37.53	35.78
T_4	20.86	20.79	19.35	18.91	18.92	37.39	53.51	44.17	41.40
T_5	19.06	18.51	16.71	16.11	15.51	24.29	45.46	23.11	24.71
SEm ±	1.064	1.013	0.926	0.814	0.913	1.563	1.324	1.067	1.082
C.D.(0.05)	N.S.	N.S.	2.86	2.51	2.51	4.82	4.08	3.287	3.334

periods of observation are given in Table 16 and Fig 10. There have been frequent occurrences of rainfall upto 67th day of planting. During this period the maximum storage of subsoil moisture was seen in T_3 and the minimum in T_8. The maximum quantity of subsoil moisture storage observed in T_3 can be attributed to the high retention of rainfall in T_3. ~~In T_5, the storage was minimum due to high runoff as the field was kept as uncultivated bare fallow.~~ It is seen from the data that there was no rain from 67th day upto 193th day after planting. The study of the subsoil moisture storage revealed that there was gradual and continuous depletion of subsoil moisture during this period and the cultivated plots showed maximum depletion where as depletion was minimum in bare fallow (T_5). Among the cultivated plots the higher rate of depletion and thereby minimum storage was shown by T_1 during this period. The maximum storage of subsoil moisture by the uncultivated bare fallow can be attributed to the lack of root extraction of subsoil moisture and subsequent evapo-transpiration. In other treatments the roots of tapioca which extends upto 50cm would have extracted much of the subsoil moisture resulting in maximum depletion of subsoil moisture.

4.10. Biometric observations of maincrop (tapioca)

Biometric observations such as height of plant,

Table 16. Subsoil (22.5cm.to 112.5cm.) moisture storage as as affected by different treatments and periods of observations (mm)

Dates of observation	17.9.79	30.9.79	13.10.79	27.10.79	10.11.79	24.11.79	8.12.79	23.12.79	5.1.80	19.1.80
Treatments	1	2	3	4	5	6	7	8	9	10
T_1	370.25	364.55	368.10	360.99	361.38	378.06	331.17	299.74	263.41	247.37
T_2	360.18	349.11	347.80	338.36	344.89	367.08	328.12	290.68	266.38	253.58
T_3	391.19	382.31	389.70	386.77	393.58	403.04	351.58	320.80	300.23	284.91
T_4	399.67	379.09	376.27	361.69	367.91	385.95	335.72	311.57	299.32	281.18
T_5	362.73	359.38	360.53	351.41	354.22	372.74	344.27	330.14	318.96	305.89
SEm $\pm$	5.694	5.682	6.909	9.236	8.427	8.066	11.188	13.948	14.969	16.836
CD.(0.05)	17.55	17.51	21.29	29.46	25.97	N.S.	34.48	N.S.	N.S.	N.S.

(contd.)

Table 16.(Contd.)

Dates of observation	2.2.80	16.2.80	1.3.80	15.3.80	29.3.80	12.4.80	26.4.80	10.5.80	20.5.80
Treatments	11	12	13	14	15	16	17	18	19
T_1	234.28	224.10	217.45	211.88	206.59	219.55	246.03	235.29	231.89
T_2	238.61	228.69	221.87	218.03	215.38	229.65	251.02	242.10	240.16
T_3	272.16	263.21	257.60	254.70	251.24	261.96	279.16	277.93	275.11
T_4	264.11	251.46	244.57	238.39	235.67	249.68	274.52	274.30	273.86
T_5	297.17	294.84	280.30	279.30	276.76	282.33	287.14	282.77	280.63
SEm ±	16.790	17.572	17.654	18.002	18.064	17.413	16.816	16.485	16.246
C.D.(0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

number of total leaves per plant, number of functional leaves per plant and canopy diameter of tapioca were studied at monthly intervals.

4.10.1. Height of plant.

The data on height of plant recorded at monthly intervals are given in Table 17. In all cases there were no significant differences between the treatments. This suggests that the different methods of cultivation and intercropping have no effect on the growth of tapioca as evidenced by the height of plant. This is similar to the results reported by Prasad and Choudhury (1975) who noticed that there was no adverse effect to the principal crop due to legumes in grass-legume association.

4.10.2. Total number of leaves per plant.

The data on the total leaves of tapioca as affected by different treatments and periods of observation are given in Table 18. In all the cases highest number of total leaves was produced by T_3 and lowest by either T_2 or T_4 during different observations. However, the differences were statistically significant on 61st, 91st ,122nd and 153rd days of planting. Towards the end of the season the differences again become nonsignificant. The higher number of total leaves in T_3 can be attributed to the better growth conditions in that treatment in which the tapioca was planted

Table 17. Height of Tapioca plant at monthly intervals (cm.) as affected by different Agro-Techniques

Treatments	30 days	61 days	91 days	122days	153days	181 days	212 days	246 days (at harvest)
T_1	22.09	69.00	127.58	137.00	144.98	148.67	164.25	197.25
T_2	23.75	66.67	124.58	136.42	146.17	151.92	167.58	205.50
T_3	23.05	71.50	134.75	141.96	148.50	153.09	173.58	206.25
T_4	21.30	70.17	125.42	132.00	143.58	148.50	167.25	204.67
SEm ±	1.726	2.817	3.000	3.626	3.865	3.564	5.708	5.779
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 18. Total leaves per plant at monthly intervals as affected by different Agro-Techniques (tapioca)

Treatments	30 days	61 days	91 days	122days	153 days	181days	212 days	246 days (at harvest)
T_1	12.16	33.75	59.17	66.08	77.92	90.39	108.10	126.24
T_2	11.14	29.84	50.67	62.00	74.58	86.02	102.92	120.42
T_3	11.75	33.75	62.25	70.92	83.67	96.43	115.50	127.58
T_4	11.25	30.42	56.25	58.67	72.83	89.66	103.34	126.67
SEm ±	0.607	1.065	1.716	2.062	1.497	2.253	3.080	4.058
C.D.(0.05)	N.S •	3.423	5.488	6.596	4.788	N.S •	N.S •	N.S •

in ridges across the slope. It is revealed from the data that intercropping had significantly reduced the total leaf production in tapioca during the earlier periods which may be because of the initial smothering effect of intercrop on the vegetative growth of tapioca which has been reflected on the leaf production (Thamburaj and Muthukrishnan,1976).

4.10.3. Functional leaves per plant.

The data on functional leaves of tapioca at monthly intervals are given in Table 19. It is seen that the no of functional leaves per plant was not affected by various treatments except on 91st day after planting. During the period the maximum number of functional leaves per plant was recorded by T_3 and minimum by T_2. It is quite natural that the treatment T_3 in which the total number of leaves was also maximum recorded the maximum number of functional leaves per plant. This is clearly a reflection of better vegetative growth in that treatment.

4.11.4. Canopy diameter.

The data on canopy diameter of tapioca at monthly intervals are given in Table 20. In most of the cases the canopy diameter was not significantly altered by different treatments suggesting that the canopy

Table 19. Functional leaves per plant at monthly intervals as affected by different Agro-Techniques (tapioca)

Treatments	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
T_1	12.16	33.09	43.67	38.33	25.83	18.50	40.67	49.92
T_2	11.39	29.42	35.58	35.50	25.67	20.00	43.75	50.42
T_3	11.75	32.92	46.42	43.08	28.75	22.42	43.42	45.33
T_4	11.00	30.09	43.08	41.75	26.25	18.75	42.50	50.75
SEm ±	0.576	0.999	1.867	3.547	1.911	1.550	3.250	1.701
C.D.(0.05)	N.S.	N.S.	5.972	N.S.	N.S.	N.S.	N.S.	N.S.

Table 20. Canopy diameter of tapioca at monthly intervals (cm) as affected by different Agro-Techniques.

Treatments	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
T_1	48.17	94.58	117.75	104.50	63.84	33.42	50.84	92.83
T_2	44.42	91.17	113.33	106.75	59.25	32.33	56.09	102.50
T_3	46.0	91.84	118.17	108.92	61.50	37.27	55.92	93.50
T_4	40.34	89.50	118.17	114.84	60.00	32.50	55.67	99.34
SEm ±	3.071	2.372	2.230	2.972	0.922	1.613	2.901	3.084
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	2.948	N.S.	N.S.	N.S.

diameter was not markedly influenced by the various Agro-Techniques employed.

4.11. Yield attributes and yield of main crop (tapioca)

The data on yield attributes and yield of tapioca are given in Table 21.

4.11.1. Number of productive tubers per plant.

It is seen from the data (Table 21) and Fig 11 that the number of productive tubers per plant was not affected by different treatments. This means that there is no significant effect on the number of productive tubers per plant either by intercropping with groundnut or by ridge or mound method of cultivation of tapioca.

4.11.2. Number of unproductive tubers per plant

It is seen from the data that the number of unproductive tubers per plant was not significantly affected by different treatments. The maximum number of unproductive tubers was recorded by T_2 followed by T_4 . All the other treatments recorded almost the same number of unproductive tubers per plant. The higher number of unproductive tubers in T_2 and T_4 may be due to the stimulation of root primordia by the nitrogen excreted from the legume intercrop (Russel,1961).

Table 21. Yield attributes and yield of tapioca as affected by different Agro-Techniques

Treatments	Number of productive tubers/plant	Number of unproductive tubers/plant	Length of tubers (cm)	Mean girth of tubers (cm)	Yield of tubers (fresh weight (kg/ha.)	Dry weight of tops (kg/ha.)	Harvest index* (%)
T_1	13.57	5.08	29.78	13.49	15163.85	2149.7	65.46 (54.039)
T_2	11.50	10.17	25.10	13.58	14607.53	2130.9	65.60 (54.109)
T_3	12.48	5.49	25.00	13.18	18640.45	2336.4	69.03 (56.201)
T_4	12.92	5.75	23.10	12.95	13984.15	1950.2	66.65 (54.74)
SEm ±	1.015	1.339	1.604	0.526	1133.36	66.6	(0.8005)
C.D.(0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	213.3	N.S.

* Figures in brackets are angles.

4.11.3. Length of tubers

The data on the length of tubers are presented in Table 21 and Fig 12. It is seen from the data that the length of tubers was not significantly influenced by different treatments. However, maximum length of the tubers was recorded by T_1 and minimum by T_4. From the data it can be concluded that neither the method of cultivation nor intercropping with groundnut had any significant influence on the length of tubers.

4.11.4. Girth of tubers

The data on girth of tubers are given in Table 21 and Fig 12. As in the case of length of tubers data on the girth of tubers also were not statistically significant. Thus it can be concluded that neither the different methods of cultivation of tapioca nor intercropping with groundnut had any significant influence on the mean girth of tubers.

4.11.5. Yield of tubers.

The data on the yield of tapioca tubers (fresh weight) are presented in Table 21 and Fig 13. It is seen that maximum yield was recorded by T_3 being 17640.45kg/ha and minimum yield by T_4 being 13984.15 kg/ha. However, the difference in yield was not statistically significant.

This is in agreement with the findings of Singh and Mandal (1968) who found that growing groundnut as intercrop in cassava did not affect the latter. The present study also revealed that growing tapioca either in ridges or in mounds does not affect the yield.

4.11.6. Dry weight of tops

The data on the dry weight of tops are given in Table 21. It is seen that maximum dry weight of tops was recorded by T_3 which was on par with T_1 and T_2 but was significantly superior to T_4. All the other comparisons were on par. The data on the total number of leaves per plant (Table 18) and functional leaves per plant (Table 19) revealed the superiority of T_3 on the vegetative growth of tapioca and as such it is quite natural to have the maximum dry weight of tops also in T_3.

4.11.7. Harvest index.

The data on harvest index are given in Table 21. It is seen that the maximum harvest index was recorded by T_3 (69.03%) and minimum by T_1 (65.46%). However, this was not statistically significant suggesting that the different methods of cultivation and intercropping with groundnut have no significant influence on the harvest index of tapioca.

4.12. Biometric observations of intercrop (groundnut)

The data on the biometric observations such as height, functional leaves and the number of branches per plant were recorded at monthly intervals and presented in Table 22.

4.12.1. Height of plant

The data indicated that there were only very small differences in the height of groundnut between the treatments. This indicates that ridge or mound method of cultivation does not have any marked effect on the height of the intercropped groundnut during the entire period of growth. As the canopy diameter of tapioca was almost alike in all the treatments the light infiltration in the interspaces also can be expected to be uniform. This uniform light infiltration may be one of the reasons for the maintenance of uniform height in the intercropped groundnut.

4.12.2. Functional leaves per plant

The data indicated only small difference between treatments. This reveals that ridge or mound method of cultivation does not have any marked effect on the functional leaves of the intercropped groundnut.

4.12.3. Number of branches per plant

As in the case of height of plant and functional

Table 22. Periodical biometric observations of groundnut as affected by different Agro-Techniques.

Characters	Height of plant (cm.)			Functional leaves/plant			Number of branches/ plant		
Dates of observation / Treatments	30 days	61 days	96 days	30 days	61days	96 days	30days	61days	96days
T_2	14.90	41.33	47.03	28.88	36.40	13.93	4.84	5.19	5.19
T_4	14.65	42.88	45.80	27.40	34.80	14.38	4.78	5.03	5.03
SEm ±	0.308	1.388	1.579	1.998	1.295	0.518	0.359	0.341	0.341

leaves per plant, the number of branches per plant also showed only small differences between treatments indicating that the ridge or mound method of cultivation does not have any marked effect on the number of branches of the intercropped groundnut.

4.13. Yield attributes and yield of intercrop (groundnut)

The data on the yield attributes and yield of the intercropped groundnut are given in Table 23.

4.13.1. Number of pegs per plant.

The total number of pegs per plant showed only small differences between the treatments. This indicates clearly that the number of pegs per plant was not markedly influenced by different methods of cultivation of the main crop.

4.13.2. Number of pods per plant

As in the case of number of pegs per plant, the number of pods per plant also exhibited only small differences between the treatments. This suggests clearly that the different methods of cultivation of the main crop do not have any marked effect on the number of pods of the intercropped groundnut.

Table 23. Yield attributes and yield of groundnut as affected by different Agro-Techniques.

Treatments	Number of pegs/plant	Number of pods/plant	Yield of dry pods (kg/ha.)	Dry weight of bhusa (kg/ha.)	Harvest index* (%)
T_2	18.85	6.38	1015.09	1504.34	40.58 (39.56)
T_4	20.58	5.35	941.93	1351.93	41.06 (39.85)
SEm ±	0.746	0.622	27.28	112.79	(0.901)

* Figures in brackets are angles for comparison.

4.13.3. Yield of dry pods

Although the maximum yield of dry pods was recorded by T_2, the difference was only very small. This suggests that the different methods of cultivation of tapioca do not have any marked effect either on the yield attributes or on the yield of the intercropped groundnut.

4.13.4. Dry weight of bhusa

In the case of dry weight of bhusa also differences between the treatments were only very small. Thus the data clearly indicate that the different methods of cultivation of tapioca do not have any significant influence on the dry yield of bhusa of the intercropped groundnut.

4.13.5. Harvest index

The data indicated that maximum harvest index was recorded by T_4. However, the difference was very meagre suggesting that the different methods of cultivation of tapioca do not have any marked effect on the harvest index of the intercropped groundnut. As there was not much difference between the treatments in respect of both vegetative as well as productive attributes, it is quite natural to show only small differences in the harvest index also.

4.14. Future line of work

The present investigation was conducted principally to study the effect of intercropping and methods of cultivation of tapioca on reducing runoff and soil loss. The study revealed that intercropping with groundnut as well as cultivation of tapioca in ridges across the slope could significantly reduce the runoff and soil loss in tapioca planted on hill slopes. As it is a first step for evaluating the soil and water losses in hill slopes in Kerala, detailed for further investigations are required to assess other Agro-Techniques to control soil and water losses.

Summary

5. SUMMARY

An experiment was conducted at the Instructional Farm, Vellanikkara from September 1979 to May 1980 to study the effect of different Agro-Techniques on soil loss, surface runoff and soil moisture storage in hill slopes. The treatments included (1) tapioca alone in mounds, (2) tapioca in mounds with groundnut as intercrop, (3) tapioca alone in ridges across the slope, (4) tapioca in ridges across the slope with groundnut as intercrop and (5) uncultivated bare fallow as a control. The experiment was conducted in runoff plots of size 24.3M x 2.7M. The runoff and soil loss were determined under 18 erosive rainfalls which occurred during the period under the study. The data were subjected to statistical analysis and the results are summarised below.

1) Among the various erosion indices AIm index was better correlated with runoff.

2) EI_{15} index was better correlated with soil loss than other indices. Prediction equations have been formulated to determine runoff and soil loss under the existing conditions of length and gradient factors for different rainfall intensities.

3) Maximum runoff and soil loss were observed in uncultivated bare fallow plot which was significantly superior to all the other treatments. Among the various Agro-Techniques, maximum runoff was observed in the plot where tapioca alone was planted in mounds without intercrop. Runoff was considerably lower in all the other treatments.

4) Groundnut intercropping could significantly reduce runoff and soil loss before and after the harvesting of the intercrop.

5) The planting of tapioca in ridges across the slope was found to be effective in reducing soil and water losses.

6) Under high intensity rainfall conditions the content of sand in runoff sediment was found to be higher.

7) Uncultivated bare fallow plots recorded the maximum losses of nutrients being 107.47kg. nitrogen, 28.476kg. phosphorus and 82.479kg. potassium per hectare during the entire cropping season. Among the Agro-Techniques, maximum losses of nutrients were recorded by tapioca alone in mounds being 44.01kg.nitrogen, 14.845kg. phosphorus and 39.08kg.potassium per hectare during the

entire season.

8) Maximum retention of rainfall was recorded by tapioca in ridges across the slope with groundnut as intercrop.

9) The pH and conductivity of runoff water were not significantly influenced by different treatments.

10) During the dry periods maximum storage of sub soil moisture was recorded by uncultivated bare fallow plots. The depletion of subsoil moisture was higher in cultivated plots as compared to uncultivated bare fallow plots.

11) The growth and yield of tapioca were not significantly reduced by the groundnut intercropping. Maximum yield of tapioca tubers was recorded by ridges across the slope without intercrop.

12) The yield of the intercropped groundnut was not markedly affected by the ridge or mound method of cultivation.

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* Originals not refered.

Appendices

APPENDIX I

Weather data (fortnightly mean) from 3rd Sept'79 to 27th May '80

Period	Fort nights.	Temperature (°C)		Relative humidity (%)		Total rain fall (mm)	Number of rainy days	Sunshine (hours/day)
		Maximum	Minimum	F.N	A.N			
Sept.3 - Sept.16	1	31.75	24.0	93.5	70.5	32.6	4	2.3
Sept.17- Sept.30	2	29.2	23.25	95.0	81.0	109.45	12	0.38
Oct .1 - Oct.14	3	31.0	23.6	92.5	73.5	41.25	4	2.0
Oct .15- Oct.28	4	32.6	23.65	85.0	62.0	64.20	5	1.8
Oct .29- Nov.11	5	31.8	24.1	86.5	69.5	35.75	6	0.6
Nov .12- Nov.25	6	30.1	23.35	92.0	75.5	179.35	11	0.45
Nov .26- Dec.9	7	31.25	23.7	87.0	66.5	78.25	2	1.10
Dec .10- Dec.23	8	26.45	22.7	80.0	57.5	0	0	1.90
Dec .24- Jan.7	9	30.85	21.55	74.0	51.0	0	0	3.75
Jan .8 - Jan.21	10	30.85	21.5	72.0	45.0	0	0	4.4
Jan. 22- Feb.4	11	32.4	20.35	77.5	40.0	0	0	3.65
Feb .5 - Feb.18	12	34.3	21.35	80.0	35.0	0	0	0.75
Feb .19- Mar.4	13	36.0	22.5	87.5	39.0	0	0	2.15
Mar .5 - Mar.18	14	35.55	23.25	88.0	47.5	0	0	--
Mar .19- April.1	15	36.35	23.75	86.0	51.5	0	0	--
April.2- April.15	16	35.7	25.4	90.0	57.5	36.40	4	--
April.16- April 29	17	35.35	25.15	87.5	53.5	83.50	3	--
April.30- May 13	18	34.75	24.85	89.5	61.5	27.25	5	--
May. 14 - May 27	19	34.10	25.35	89.5	61.0	94.25	3	--

APPENDIX II

Analysis of various rainfall parameters for erosion characteristics

Dates of observation	26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	29.10.79
Rainfall character	1	2	3	4	5	6
Total rainfall (mm)	12.50	39.65	25.50	12.60	24.75	20.60
Average Intensity (mm/hr)	9.49	6.47	14.04	4.20	6.27	6.27
Maximum Intensity (cm/hr)	2.14	4.75	4.27	2.22	3.00	1.62
Maximum 5 minutes Intensity (mm/hr)	21.40	47.50	42.70	22.20	30.00	16.20
Maximum 15 minutes Intensity (mm/hr)	14.00	26.10	42.70	22.20	30.00	16.20
Maximum 30 minutes Intensity (mm/hr)	7.60	21.26	38.90	17.48	29.10	14.00
Maximum 60 minutes Intensity (mm/hr)	6.80	13.30	24.37	9.75	20.00	10.75
EI_5 (metric units)	4.77	39.11	27.19	5.41	17.21	6.90
EI_{15} (metric units)	3.12	21.49	27.19	5.41	17.21	6.90
EI_{30} (metric units)	1.70	17.51	24.77	4.26	16.69	5.96
EI_{60} (metric units)	1.52	10.95	1.55	2.38	11.47	4.58
Total kinetic energy (metre tonnes/ha)	223.04	833.44	636.77	243 .75	573.60	425.89
KE>1(metre tonnes/ha)	0.00	375.88	493.40	0.00	501.50	0.00
AIm	2.675	17.955	10.889	2.797	7.44	3.337

(Contd.)

APPENDIX II (Contd)

30.10.79	7.11.79	13.11.79	16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
7	8	9	10	11	12	13	14	15	16	17	18
12.50	12.50	26.00	32.25	54.30	13.25	25.50	76.50	23.00	12.50	64.00	21.00
16.67	31.25	4.11	26.04	4.75	11.04	13.30	21.75	9.86	11.54	15.80	9.64
2.81	3.96	1.70	2.81	2.25	4.65	3.92	8.57	5.06	3.20	10.00	3.92
28.10	39.60	13.20	28.10	22.50	46.50	39.20	85.70	40.00	32.00	100.00	42.70
28.10	37.00	13.20	28.10	22.50	32.12	38.32	54.28	40.00	32.00	100.00	26.10
16.50	23.50	11.00	26.20	16.67	17.36	31.66	47.50	43.00	23.10	100.00	27.20
10.25	12.50	5.50	18.56	13.55	10.00	18.15	33.50	20.88	12.31	50.07	20.20
7.64	12.78	6.26	19.77	33.60	14.67	23.99	169.32	23.17	9.54	179.25	19.45
7.64	11.94	6.26	19.77	33.60	10.13	23.46	107.24	23.17	9.54	179.25	16.14
4.49	7.59	5.22	18.43	24.90	5.48	19.38	93.85	24.91	6.99	179.25	14.31
2.79	4.03	2.61	13.06	20.24	3.16	11.11	66.19	12.10	3.67	89.75	8.54
[illegible]	322.78	474.20	703.51	1493.52	315.53	612.10	1975.71	579.34	298.17	1792.53	582.32
187.58	307.30	0.00	278.57	0.00	209.02	385.74	1561.86	449.38	204.24	1743.70	537.41
3.513	4.95	4.42	8.795	12.218	6.185	9.996	65.56	11.638	4.00	64.00	9.03

APPENDIX III

Mean Squares of Analyses of Variance for runoff in 10^{-3} mm (transformed data)

Dates of observation		26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Source	df	1	2	3	4	5	6	7	8	9
Block	3	0.0735	0.147	0.021	0.027	0.030	1.202	0.002	0.001	0.061
Treatment	4	0.068	0.492*	0.787**	0.729**	0.474**	2.916**	0.993**	4.429**	4.588**
Error	12	0.023	0.111	0.029	0.027	0.012	0.048	0.006	0.009	0.404

Dates of observation		16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Source	df	10	11	12	13	14	15	16	17	18
Block	3	0.015	1.250*	0.036*	0.006	0.028	0.00006	0.077	0.043	0.0256
Treatment	4	0.621**	3.676**	0.750**	0.949**	0.767**	0.204**	1.326**	0.911**	1.574**
Error	12	0.006	0.289	0.008	0.011	0.013	0.00133	0.051	0.0161	0.0335

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX IV

Mean Squares of Analyses of Variance for Soil loss in kg/ha (Transformed data)

Dates of observation		26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Source	df	1	2	3	4	5	6	7	8	9
Block	3	0.073	0.0115	0.0516*	0.0883*	0.0427	0.0936*	0.0632	0.2151*	0.1459**
Treatment	4	0.167	0.923**	0.455**	0.2856**	0.3959**	0.1682**	1.0251**	1.5519**	0.5179**
Error	12	0.096	0.0243	0.0099	0.016	0.0275	0.0258	0.0371	0.0370	0.0140

Dates of observation		16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
source	df	10	11	12	13	14	15	16	17	18
Block	3	0.0934	0.23**	0.2617**	0.1867**	0.1209**	0.0192	0.0065	0.1164	0.1387
Treatment	4	2.1828**	1.0074**	1.6709**	0.2528**	2.5574**	0.5505**	0.3632**	1.4629**	1.0834**
Error	12	0.0378	0.0347	0.0243	0.0194	0.0044	0.007	0.0332	0.0418	0.0476

* Significant at 5 per cent level.

** Significant at 1 per cent level.

APPENDIX V

Mean Squares of Analyses of Variance for runoff and soil loss during different stages of the crop growth

SOURCE	df	Total runoff before harvesting intercrop (mm)(Transformed data)	Total runoff after harvesting intercrop (mm)(Transformed data)	Total runoff during the season (mm) (Transformed data)	% of Total rainfall (Total runoff)	Before harvesting intercrop in kg/ha (Transformed)	After harvesting intercrop in kg/ha (Transformed)	Total during the season in kg/ha (Transformed)
Block	3	0.0082	0.0139	0.00904	1.932**	0.08149**	0.10156	0.08811**
Treatment	4	0.7555**	0.644**	0.7205**	435.155**	1.5469**	1.3559**	1.445**
Error	12	0.00238	0.0051	0.00263	0.297	0.006765	0.03155	0.01035

APPENDIX VI

Mean Squares of Analyses of Variance for available P loss (g/ha.cm)

Dates of observation		26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Source	df	1	2	3	4	5	6	7	8	9
Block	3	6.343*	4.307	6.906	13.759	4.472	235.549	12.917**	40.130**	459.236
Treatment	4	4.155	0.937	5.285	14.597	5.045	1183.314**	1.078	76.997**	4001.139*
Error	12	1.809	5.213	6.784	8.642	4.324	160.247	1.251	2.719	974.840

Dates of observation		16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Source	df	10	11	12	13	14	15	16	17	18
Block	3	5.603	1129.177	6.515	22.712	12.777*	8.296**	17.100	31.397	455.816*
Treatment	4	16.345*	1679.074	7.606	24.874*	23.676**	0.679	20.664	39.158	323.499*
Error	12	4.121	581.460	5.410	6.906	3.150	1.357	14.451	15.159	85.010

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX VII

Mean Squares of Analyses of Variance for available K loss

(g/ha.cm)

Dates of observation		26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Source	df	1	2	3	4	5	6	7	8	9
Block	3	41356.7	6309.8	97246.6	11333.5	65762.4*	177350.65	10342.3	80905.0	5086187.6
Treatment	4	26999.7	23709.0	63270.7	65617.8	18678.4	8258309.1*	19302.5	390164.9**	18330061.9
Error	12	14170.4	10394.9	54642.5	26320.0	15487.1	1545168.8	11308.9	40255.1	7740199.0

Dates of observation		16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Source	df	10	11	12	13	14	15	16	17	18
Block	3	39977.4	4615906.4	12274.8	77564.3	42153.6**	14360.3	92727.7	243364.3	2874383.8*
Treatment	4	127469.8	5667186.7	76636.6**	171595.2**	163346.4**	27192.7	342334.9	265208.2	2679684.5*
Error	12	47549.9	2245652.9	9321.9	27130.2	6062.0	25838.0	159094.1	110257.2	615032.0

* Significant at 5 per cent level.

** Significant at 1 per cent level.

APPENDIX VIII

Mean Squares of Analyses of Variance for retentive rainfall percentages (Transformed to angles)

Dates of observation		26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Source	df	1	2	3	4	5	6	7	8	9
Block	3	7.588*	30.977	3.245	5.839	3.672	1.463	2.476**	16.53	4.737
Treatment	4	5.769	209.592**	502.219**	486.53**	151.45**	388.72**	445.297**	1373.70**	250.77**
Error	12	2.020	14.120	6.673	15.45	1.334	2.307	3.549	19.777	10.208

Dates of observation		16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Source	df	10	11	12	13	14	15	16	17	18
Block	3	7.978	21.485	31.84**	5.622	18.634	0.335	9.29	12.027	1.857
Treatment	4	646.66**	464.79**	959.27**	809.538**	1022.77**	214.195**	467.86**	886.954**	355.196**
Error	12	5.693	7.37	4.826	6.617	6.008	2.120	2.694	4.91	4.998

* Significant at 5 per cent level.

** Significant at 1 per cent level.

APPENDIX IX

Mean Squares of Analyses of Variance for runoff percentages (Transformed data) as affected by different treatments and dates of observation

Dates of observation		26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Source	df	1	2	3	4	5	6	7	8	9
Block	3	7.588*	30.977	3.245	5.839	3.672	1.463	2.476**	16.53	4.737
Treatment	4	5.769	209.592**	502.219**	486.53**	151.45**	388.72**	445 .297**	1373.70**	250.77**
Error	12	2.020	14.120	6.673	15.45	1.334	2.307	3.549	19.777	10.208

Dates of observation		16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Source	df	10	11	12	13	14	15	16	17	18
Block	3	7.878	21.485	31.84**	5.622	18.634	0.335	9.29	12.027	1.857
Treatment	4	646.66**	464.79**	958.27**	809.538**	1022.77**	214.195**	467.96**	986.954**	355.196**
Error	12	5.693	7.37	4.826	6.617	6.008	2.120	2.694	4.91	4.998

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX X

Mean Squares of Analyses of Variance for the pH of runoff water

Dates of observation		26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Source	df	1	2	3	4	5	6	7	8	9
Block	3	0.0067	0.01917	0.0578*	0.0218	0.0592	0.0345**	0.0112	0.0173	0.0352*
Treatment	4	0.00075	0.00575	0.005	0.0633	0.0233	0.0100	0.0295	0.002	0.02**
Error	12	0.0121	0.03042	0.012	0.0323	0.0413	0.0103	0.1117	0.0157	0.0093

Dates of observation		16.11.79	19.11.79	21.11.79	23.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Source	df	10	11	12	13	14	15	16	17	18
Block	3	0.0418	0.0325	0.0193	0.0125	0.0205	0.0098	0.0178	0.0147	0.0565
Treatment	4	0.0283	0.0095	0.0033	0.0093	0.0170	0.0138	0.0138	0.0408	0.0108
Error	12	0.0256	0.0208	0.0299	0.0196	0.0350	0.0144	0.0241	0.0251	0.029

* Significant at 5 per cent level.

** Significant at 1 per cent level.

APPENDIX XI

Mean Squares of Analyses of Variance for electrical conductance of runoff water (micromhos/ cm).

Dates of observation		26.9.79	29.9.79	11.10.79	15.10.79	27.10.79	28.10.79	30.10.79	7.11.79	13.11.79
Source	df	1	2	3	4	5	6	7	8	9
Block	3	371.73*	30.91	17.67	134.71*	686.47	25.74	66.47	51.68	360.84
Treatment	4	26.05	275.19	227.34	44.63	422.46	30.70	126.57	96.89	71.91
Error	12	104.12	205.04	123.62	32.60	276.78	67.29	101.31	62.88	298.73

Dates of observation		16.11.79	19.11.79	21.11.79	25.11.79	28.11.79	7.4.80	17.4.80	26.4.80	20.5.80
Source	df	10	11	12	13	14	15	16	17	18
Block	3	173.68	79.54	36.25	16.22	20.04	147.72	56.87	76.71	40.65
Treatment	4	46.42	119.42	54.46	88.77	21.50	66.95	11.67	36.65	130.17*
Error	12	107.14	129.66	87.15	84.62	89.36	51.03	51.49	32.40	35.42

* Significant at 5 per cent level.

APPENDIX XII

Mean Squares of Analyses of Variance for surface soil moisture storage (mm)

Dates of observation		17.9.79	29.9.79	13.10.79	27.10.79	10.11.79	24.11.79	8.12.79	23.12.79	5.1.80	19.1.80
Source	df	1	2	3	4	5	6	7	8	9	10
Block	3	2.192	7.854	7.223	11.476	6.987	2.807	30.290	32.587*	9.273	8.767
Treatment	4	16.459**	36.462*	39.973**	33.378*	34.568*	50.148*	4.035	7.313	9.475*	7.008
Error	12	1.925	7.571	5.469	8.253	7.802	9.910	17.060	7.104	2.405	6.549

Dates of observation		2.2.80	16.2.80	1.3.80	15.3.80	29.3.80	12.4.80	26.4.80	10.5.80	20.5.80
Source	df	11	12	13	14	15	16	17	18	19
Block	3	5.693	4.740	4.063	3.863	5.170	14.610	12.910	19.302*	14.798
Treatment	4	9.370	11.783	13.323*	16.643**	18.585**	99.350**	40.236**	152.159**	174.131**
Error	12	45.25	4.103	3.433	2.651	2.643	9.768	7.009	4.551	4.683

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XIII

Mean Squares of Analyses of Variance for subsoil moisture storage (mm)

Dates of observation		17.9.79	29.9.79	13.10.79	27.10.79	10.11.79	24.11.79	8.12.79	23.12.79	5.1.80	19.1.80
Source	df	1	2	3	4	5	6	7	8	9	10
Block	3	537.73*	533.42*	655.14	1001.65	1089.18*	463.84	2500.69*	2252.34	2431.56	2838.66
Treatment	4	969.91**	796.41**	1002.05*	1262.22*	1356.86*	780.47	373.01**	1001.39	2294.43	2311.76
Error	12	129.67	129.12	190.95	341.21	284.08	260.23	500.71	778.22	896.16	1133.86

Dates of observation		2.2.80	16.2.80	1.3.80	15.3.80	29.3.80	12.4.80	26.4.80	10.5.80	20.5.80
Source	df	11	12	13	14	15	16	17	18	19
Block	3	2500.10	2123.61	2363.02	2519.48	2535.26	3142.96	2622.55	2370.96	2346.30
Treatment	4	2657.53	2514.02	2696.64	3035.55	3177.66	2599.36	1303.59	1945.18	2029.25
Error	12	1127.64	1235.09	1246.71	1290.36	1305.24	1212.89	1131.14	1086.98	1055.69

* Significant at 5 per cent level.

** Significant at 1 per cent level.

APPENDIX XIV

Mean Squares of Analyses of Variance for yield and yield attributes of tapioca.

Source	df	No. of productive tubers/plant	No. of unproductive tubers/plant	Length of tubers (cm)	Mean girth of tubers (cm)	Yield of fresh tubers Kg/ha	Dry weight of tops kg/ha	Harvest index (percentage converted to angles
Block	3	11.145	13.133	20.765	0.368	1062.009*	1.008	11.02*
Treatment	3	3.017	22.615	32.277	0.322	747.909	4.292*	4.02
Error	9	4.117	13.525	10.289	1.107	221.147	0.765	2.56

* Significant at 5 per cent level.

APPENDIX XV

Mean Squares of Analyses of Variance for functional leaves per plant at monthly intervals (tapioca)

Source	df	30 days	61 days	91 days	122days	153days	181 days	212 days	246 days (at harvest)
Block	3	1.252	4.083	43.467	132.223	12.569	11.737	35.219	6.312
Treatment	3	0.981	14.399	85.986*	46.894	8.268	12.822	7.645	25.761
Error	9	1.329	3.989	13.942	50.325	14.609	9.604	42.240	11.572

* Significant at 5 per cent level.

APPENDIX XVI

Mean Squares of Analyses of Variance for total leaves per plant at monthly intervals (tapioca)

Source	df	30 days	61 days	91 days	122days	153days	181 days	212days	246 days (at harvest)
Block	3	0.990	8.082	35.95	63.322	31.032	30.163	25.964	17.173
Treatment	3	0.889	17.759*	97.24**	111.894*	91.076**	74.54	136.926	42.361
Error	9	1.472	4.533	11.773	17.005	8.962	20.312	37.954	65.879

* Significant at 5 per cent level.

** Significant at 1 per cent level.

APPENDIX XVII

Mean Squares of Analyses of Variance for height of tapioca at monthly intervals (cm)

Source	df	30 days	61 days	91 days	122 days	153 days	181 days	212 days	246 days (at harvest)
Block	3	16.41	112.25	176.91*	155.47	174.47	168.42	281.73	207.19
Treatment	3	4.64	16.83	85.43	66.46	17.59	21.40	61.14	69.26
Error	9	11.91	31.73	35.99	52.60	59.75	50.81	130.32	133.59

* Significant at 5 per cent level.

APPENDIX XVIII

Mean Squares of Analyses of Variance for Canopy of diameter of tapioca at monthly intervals (cm)

Source	df	30 days	61 days	91 days	122 days	153 days	181days	212 days	246 days (at harvest)
Block	3	35.76	88.44*	52.43	94.24	18.53*	0.49	26.50	55.50
Treatment	3	43.79	17.92	22.20	78.81	16.35*	21.34	25.67	87.12
Error	9	37.73	22.49	19.90	35.340	3.40	10.41	33.67	38.03

* Significant at 5 per cent level.

APPENDIX XIX

Dates of observation and amount of rainfall with presence/ absence of erosion in experimental plots

Dates of measurement	Amount of rainfall (mm)	Presence/ absence of erosion	Dates of measurement	Amount of rainfall (mm)	Presence/ absence of erosion
1	2	3	1	2	3
17.9.79	9.2	Planting	27.9.79	9.5	Absent
18.9.79	10.3	Absent	28 & 29.9.79	39.65	Present
19.9.79	4.1	Absent	2.10.79	8.5	Absent
20.9.79	2.5	Absent	10.10.79	6.0	Absent
22.9.79	1.4	Absent	11.10.79	25.5	Present
23.9.79	1.9	Absent	12.10.79	1.25	Absent
24.9.79	9.3	Absent	15.10.79	12.6	Present
25.9.79	9.1	Absent	16.10.79	2.75	Absent
26.9.79	12.5	Present	24.10.79	3.5	Absent.

(contd.)

APPENDIX XIX (Contd.)

1	2	3	1	2	3
27.10.79	24.75	Present	13.11.79	26.0	Present
28.10.79	20.6	Present	14.11.79	1.75	Absent
29.10.79	1.0	Absent	16.11.79	32.25	Present
30.10.79	12.5	Present	17.11.79	4.0	Absent
2 .11.79	5.0	Absent	18.11.79	3.15	Absent
3 .11.79	0.75	Absent	19.11.79	54.3	Present
4 .11.79	4.0	Absent	20.11.79	7.5	Absent
7. 11.79	12.5	Present	21.11.79	13.25	Present
12. 11.79	3.5	Absent	23.11.79	25.5	Present

(Contd.)

APPENDIX XIX (contd.)

1	2	3	1	2	3
24.11.79	9.15	Absent	26.4.80	64.0	Present
27.11.79	1.75	Absent	2.5.80	2.5	Absent
28.11.79	75.5	Present	3.5.80	5.5	Absent
2.4.80	8.0	Absent	9.5.80	6.75	Absent
3.4.80	4.25	Absent	12.5.80	5.5	Absent
7.4.80	23.0	Present	13.5.80	7.0	Absent
8.4.80	1.15	Absent	15.5.80	7.65	Absent
17.4.80	12.5	Present	20.5.80	21.0	Present
19.4.80	7.0	Absent	Total rainfall	634.05	..

EFFECT OF AGRO - TECHNIQUES ON SOIL LOSS, SURFACE RUNOFF AND SOIL MOISTURE STORAGE IN HILL SLOPES

BY

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ABSTRACT OF A THESIS

Submited in partial fulfilment of the

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A B S T R A C T

A Field experiment was conducted at the Instructional Farm, Vellanikkara during September 1979 to May 1980 to study the effect of various Agro-Techniques on soil loss, surface runoff and soil moisture storage in hill slopes. The experiment was conducted with the main objective of studying the effect of groundnut intercropping as well as the different methods of planting of tapioca on reducing soil and water losses in hill slopes.

The experiment was laid out in a Randomised Block Design with five treatments and four replications. The treatments consisted of (1) tapioca alone in mounds, (2) tapioca in mounds with groundnut as intercrop, (3) tapioca alone in ridges across the slope, (4) tapioca in ridges across the slope with groundnut as intercrop and (5) uncultivated bare fallow as a control.

The experiment was conducted in field runoff plots of 24.3M x 2.7M size. The runoff from the field were collected directly into water proof polyethylene lined earthen tanks and measured after each rainfall.

Only rainfalls more than 12.5 cm were taken for the purpose of the study.

From the experiment it is observed that AIm index was better correlated with runoff as compared to other erosion indices. Similarly EI_{15} index was better correlated with soil loss.

Maximum runoff and soil loss occurred in uncultivated bare fallow. Among the various cultivation methods, tapioca in mounds registered maximum soil and water losses.

Groundnut intercropping as well as tapioca planting in ridges across the slope were effective in reducing soil and water losses.

Uncultivated bare fallow runoff plots recorded the maximum losses of N,P and K being 107.47kg, 28.476kg, and 82.479kg/ha respectively. Among the Agro-Techniques, tapioca in mounds recorded the maximum loss of N,P and K being 44.01kg , 14.845kg and 39.08 kg/ha respectively during the entire season. However, the nutrient losses from other plots were meagre.

Maximum retention of rainfall was recorded by tapioca in ridges across the slope with groundnut as intercrop.

The pH and conductivity of runoff water were not significantly influenced by different treatments.

During the dry periods maximum storage and minimum depletion of sub soil moisture were recorded by uncultivated bare fallow plot.

The growth and yield of tapioca were not significantly affected by the groundnut intercrop. Maximum yield of tapioca was recorded by the treatment of planting tapioca in ridges across the slope without intercrop.

The yield of the intercropped groundnut was not affected by various cultivation methods of tapioca.