STUDIES ON THE PRODUCTION POTENTIAL, RUN-OFF, SOIL AND NUTRIENT LOSSES UNDER DIFFERENT SYSTEMS OF CROPPING AND MANAGEMENT PRACTICES ON STEEP SLOPY JHUM *LAND*

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CERTIFICATE

We certify that the thesis entitled "Studies on the production potential, runoff, soil and nutrient losses under different systems of cropping and management practices on steep slopy Jhum land" submitted for the award of the degree of Doctor of Philosophy in Agriculture (Agronomy), Bidhan Chandra Krishi Viswavidalaya, Kalyani, is a bonafide record of research work carried out by Shri Rajendra Prasad Awasthi under our guidance and supervision. No part of this thesis has been submitted for any other degree or diploma. The help and source of information as have been availed of in course of the investigation have been duly acknowledged.

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INTRODUCTION

In north eastern hill region of India shifting cultivation commonly known as 'Jhuming' is widely practised on steep slopes of more than 40 per cent. This most primitive system of farming, believed to have originated in the Neolithic period around 7000 B.C. (Sharma 1976), is not only confined to North Eastern Region and other parts of India but is also prevalent in other countries of the world like wet tropics of South East Asia, Africa, Central and South America (Schlippe 1956, Conklin 1957). In north east India it is practised almost in all the states with some variations from tribe to tribe except the two tribes of Angami of Nagaland and Apathani of Arunachal Pradesh (Goswami 1971).

It has been estimated that about 36 million square kilometres of land or about 30 per cent of worlds exploitable soils are at present under shifting cultivation which produce the bulk of the food for more than 250 million people or about 8 per cent of the world population (Hauck 1973). Though exact statistics is not available, a rough estimate given by Mukherji (1974) shows that 2 million people in India cultivate approximately 11 million hectares of land under shifting cultivation. According to the report of the National Commission on Agriculture (Part IX on Forestry 1976) 4,92,000 tribal families of North Eastern region of India are involved in jhuming and the total area affected by jhuming is 2,694,000 hectares while 453,000 hectares remain under jhum at any one time and these clearly indicate the magnitude and severity of the problem. The percentage of population dependent on this system of cultivation varies from 0.48 % in Assam to 80 % in Mizoram, the worst affected areas being Nagaland, Mizoram, Arunachal Pradesh and Garo Hills of Meghalaya.

In early days the system worked well and non-detrimental as it is in present days because there was a great balance between population and soil fertility and therefore restricted soil erosion (Datiri 1973) as a result of longer fallow cycle of 15 to 20 years to recoup the soil fertility, structure and organic matter content. The system was able to provide just sufficient calories with minimum risk and least income variability. But with the rapid growth of population the area under shifting cultivation is also increasing at faster rate and as a result the *jhum* cycle of restoration has gone down from 20 to 30 years in the past to 2 to 3 years at present. The system of cultivation has become one of the most unproductive systems and the farmers depending on this are nearly starving. From resources degradation point of view it can further be regarded as one of the most destructive forms of land use as well as a wasteful practice because it ~~does~~ not only involves deforestation leading to accelerated erosion and low productivity of land but also causing ecological imbalance that affects the hydrological cycle, nutrient recycling, micro-climate and biotic environments including soil micro flora and faunal activity as well as other adverse socio-economic effects (Cunningham 1963, Borthakur *et al*., 1976, Lal and Cummings 1979) ~~but also requires~~ a huge area to sustain the population. Since the time scale is involved in the process of degradation of land and water resources, its harmful effects by the common people are normally realised only when the harm has already been done to a great extent. Recent studies in India on silting of 17 major reservoirs indicated that their life had been reduced by 3 times the expected because very vast areas of forest have been deforested (Tejwani 1977). Kanwar (1972 a, b) reported that India was annually losing 6,000 million tonnes of soil from 91 million hectares which are reported to be suffering from erosion problem.

Inspite of its devastating effects on ecological system and lower productivity, the system is till continuing without any serious thought of regeneration of land. Therefore it has become a matter of great concern. However, since this method of food production is a way of life and therefore difficult to do away with, it is necessary that some remedial measures are suggested which may lead towards minimum erosion hazards resulting in sustained productivity per unit area of land. Many efforts in the past were made by various agencies to wean away the jhum cultivators from this wasteful method of cultivation but without much success primarily because the measures suggested were not in full agreement with the socio-economic and cultural structure of people basically involved with the system. Although a number of studies were made in the past but they were mainly confined to anthropological and socio-economical aspects. No worth mentioning study could be made either on the quantitative or qualitative evaluation of its effects on run-off, soil erosion and nutrient losses or to develop cropping systems with appropriate production technology to minimise soil erosion, conserve physical environment of crops for better productivity.

There is no precise information available in the north-eastern region, where the rainfall is high and slopes are very steep, on the quantitative and qualitative evaluation of the effect of different cropping system on the productivity of crops, on run-off, soil erosion and nutrient losses. Keeping these ideas in view, the present investigation was undertaken by involving ten different treatments, comprising of cropping,systems and management practices with the following broad objectives :

1. Crop production potentiality under different cropping systems and fertilizer management following clearing and burning of vegetation in slopy land.

2. To estimate the run-off, soil erosion and nutrient losses under different cropping and land use systems.

3. To estimate the different parameters of erosion equation most applicable on steeper slopes in the north east hill region.

4. To explore the economic feasibility of continuous cropping through adequate fertilization.

2. REVIEW OF LITERATURE

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Shifting cultivation has been practised in different forms throughout the world since time immemorial. Out of the tropical zone it is also prevalent in Korea in temperate Asia. It was practised in Sweden even upto 1920. In Asia apart from India, shifting cultivation is found in Philippines, Indo-China, Malaysia, Burma and Ceylon. In India, it is also practiced in Orissa, Andhra Pradesh and Madhya Pradesh (Palit, 1973; Borthakur, 1976). The system of cultivation is known by different names in different parts of the world such as "Milpa" in Mexico and Central America "Conuco" "Roza" "monte" and "Chaco" in south America, "Kaingin" in the Philippines, "Chena" in Sri Lanka, "Lua" in Vietnam, "ray" in Laos, and "ladong" in Indonesia. In English it is also called "Slash and burn agriculture" "bush fallowing" and "Swidden farming". Recently the term "Land rotation" was coined for shifting cultivation systems in which the farmers live in permanent settlements, as opposed to "true" shifting cultivation, in which both fields and settlements move (Sanchez, 1976).

In north-eastern India it is known as 'Jhum', in Orissa 'padu', 'Dabi', 'Koman' or 'Bringa' in Bastar as 'Deppa', 'Kumari', in Western Ghats 'Wat', in S.E. Rajasthan 'penda', 'Bewar' or 'Dahia' in Madhya pradesh (Bhowmik, 1976).

Approximately ten million hectares are cleared annually by shifting cultivation alone and it is estimated that because of increasing demographic pressure the arable land area in tropical countries may have to be increased from 737 million hectares in 1970 to 890 million hectares in 1985, with an annual rate of 6 to 10 million hectare of new land development (Boerma, 1975; Boer, 1977; Thijsse, 1977; a, b; Silva and Laurence, 1977).

There are many aspects on which further investigations are needed to derive more precise and specific information with particular reference to soil, climate, vegetation and land forms which may be of practical and scientific value. Although very little information is available on these aspects under humid and sub-humid tropical conditions more specifically under traditional situations where cultivation has become one of the most menacing problems. However, a good deal of work has been done in other countries of the world where various workers have studied run off and erosion losses under different soils, crops and cropping systems under varying slopes and management practices and some of the governing principles involved in the process.

2.1 Loss of biomass/natural vegetation

The main concept of shifting cultivation is dependence on forest regeneration period as the source of nutrients to crops. These nutrients are gradually accumulated during the fallow period and provide an alternative to fertilization. The total biomass of mature tropical forest ranges from 200 to 400 t / ha of dry matter. Studies conducted in Zaire (Bartholomew et al, 1953), Ghana (Greenland and Kowal, 1960), Panama (Golley et al, 1969) and Puerto Rice (Ovington and Olson, 1970) indicated that the proportion of the main forest parts is fairly constant. Approximately 75 % of the biomass consists of branches and trunks, 15 to 20 % of roots, 4 to 6 % of leaves and 1 to 2 % of litters. DeByle and Packer (1972) reported fuel load of 115 tonnes / acre on Miller Creek (elevation ranging from 4200 to 5000 feet with a slope average of 24 % and a range from 9 to 35 %) and 104 tonnes per acre on Newman Ridge (elevation ranging from 4400 to 5400 feet with a mean slope of 55 % ranging from 44 to 76 %). About 88 % of this fuel was coarse debris more than 4 inches in diameter.

2.2 Nutrient storage in vegetation

The range of nutrient content in total biomass of mature forests in Zaire, Ghana, Panama and Puerto Rice reported by Sanchez (1976) were nitrogen 701 - 2044, phosphorus 33 - 137, potassium 600 - 1017, calcium 653 - 2760, magnesium 381 - 3890, sulphur 196, iron 43, zinc 13, manganese 5 and copper 3 kg / ha.

2.3 Nutrient storage in soil

The magnitude of the nutrient storage capacity of west African Alfisols in equilibrium with a mature forest was estimated by Greenland and Kowal (1960). The top 30 cm layer of an Alfisol contained 2.6 times as much total nitrogen as the biomass and about the same amount of exchangeable calcium and magnesium as the total plant, calcium and magnesium. The top soil contained 75 % of the biomass potassium as exchangeable potassium but only 9 % of the biomass phosphorus as available phosphorus (Sanchez, 1976).

2.4 Mining of nutrients

The existence of a nearly closed nutrient cycle between a mature tropical forest and the soil was first recognised by Hardy (1936) in Trinidad.

The available literature that includes all the four sources of nutrient transfer is that of Nye (1961) for an Alfisol from Ghana which is given in the following table.

Table 1 Annual nutrient additions from a mature forest to an Alfisol in Ghana

Transfer pathway	Dry matter (kg/ha)	Nutrient (kg/ha)				
		N	P	K	Ca	Mg
Rain wash		12	3.7	220	20	18
Litter fall	10,528	199	7.3	68	206	45
Timber fall	11,200	36	2.9	6	82	8
Root decomposition	2,576	21	1.1	9	15	4
Total	24,304	268	15.0	303	332	75
Annual turn over (%)	7	13	11	33	12	19

Source : Sanchez 1976 as calculated from data by Nye (1961)

The nutrient additions from the vegetation to the soil are nicely balanced by the nutrient uptake by the vegetation from the top soil. Apparently the shallow nature of tropical forest roots provides a very effective means of maintaining a newly closed nutrient cycle (Nye and Greenland, 1960).

Dommergues (1963) observed that total dry weight of the vegetation in a mature forest may be as much as 3,400 t / ha contributing annually 200 kg N, 100 kg P, 900 kg K, 2700 kg Ca, and 250 kg mg, to the soil.

2.5 Effects of clearing and burning on soil properties

The process of shifting cultivation starts with the clearing and burning operations of the existing vegetation which not only affects the vegetative ground cover but also many physical and chemical properties of soils and thereby influencing run-off and soil erosion behaviour to great extent.

2.5.1 Temperature

Air temperature over a burning tropical forest may attain 450 to 650°C at 2 cm above the soil surface. Temperatures decrease at a rate of 100°C / cm below the soil surface for the first 5 cm (Zinke *et al.*, 1978). Below this depth no changes in soil temperature was recorded during burning in Colombia (Suarez de Castro, 1957). The maximum air temperature increased from 25 to 32°C after a forest was cleared in Thailand, but no change was recorded in minimum air temperature (Applied Scientific Research Corporation of Thailand, Bangkok ASRCT 1968).

The maximum soil temperature at 7.5 cm depth increased from 27 to 38°C when the forest was cleared in Ghana, while the minimum temperature remained at 24°C (Cunninghan, 1963).

Sanchez (1976) reported increase in top soil temperature by 7 to 11°C when a forest was cleared because of higher solar radiation. Lal and Cummings (1979) reported soil temperature of 80°C at 2 cm depth ~~and may~~ which might exceed 40°C even as deep as 10 cm.

Vegetation removal increases diurnal soil temperature fluctuations to levels as high as 20 to 30°C in Nigerian Aftisols (Lal *et al.*, 1975). In a virgin forest of Gautemala only 4 per cent of the total solar radiation reaches the soil surface (Snelaver, 1970). Consequently, the incoming solar energy reaching a cleared soil is 25 times greater than in the forest.

2.5.2 Physical properties

Amongst the physical properties soil structure~~s~~, water holding capacity, porosity and infiltration are generally affected by temperature which depends on the type, quantity of burning materials and duration of burning.

2.5.2.1 Soil structure

It is known that clearing and burning cause a deterioration of soil physical properties. Burning increased infiltration rates and the soil aggregate fractions larger than 0.25 mm in an Andept of Colombia (Suarez de Castro. 1957). Popenoe (1957) reported that the bulk density of the 5 to 10 cm layer of Guatemalan volcanic soils increased from 0.56 to 0.66 g / cc after clearing and decreased from 0.74 to 0.70 g / cc after 3 or 5 years of forest regeneration. Similar result has been also reported by Packer and Williams (1976).

Sharp decrease in infiltration rate on an Oxisol of Brazil from 82 to 12 cm / hour was recorded when the original forest was cleared and the land was cultivated for 15 years (Moura and Buol, 1972). In Alfisols of Nigeria, Lal et al (1975) reported reduced infiltration rates after forest clearing and cultivation. A decrease in total porosity from 52 to 43 % and a similar decrease in water stable aggregates over 3 years of clearing were reported on Alfisols from Ghana, which were kept bare for that period of time (Cunningham, 1963). Seubert (1975) recorded decreased infiltration rate from 26 to 14 cm / hour after clearing a mature secondary forest on sandy ultisols of peruvian Amazon during the first year. In Alfisols from Tripura (India), Jha et al (1979) reported decreased water holding capacity of soil due to burning.

2.5.3 Chemical changes

2.5.3.1 Ash composition

The composition of ash depends upon the type of burning materials. Ramakrishnan and Toky (1981) reported higher concentration of Ca in dicot trees, K in bamboo and P in herbaceous species. Seubert (1975) analysed the ash samples collected immediately after burning a 17 years old secondary forest growing in Ultisol of Peru. The ash contained N (1.72 %), P (0.14 %), K (0.97 %), Ca (1.92 %), Mg (0.41 %), Fe (0.19 %), Mn (0.19 %), Na (180 ppm), Zn (137 ppm) and Cu (79 ppm).

2.5.3.2 Changes in soil P^H

The extent of change in soil P^H depends on the soil properties and quantity of ash. In an Alfisol from Ghana, Nye and Greenland (1964) showed that the P^H increased from 5.2 to 8.1 in the top 5 cm layer right after burning and decreased to 7.0 after 2 years. The P^H in the 5 to 15 and 5 to 30 cm layers increased from 4.9 to 6.2 with burning and decreased to 5 after 2 years. Borthakur et al (1981) reported increase in P^H due to burning by 0.4 unit in Ultisol of Meghalaya. Awasthi et al (1981) recorded change in P^H from 5.1 to 6.6 in the bun system of burning in Alfisol from Central Plateau of Khasi Hills (Meghalaya). Brinkmann and de Nascimento (1973) showed that the P^H of Oxisol top soils increased from 3.8 to 4.5 with burning and decreased quickly to original level within 4 months. Seubert (1975) found that the P^H increased from 4.0 to 4.5 in the top soil of an Ultisol and this level remained stable during first year. Zinke et al (1978) reported increased P^H of soil in Thailand due to burning but it came back to original P^H after 4th year of regrowth. Ellis et al (1982) also reported increased P^H in the soil of Tasmania (Australia).

2.5.3.3 Exchangeable bases

The changes in exchangeable Ca, Mg, K levels after burning have been reported by Ellis et al, (1982) and Nye and Greenland, (1964), Borthakur et al, (1981) and Zinke et al (1978). Increase in the concentrations of bases depends on the type of forest vegetation. Ellis et al (1982) reported, 250, 150 and 20 per cent increase in the concentration of Ca, Mg and K in mixed forest against only 30 % increase in Ca in dry sclerophyll forest in Tusmania. Percent base saturation in former vegetation increased from 39 to 60 per cent against 63 to 71 per cent in case of latter. Similar trends of exchangeable cations were reported by Perry et al (1958) Charles Grier and Cole (1971) Nye and Greenland (1974) and Seubert (1975), Theodore et al (1976).

2.5.3.4 Soil organic matter

Although burning volatilizes most of the carbon, sulphur and nitrogen present in the vegetation, it has little effect on soil organic matter. Burning in the process of shifting cultivation does not destroy soil organic matter. Soil temperature during burning are not high enough for a sufficiently long time for combustion, except in reburn pile situations (Sanchez 1976). Studies by Nye and Greenland (1964) in Ghana, Seubert (1975) in Peru actually showed small increase in soil organic carbon and total nitrogen after burning. Increase in organic carbon after burning has been also reported by Nye and Greenland (1964) and Lal and Cummings (1979). These have been attributed to incomplete combustion of the vegetation and measurement of charcoal particles as organic carbon (Sanchez 1976). On the other hand Borthakur et al (1981), Ellis et al (1982), Zinke et al (1978), Jha et al (1979) reported a decrease in the content of organic carbon. Ellis et al (1982) found that mean concentrations of both C and N for burnt coupes were lower than those of uncut control, although the ratio did not differ. Sanchez (1982) working on the dynamics of nitrogen in shifting cultivation and related cropping systems in the humid tropics of Latin America under predominated oxisols and ultisols reported that losses of nitrogen through clearing and burning are at about 20 to 25 % of the N existing in the eco-system.

2.5.3.5 Cation exchange capacity

Brams (1971) in two oxisols from Sierro Leone observed that a 50 per cent reduction in soil organic matter within 5 years after clearing resulted in a 30 per cent reduction in CEC. Sanchez (1976) reported that the change in p^H and organic matter contents of soils under shifting cultivation affected their effective CEC because of the predominant p^H dependent status in many shifting cultivation areas. During the first few months after burning the effective CEC of a Peruvian Ultisol increased from 2.9 to 3.4 meq per cent, probably as a result of the p^H increase due to burning. At later stage CEC decreases because of decrease in p^H and soil organic matter contents. Theodore et al (1976) however reported lower C.E.C. after burning. Ellis et al (1982) also reported increase in CEC for the first two years and then decreased slightly in the soils of Tasmania (Australia). Zinke et al (1978) also reported increased CEC in burnt samples in soils from Thailand.

2.5.3.6 Available P

The available P level of a soil increases upon slash and burning because of high phosphorus contents in the ash. Nye and Greenland (1960) reported increase in P from 7 to 25 kg P / ha. Zinke <u>et al</u> (1978) obtained higher value of P in burnt field (1.1 g / m^2) than the unburnt forest (0.2 g / m^2). Awasthi <u>et al</u> (1981) and Borthakur <u>et al</u> (1981) reported slight increase in available P due to burning in the Alfisols and Ultisols of Meghalaya (India).

The decrease in available phosphorus with cropping has also been reported by Sanchez (1976) and Zinke <u>et al</u> (1978).

2.6 Effect of land clearing, different crops, cropping systems and management practices on run off and soil losses

2.6.1 Effect of land clearing on runoff & soil losses

Popenoe (1957) reported little surface erosion in cleared fields having steep slopes because of low bulk density of the soil. Suarez de Castro (1957) under soil conditions of Colombia reported that run off decreased after clearing and this he attributed was due to increase in permeability of soil due to burning. Le Buanec (1972), Lal (1974) and Lal <u>et al</u> (1975), based on their studies in Ivory Coast and Nigeria, reported huge amounts of soil loss after land clearing. Singh and Singh (1978) from steep hill slopes of Burnihat (India) reported 3 - 7 tonnes of soil per hectare to slide down in the process of cutting the forest, burning, clearing and dibbling of seeds. Singh (1978) in a study on soil erosion under shifting cultivation from steep hill slopes (80 to 70 %) at Burnihat estimated 146.6 and 170.2 t / ha of soil losses during first and second year of shifting cultivation as against the soil losses of 30.2 and 8.2 t / ha / yr under abandoned <u>Jhum</u> land (1st year follow) and bamboo forest respectively.

2.6.2 Effect of different crops and cropping systems on run off and soil losses

Suarez de Castro (1955) from his study on erosion in a coffee producing region of Colombia on 43 % slope reported water losses in excess of 50 % of the total rainfall and soil losses of over 500 t/ha/y from base plots. He also observed that during the same period adjacent plots with 53 % slope having good vegetative cover had negligible water and soil losses. Hudson (1957) from his study on 4.5 % slope reported 127 times greater soil loss and 13 times greater runoff from the unprotected ferrallitic sandy clay loam soil than plots covered with mosquito gauge nylon net. A plot with grass cover gave results similar to the one with mosquito gauge net cover. Similar results have been reported from elsewhere also (Hudson 1957, Hutchinson et al. 1958, Hudson and Jackson 1959, Elwell and Stocking 1976). Langbein and Schumn (1958) and Douglas (1967) indicated that sediment yield increased with effective rainfall upto a point where improved vegetative ground cover leads to less erosion.

Horner (1960) working on the effects of cropping systems on runoff, erosion and crops yield on Palonse silt loam at Pullman, Washington, reported that crop rotations that include legume grass sod crops were more effective for runoff and erosion control, maintenance of soil organic matter and high wheat yields than the unfertilized pea-wheat and fallow systems. Summer following caused the largest erosion losses and the most rapid depletion of organic matter.

Roose (1967) reported from his work in Senegal that on plots cultivated for 10 years, the surface runoff accounted for 21 per cent of the rain water and carried 9.26 t / ha of soil per year. On an average a layer of 0.6 mm deep was removed annually. Fournier (1967) observed that erosion losses even on 1.5 % slope were 1420, 433 and 945 tonnes per km^2 under sorghum, groundnuts and rice respectively. Kelman (1969) in a study on soil loss from small plots with 25 % slope in Mt.Apo reported exponential rate of increase in soil loss with decreasing vegetative cover. Kowal (1972) reported from northern Nigeria, an average soil loss of 10 t / ha / yr. Charreau (1972) from West Africa recorded negligible runoff and soil erosion under forest cover. Soil erosion under grass fallow occupied intermediate position between forest and cultivated land. Wrigley (1969) from a catchment study of Mbeya Range reported maximum runoff from cultivated catchment to an extent of 76 cusec / m^2 as compared with 12 causec / m^2 from the forested region. Rapp et al (1972) reported a negligible soil loss from thicket grass plot.

Young (1974) reported negligible soil loss from virgin forest. Brunig (1975) also reported very low amount of soil loss of 0.2 t / ha under virgin forest whereas cultivation increased soil loss to an alarming rate of 600 to 1200 t / ha / yr.

While reviewing the erosion losses from agricultural lands (runoff plots), Tejwani et al (1975) found that losses were the highest in bare fallow and the least under grass cover. Legumes such as moong (Phaseolus aureus) and cowpea (Vigna sinensis) suffered lower erosion losses than non-legume such as jowar (sorghum vulgare), bajra (Pennisetum typhoideum) and maize (Zea mays).

Elwell and Stocking (1976) proposed that vegetal cover should be included as an independent factor in the universal soil loss equation, on the basis of the very significant differences in cover produced of different growth stages by crops and differences observed in soil erosion when the soil was even partially protected by netting (Aina et al., 1979).

Chakraborty (1976) on the basis of his study through designed runoff plots under Tripura condition reported that under natural grass cover 49.5 % of the precipitation was lost as runoff with a corresponding soil loss of 1432.0 kg / ha from 3 % slope whereas 62.6 % of the precipitation was lost with corresponding loss of 2440.0 kg / ha from 6 per cent slope.

Khybri et al (1977) studied the soil conservation value of common hill crops and grouped them into three classes as follows :

i) High runoff and soil loss - Maize, soybean (Glycine max)
ii) Medium runoff and soil loss - Jhangora (Paspalum scorbiculatum) Mandua (Elusine coracana) and Niger (Guizotia abyssinica)
iii) Low runoff and soil loss - Napier grass (Pennisetum purpureum)

Juo and Lal (1977) found perennial or annual pigeon pea as a good soil building and conserving crop Aina, Lal and Taylor (1979) reported that vegetal cover provided by close canopy and low growing soybean was quite effective in controlling erosion.

At Kota, Pratap Narain et al., (1978) reported higher soil loss and runoff under soybean (Glycine hispida) and urd (Phaseolus mungo) (about 6 t / ha and 20 % of rainfall) when compared with jowar + arhar (cajanus cajan) and cowpea (about 3.3 t / ha and 14 % of rainfall).

Bhatia and Chaudhary ~~et al~~ (1977) on the basis of a study at Kanpur with 2.35 per cent slope reported minimum soil loss from Jowar plot on contour while loss for up and down cultivation was minimum under maize crop.

2.6.2.1 Strip cropping

In West Africa strip cropping showed limited success in reducing runoff and erosion losses. The results of experiments conducted at IITA (1974) on the effect of different vegetal covers on runoff soil losses were in order of cowpea>rice>maize (Lal 1974). Conjon et al (1968) from experiments in Madagascar recommended that contour benches be planted with grasses to reduce runoff losses. Jurion and Henry (1969) suggested improvement of shifting cultivation by developing a corridor system of rotation which although was found successful in reducing runoff losses and soil erosion, yet it was a washful use of land and certainly ~~by~~ not an intensive method of land utilization. Roose and Bertrand (1971) found that permanent grass strips 2 to 4 m wide were effective in controlling runoff losses.

Dimiterescu (1977) working on the contribution of growing crops in strips in the Moldavion plain emphasised the advantages of growing crops in strips. However, the results of experiments on strip cropping conducted at IITA using alternate strips of maize and cowpeas were not in favour of strip cropping (Lal 1974)

2.6.2.2 Mixed cropping

One of the most characteristic features of 'Jhum' cultivation is mixed cropping which besides, meeting the food requirements, ensures greater risk minimization. Mixed cropping, with the so called soil depleting and soil protecting crops has been tried by many researchers. Michandani et al (1958) studied the effect of mixing pigeon pea or blackgram in 'gora' paddy and maize on soil and water loss in runoff plots. They observed that mixed cropping did not reduce soil loss which varied from 3.28 to 2.55 t / ha and runoff which varied from 8.6 to 6.4 per cent of total rainfall.

Hays (1961) showed that total soil and water loss from agricultural areas can be reduced significantly by inter planting of legumes between corns. Norman ~~et al~~ (1974) concluded on the basis of experiments conducted upto mid 1960's in Kenya, Malawi, Nigeria, Sudan and Tanzania that more than one acre of crops in monoculture was required to equal the yield of an acre of intercropping. ~~They~~ He advocated intercropping as one of the modifications and alternative to shifting cultivation. Recent studies on intercropping under optimum technology by Harwood (1973), Rao (1974) and Krantz et al (1974) indicated substantial (50 % or more) yield increases from various combinations of alternate row cropping over these of two separate pure cultures. Fournier (1967) reported that mixed cropping of maize with mascatle peas proved effective in controlling soil erosion in Madagascar. In India its importance was highlighted almost 30 years ago by Aiyer (1949).

The effect of intercropping maize with *Stylosenthes gracilies* was investigated at International Institute of Tropical Agriculture (IITA) 1972 at Nigeria. *S. gracilis*, though it provided excellent protection against runoff [illegible] erosion, was found to be aggressively growing crop and competes strongly with maize for the small quantity of available water in the root zone (Lal 1974). At Deochanda Research Station of Damodar Valley Corporation (DVC), Hazaribagh (Anon, 1972), it was found that 'gora' paddy + Jowar was the most suitable mixed cereal crop for reducing erosion (4.1 tonnes / ha soil loss and runoff 17.2 % of rainfall) when compared with mixing either blackgram, finger millet, ground nut, pigeonpea, maize, cotton (*Gossypium* spp.) or castor with 'gora' paddy (4.7 - 8.4 tonnes / ha soil loss and runoff 21.5 - 24.5 per cent of rainfall). At DVC, Hazaribagh, intercropping of cowpea with cotton reduced soil loss from 6.4 to 4.1 t / ha and runoff from 30 to 19 per cent when compared with cotton alone; ground nut and greengram reduced the soil loss and runoff to some extent and blackgram and cluster bean did not have any effect on soil runoff and soil loss (Anon, 1972).

Greenland (1975) has emphasised that mixed cropping has a significant role in tropical agriculture. Lal (1976) observed that a crop with rapid development of ground cover such as soybean and cowpea, would be suitable for those regions where frequency of erosive storms is high, especially early in the growing season.

In study conducted at Burnihat in mini watersheds to evaluate the effect of different land uses on runoff and sediment yield Borthakur _et al_ (1978) reported a loss of 13.3 and 214.8 mm of water as runoff with corresponding soil losses of 5.1 and 76.8 t / ha during first and second year of shifting cultivation respectively. At Kota, Pratap Narain _et al_. (1978) reported higher soil loss and runoff under soybean (Glycine hispida) and urd (Phaseolus mung) (about 6 t / ha and 20 % of rainfall) when compared with Jowar + arhar (Cajanus cajan) and Cowpea (about 3.3 t / ha and 14 % of rainfall).

Thomas _et al_ (1981) in a study of relationship between erosion losses and grass cover suggested that a critical value of 15 to 20 % is important. A value less than this erosion was found to be intense whereas at higher values above 15 to 20 % there is little further reduction in soil loss. Dunne (1979) also reported similar result from the range land areas of Kajiado.

Newman _et al_ (1979) reported that while yield of individual crop grown in mixture was depressed such reductions were more than offset by intercrops mixtures resulting in higher returns per mixture in terms of value, as well as higher and more evenly spread out employment of labour, as compared to mono-cropping.

2.7 Effect of different cropping systems and management practices on nutrient loss

2.7.1 Organic carbon and nitrogen

Duley and Miller (1923) obtained a loss of 111 kg of nitrogen from 5818 kg of soil loss per hectare from fallow shelby loam on 3.68 % slope of which only 6.7 kg was in nitrate form. Duley (1926) reported very small losses of nitrogen in ammonium nitrate and nitrate ionic form because he observed that soluble nitrogen was mostly in organic form but annual loss of nitrogen in this form was insignificant.

Knoblauch _et al_ (1942) reported an annual loss of 1287 kg. and 75 kg / ha of organic matter and nitrogen from plots left fallow as against a loss of 377 kg and 21.3 kg / ha of organic matter and nitrogen, respectively when cover crop was established and manure applied from Collington sandy loam soil having 3.5 per cent slope.

Neal (1943,1944) obtained an enrichment ratio as high as 4 to 4.7 for organic matter from Collington silt loam. Hays *et al* (1948) obtained an annual loss of 47 kg / ha of nitrogen from Fayette silt loam planted to oats but this loss was reduced to 2.2 kg / ha when planted to corn.

Free (1946) observed no difference between ammonical form of nitrogen in eroded soil and original soil from Heneoye silt loam, but found that eroded material contained 48 % less nitrate nitrogen than the original soil. Bryant and Slater (1948) reported an annual loss of 11.6 kg / ha of dissolved nitrogen from Dunkirk sandy loam on 5 % slope and less than 1.1 kg N / ha from Ontario sandy loam on 8 % slope. Hays *et al* (1948) reported an annual loss of 1065 kg / ha of organic matter from moderately eroded Fayette silt loam and 748 kg / ha from severely eroded phase. Jackson (1952) and Massey *et al*. (1953) in their study from two Wisconsin soils obtained an enrichment ratio of 1.34 and 1.24 for total nitrogen and organic matter from Alemna silt loam and an enrichment rates 1.08 and 1.15, respectively from Fayette silt loam. Moe *et al*. (1967) observed the greatest loss of nitrogen to an extent of 1.5 % of the applied fertilizer nitrogen after 5 inches of rainfall from sod and fallow plots receiving ammonium nitrate pellets.

Goel *et al*. (1968) working on an alluvial soil at Lucknow (India) found that the loss of nutrients increased with increase in the degree of slope. They reported that with an increase from 1.5 to 3.0 per cent slope, the losses in respect of organic matter, nitrogen, phosphorus and potash were doubled while the losses in respect of calcium and magnesium was more than three times.

Goel and Khanna (1969) in their study ~~from~~ in Uttar Pradesh (India) observed that the loss of nutrients from plots left fallow on 8.5 per cent slope were two to three times higher than the losses when the plots were under some crop. They reported a loss of 245.8 kg / ha of organic matter from cultivated fallow-barley treatment. This loss was reduced to 86.9 kg / ha under sesamum -

gram rotation. They further estimated the losses of plant nutrients by water erosion in alluvial tracts of Uttar Pradesh under different cropping pattern. Losses of total N varied from 7.37 to 13.64 kg / ha under various crop rotations.

Bhat et al. (1971) reported highest loss of nitrogen amounting to 228.1 kg / ha under cultivated fallow followed by 79.9 kg / N / ha under maize-wheat rotation and no loss of nitrogen under grass cover under Dhulkot silty clay loam soil on 8 % slope at Dehradun (India). Bhat et al. (1971) in their study from Dhulkot silt clay loam on 8 per cent slope in Doon valley (India) obtained a loss of 2167.7 kg / ha of organic carbon under cultivated fallow conditions, whereas the loss from grass cover was nil.

DeByle and Packer (1972) reported a loss of 387 kg / ha of organic matter from Newman Ridge. Kowal (1972) reported an average loss of nitrogen ranging from 7 to 19 kg / ha per year for some soils in Northern Nigeria. Lal (1976) observed that the magnitude of nitrogen losses in runoff is affected by cropping systems and mode of crop residue management. Based on observations from small runoff plots, he found that losses of nitrate nitrogen in the runoff water during one season 1973 were 3.3 kg / ha from bare fallow, 1.5 kg / ha from conventionally tilled maize, 0.1 kg / ha from no till maize, and 0.04 kg / ha from unmulched maize plots.

Borthakur et al. (1978) from their study at Burnihat reported a loss of 84.7 and 1321.0 kg / ha of organic carbon from the first and second year of 'Jhum' cultivation.

Jayaram et al. (1982) reported an enrichment ratio of 2.09 and 2.43 for organic matter and 2.55 and 2.21 for nitrogen loss from the clay soils of two plots planted to sorghum and safflower, respectively on an average slope of 1.5 per cent from rainfed vertisols of Bellary (India).

2.7.2 Phosphorus

Scarseth and Chandler (1938) observed that phosphorus applied to the soils remain in the surface layers unless mechanically incorporated into lower depth. They concluded that 60 per cent of the superphosphate applied over a 26 year period was lost by erosion from a nearly level field of Norfolk loamy sand under cotton-corn-oat legume rotation.

Rogers (1942) obtained an enrichment ratio of 1.3 for total phosphorus, as estimated by 0.002 N sulphuric acid, from Dunmore silt loam on 20.25 % of slope cropped to wheat.

Rogers (1942) reported loss of phosphorus from applied tripple superphosphate on Dunmore silt loam in a permanent pasture through simulated rainfall. From the first one inch shower, the loss was 9.1 % of the 224 kg superphosphate applied per hectare. The second shower carried away 4.3 % of the initially applied phosphate. Under simulated showers on dry soil about 22 % of the applied phosphorus was eroded away initially.

Volk (1945) could not account for 26 % of the native and applied phosphorus over a 14 year period on Hartsell fine sandy loam planted to cotton and he considered this loss to have occurred through erosion. Bedell <u>et al</u>. (1946) observed that nearly 60 % of phosphorus lost through erosion was in organic form. Ensminger and Cope (1947) reported 70 per cent loss of added phosphorus to an unlimed nearly level Norfolk sand cropped to cotton.

Ensminger (1952), working with Hartsell fine sandy loam of 2 to 4 per cent slope, considered that phosphorus that could not be accounted for in the surface 16 inches of soil, plus that removed by crops, was lost through the process of erosion.

Gupta and Singh (1967) from their study on Gangetic alluvium tracts of Uttar Pradesh (India) observed that calcium bound phosphorus was more vulnerable to erosion losses than aluminium bound and iron aluminium occluded phosphorus.

Lal (1976) mentioned that movement of phosphorus from agricultural lands was primarily with the soil solids. He reported that loss of phosphorus in tropical regions may be as low as 0 to 2 kg / ha per season as measured from runoff plots. Borthakur <u>et al</u>. (1978) reported a loss of 80 and 211 kg of P_2O_5 / ha from first and second year of 'Jhum' cultivation.

Jayram *et al.* (1982) working under Bellary conditions of India obtained an enrichment ratio of 2.09 and 2.43 for total phosphorus from the clay soils of two plots planted to sorghum and safflower, respectively.

2.7.3 Calcium, potassium and magnesium

Duley and Miller (1923) reported a loss of total Calcium amounting to 424.5 kg / ha from bare uncultivated soil from Shelby loam as compared to no loss under sod cover. Daley (1926) observed that annual loss of potassium in solution from Shelby loam was only 1.1 kg / ha under wheat and 10 - 1 kg / ha under sod.

Miller and Krusekopf (1932) reported a total loss of 513 kg / ha of total calcium and 200.5 kg / ha of magnesium from Shelby loam cultivated to a depth of 10 cm.

Kohnke (1941) observed that although little is known about potassium losses from newly fertilized fields, but such losses could be significant when light rains occur or during the first period of more intense storms.

Knoblaugh *et al.* (1942) obtained losses of total potassium amounting to 477 kg / ha from Collington sandy loam where as this loss was reduced to 110 kg / ha under a cover crop receiving manure. Yearly losses of total potassium from freshly ploughed Shelby loam in Missorie were found to be as high as 1400 kg / ha and this loss was reduced to less than 3.4 kg / ha under blue grass sod cover. Knoblauch *et al.* (1942) reported an annual loss of 113 kg / ha of total calcium from unprotected Collington sandy loam soil whereas this loss was reduced to 28 kg / ha under manure applied good crop cover with an enrichment ratio of 2.41 and 2.06, respectively. Higher values of enrichment ratio for available potassium have been reported by various workers (Roger, 1941, Massey *et al.*, 1953 and Stoltenberg and White 1953). Neal (1943, 1944) obtained an enrichment ratio of 5.4 for available potassium as compared to 1.4 for total potassium.

Hays *et al.* (1948) observed that loss of available potassium was 29 and 0.6 kg / ha from Fayette silt loam under oat and corn, respectively whereas the loss of total potassium amounted to 956 kg / ha from oat and 29 kg / ha under corn.

Bryant and Slater (1948) evaluated losses of calcium, magnesium and sulphur from Ontario loam (fallow) and Dundrik, silty loam on 5 % slope under corn. The losses of soluble calcium, magnesium and sulphur from the former soil were 6.7, 1.5 kg / ha and from the later soil were 13.4, 4.0 and 4.7 kg / ha, respectively.

Squarez de Castra and Rodriguez (1955, 1958) reported runoff losses of large quantities of calcium and magnesium in runoff water amounting to 238 and 152 kg / ha from bare soil with 22 per cent slope in well aggregated Andept from Chinchina, Colombia. Goel et al. (1968) also studied the effect of soil texture on nutrient losses through runoff and observed that loss of nutrients increased with increase in the fineness of the soil. From their study they found that although the maximum losses were in the fine textural soil, the composition of the runoff flowing through such soils was poorer in nutrients than from coarse textured soils, as exhibited by the enrichment ratios in clay loam.

Bhatt et al. (1971) observed that Doon valley condition of Uttar Pradesh, Dhulkot silt clay loam on 8 % slope continued to suffer heavy losses of nutrients till middle of August during South West monsoon when cropped to maize and there after the losses decreased. Major quantities of plant nutrients were lost during the first fortnight of July, when the soul was cropped to sorghum fodder and sunhemp and thereafter the losses were little. The cultivated plot, however, continued to incur loss of nutrients throughout the rainy season.

Kowal (1972) reported an average annual loss of calcium, magnesium and sodium in runoff water and eroded soil ranging from 14 to 30 kg / ha. Barnet et al. (1972) evaluated runoff losses from artificial high intensity rain storms from steep ultisols and inceptisols of Puerto Rico. They reported substantially lower runoff and nutrient removal from better aggregated Ultisols.

Lal (1976) also reported large runoff losses of potassium calcium, and magnesium from runoff plots. K losses ranged from

0.1 to 13.4 kg / ha per season and Ca from 0 to 4.2 kg / ha per season. In a recent study of nutrient losses in water runoff of the watershed experiment of IITA. Kang and Lal (1981) reported that concentration of Ca, Mg, K and Na tended to be highest in the first month of the experiment when the rainfall was highest and to be lower in subsequent two months. However, there was no clear or consistant relation between the amount of runoff and the concentration of these nutrients in the runoff though the concentration of Ca and Mg tended to decrease more rapidly with time than K.

Borthakur et al. (1978) reported a loss of 1.6 and 12.5 kg K_2O / ha during first and second year of 'Jhum' cultivation at Burnihat (India).

Under Bellary condition of India, Jayaram et al. (1982) reported enrichment ratios of 2.24, 2.69 and 2.15 for exchangeble potassium, calcium, and magnesium from the area planted to sorghum whereas from the area planted to safflower, the ratios obtained for these nutrients were 2.38, 2.99 and 2.34, respectively.

2.7.4 Micro-nutrients

Practically there is no information available on loss of micro-nutrients in runoff and eroded sediments. However, in a study made in Philippine on leaching losses of micro-nutrients showed that losses of iron ranged between 10 to 144 kg / ha and manganese from 4 to 30 kg / ha per year (Sanchez, 1976).

In a recent study of nutrients losses in water runoff at the watershed experiment of IITA, Kang and Lal (1981) reported the micro-nutrient losses under various land clearing and soil management treatments. The losses of iron ranged between 0.2 to 4.3 kg manganese 0.04 to 35 kg and zinc form from 0.09 to 0.58 kg / ha under different treatments.

From the above limited review it is evident that the information available so far on nutrient losses in runoff and eroded sediments under various cropping and management practices is far from adequate. However, under Indian Condition an idea of the extent of problem can be had from the review of Kanwar (1967) and by Goswami and Sarkar (1978). Kanwar 1972(a, b & c) reported on the basis of soil having a slope of 0.5 % and the loss of nutrients being 5 - 8 kg N, 10.7 kg P_2O_5 and 42.8 kg K_2O / ha, calculated that the minimum annual loss from Indian soil would amount to 2.5, 3.8 and 2.6 million tonnes of N, P_2O_5, respectively, which is much greater than the consumption of these nutrients in India through fertilizers.

2.8 Effect of erosion losses on soil fertility and crop yields

One of the greatest drawbacks and the main criticism of shifting cultivation is its short period of cropping in relation to its fallow period and comparatively very low crop yields in subsequent years which compell the cultivators to shift their land.

Pendleton (1954) in a very sandy soil of Trinidad noted that it was rather impossible to raise a second crop due to depletion of soil fertility. Popenoe (1957) on the basis of experiments carried out in Northern Gautemala concluded that "the three important reasons for the decline of crop production in shifting cultivation yields can be attributed to decline in soil fertility, weeds and pests".

Cowgill (1959) in Central Petan found that cultivation caused an absolute decrease in all elements measured. By comparing the results of first year 'milpas' with those of the second year, she found that pH decreased by 1.3 per cent, organic matter by 6 - 8 per cent, total nitrogen by 5 - 9 per cent phosphorus by 1.8 per cent and the exchangeable potassium, sodium, magnesium and calcium decreased by 19.6, 30.0, 3.5 and 15 per cent, respectively.

Nye and Greenland (1960) while reviewing the work on yield declines during cropping periods observed that decline in crop yields are more marked in forest than in savanna areas. Reply et al. (1961) reported that under unfertilized condition artificial removal of 7.5 and 15 cm of top soil caused a decrease in the yield of barley by 21 and 58 % respectively averaged over a ten year period whereas under fertilized condition (9 kg N + 12 kg P + 11 kg K / ha) yield reductions were 19 and 46 % respectively. However, on the basis of soil analysis data monitored for soil changes before and after buring as reported by Popenoe (1957) at Gautamela and that of Cowgill (1959) in Central Paten, Nye and Greenland (1964) found very little correlation between yield decline and measured soil changes. Siband (1972) also reported steady decrease in fertility of soil cover over a period of many years under continuous cropping with a short fallow in the Casamance area of Southern Senegal. Beasley (1972) reported 15 and 30 % reduction in yield when 5 and 15 cm of top soil was eroded.

The experiments conducted in North Carolina State University (1974) revealed that there was high correlation between yield decline of continuously grown upland rice in Turi Maguas Peru with decreases in exchangeable potassium and increases in alluminium saturation. Sanchez (1976) also found high correlation between fertility depletion and yield decline from low base status ultisols and oxisols.

On the basis of informations available from unfertilized but adequately weeded experiments, it was revealed that in general 50 per cent yield decline was reached by the fourth to sixth consecutive planting. (Anthony and Williams 1956, Cutling <u>et al</u> 1959, Nye and Greenland 1960, Nye and Stephans 1962, Newton and Jamieson 1968, Abuzeid 1973, and IITA 1974). Lal <u>et al</u>. (1975) reported from West Africa that crop yield decreased by 50 %, when 1 inch top soil was lost. Saha (1976) reported yields of crops grown under 'Jhum' condition in different parts of north eastern region of India. It varied from place to place and ranged as follows : Paddy (4 to 11 q / ha); maize (0.3 to 1.7 q / ha); millets (0.55 to 4.82 q / ha); raw cotton (0.05 to 1.47 q / ha); sesamum (0.49 q / ha); turmeric dry (0.31 q / ha); ginger (0.01 to 0.12 q / ha); yam (0.12 to 0.50 q / ha); dry chillies (0.04 to 0.40 q / ha); tobacco (0.07 q / ha); cassava (0.57 to 0.60 q / ha). Rai (1978) on the basis of survey work undertaken on 'Jhum' lands at Burnihat reported that rice yield varied from 5.36 to 13.40 q / ha on lands having varying slopes from 33 to 88 per cent. He also reported that yield and yield attributes of rice increased as the situations changed from top to bottom portion of the plot. Awasthi (1977) working on production potential of 'Jhum' land under different crop management practices reported the yield level of different crops from one hectare of land as follows :

Area	Crop	Pure stand	Mixed stand No fertilizer	Mixed stand + Fertilizer
10%	Cassava	230.49	153.99	237.90
10%	Yam	15.19	21.66	33.33
10%	Ginger	1.69	0.91	1.16
10%	Maize	3.64	12.61	16.74
10%	Sesamum	1.29	8.38	12.98
50%	Rice	5.99	6.32	11.35

Borthakur <u>et</u> <u>al</u>.,(1979) also reported sharp decline in yield of third consecutive crop in shifting cultivation areas of North Eastern Hill Region of India.

Langdale <u>et</u> <u>al</u>. (1979) obtained corn (Zea mays L.) yields of 2,226, 4674 and 6429 kg / ha on severely eroded, moderately eroded and uneroded soil (alluvial soil) respectively averaged over 3 years.

Khybri <u>et</u> <u>al</u>. (1980) in a study on the effect of top soil removal on growth and yield of maize under deep alluvial silt loam soil of Dehradun (India) reported that yield of maize grain decreased from 3701 kg / ha (control) to 1304 kg / ha, where 30 cm of surface soil was removed. On an average every centimeter of top soil removed, there was 76 kg / ha reduction in grain yield.

Frye <u>et</u> <u>al</u>. (1982) in a study on soil erosion effects on properties and productivity of two Kentucky soils, reported 12 and 21 % lower corn grain yields for Maury and Crider soil under eroded condition as compared to uneroded soil. They also reported higher clay content, higher bulk density, lower organic carbon content for the Ap horizon of eroded soil as compared to uneroded soil. Available water holding capacity averaged 4 to 5 % lower in the surface layer of eroded soil.

2.9 Effect of fertilizer application in improving yield and prolonging the cropping period

Nye and Greenland (1960) has mentioned that in much of the West Africa a period of 3 years of cropping and a 10 years of fallow would usually maintain the forest fallow. A series of continuous cropping experiments conducted in Ibadan, Nigeria from 1922 to 1951 has been summarised by Vine (1953, 1954 and 1968), which showed that yield can be maintained at levels between 0.4 to 1.7 tonnes per hectare of corn, about 7 t / ha yams and 12 t / ha of cassava almost indefinitely with sporadic applications of 60 kg N / ha and 20 kg P / ha as ammonium sulphate and ordinary superphosphate.

In Food and Agriculture Organization, Rome Freedom From Hunger Fertilizer Programme (1968) reported some responses to applied phosphorus. The responses were particularly large for tubers and vegetable crops.

Bartholomew (1972) pointed out that relatively low yield such as 600 - 1200 kg / ha maize, do not remove more than about 15 kg / ha of N in the harvested grain and therefore such modest yields could be maintained for long periods with only small amounts of fertilizer after taking into consideration natural N supply from rain water and non-symbiotic fixation.

Jones (1972) obtained corn yield of 3 to 7 t / ha and high yields of dry beans and seed cotton in ultisols of Namunglo, Uganda with fertilizer application of 51 kg N, 22 kg P, 63 kg K, 32 kg S and 78 kg Ca / ha.

In a study on the role of fertilizer in the improvement of shifting cultivation Adetunji and Agboola (1973) concluded that with the use of fertilizers, higher yields have been obtained and maintained although not for an indefinite period.

However, a series of long term experiments conducted throughout Africa have proved that fertility could be maintained for at least 10 years of cropping by use of inorganic fertilizers and manures (Vine, 1954; Stephans, 1969; Dabin, 1971; Abu Zeid, 1973; Ofori, 1973).

Vieweg and Wilms (1974) in their study on problems associated with a change from a shifting to permanent cultivation on a light soil in the Kilombero valley Tanzania have pointed out that after six years of cropping, yields fell to zero, despite reasonable dressings of NPK. The application of cattle manure and lime markedly improved the crop but neither seemed to be a practicable position. He further concluded that on the basis of their early stage of investigation no improvement could be suggested on the customary method of shifting cultivation as practised by farmers on that soil type.

2.10 Review of work done on some of the parameters of universal soil loss equation

2.10.1 Erosivity indices

Various workers have used different erosion indices to correlate soil loss. Wischmeir et al. (1958) reported that the product of kinetic energy of the storm and the maximum intensity of the rainfall during the first 30 min of a storm which he termed as EI_{30} was most significantly correlated with soil loss determined on the standard field plots. Hudson (1971) on the basis of his experiments in Rhodesia indicated that accumulative kinetic energy of storms with intensity greater than 25 mm / hr was better correlated with soil loss than EI_{30}. He also pointed out that storms with intensity of less than 25 mm / hr were not erosive. Ahmed and Breckner (1974) as well as Lal (1976) on the basis of experiments conducted in the tropics found lower correlation between EI_{30} and soil loss. 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.

Roose (1978) working on the use of the universal soil loss equation to predict erosion in West Africa indicated that this equation seemed to be well adapted to the majority of cultivated soils in West Africa. He further, pointed out that to be of maximum use in West Africa more data was needed to modify the Wischmeir Smith equation for soils with swelling clays, for mountainous regions of recent origin and for Saharien and Mediterrennean Zones where usually intense rains are important. In India the research on soil loss prediction has been reviewed by Singh et al. (1981). At Dehradun, Coimbatore and Ootacumond experiments were conducted to find out correlations between EI values and the soil loss from bare plots. At Dehradun, Ram Babu et al. (1970) found better correlation between EI_{30} values and soil loss. At Coimbatore, Balasubramaniam and Sivanappan (1981) found highly significant correlation co-efficient (r = 0.89 to 0.96 for varying slopes) between the product of kinetic energy and maximum 30 minutes intensity. However, at Ootacamend, Das et al. (1967) observed better correlation with EI_{15} which explained only 17 per cent variation. Singh et al. (1981) concluded that till sufficient soil loss data from field plot for large number of storms from various countries become available to disprove the reliability of EI_{30} value in estimating soil loss. EI_{30} may be taken as the most reliable estimate of rainfall erosion potential. Ram Babu et al. (1978) based on 15 years precipitation data of 44 locations representing different zones of India prepared Isoerodent map of India. Recently Raghunath et al. (1982) based on the rainfall data from 400 ordinary rainfall recording stations representing various climatic zones computed seasonal and annual EI_{30} values for these stations and prepared the isopleths map of India on the basis of isoerodent map of Ram Babu et al. (1978). At Burnihat, the experimental site falls in eastern zone between 750 to 1500 erosion index line.

2.10.2 Soil erodibility factor (K)

The soil erodibility factor (K) in the universal soil loss equation is the index of the resistance of soils to erosion. It is estimated directly by runoff plot which is costly proposition. It can also be estimated based on various soil properties but this is more cumbersome process. It can be easily estimated by simple nomograph developed by Wischmeir et al. (1971).

In U.S.A. Wischmier et al. (1971) found the erodibility factor (K) to vary between 0.03 to 0.6 for a majority of soils. At Ibadan (in Nigeria) Lal (1976) found soil erodibility factor (K) to vary between 0.06 and 0.36 depending on the time after forest removal and the tillage techniques are adopted.

Roose (1978) based on the results of about 50 annual experiments from West Africa indicated that ferrallitic soil are very resistant with erodibility factor (K) ranging from 0.02 to 0.20 whereas ferruginous tropical soils are much less resistant after 3 years of cultivation (K is increasing from 0.03 to 0.20 - 0.30).

The work done on soil erodibility factor in India has been reviewed by Singh et al. (1981). On an average it varied from low values of 0.04 for lateritic soils of Ootacamund to high values of 0.30 for Dehradun (Tejwani et al. 1975).

2.10.3 Cropping management factor (C)

This factor expresses the combined influence of vegetative cover and the various cultural practices on soil erosion. For the purpose of calculation Wischmier and Smith (1978) suggested to divide the crop season into six crop stages. But under Indian condition where the crop season is short, Pratap Narain et al. (1980) and Rao et al. (1981) suggested to divide the growth period into 3 stages viz. seeding to one month stage of crop growth from one to two months crop growth and from two months after to crop harvest. The cropping management factor 'C' can be calculated for each crop growth period as per following method.

$$\text{'C' value} = \frac{R\ \% \times \text{Soil loss}\ \%}{100 \times 100}$$

In absence of crop stage growth period data the 'C' factor can be calculated based on the total seasonal soil loss data. Pratap Narain et al. (1980) working on 'C' factor at Kota region of Rajasthan observed that the grass cover of Dichanthium annulatum permitted almost no soil loss whereas sorghum - pigeonpea rotation was found to be quite effective in reducing soil loss with 'C' value of 0.33 and others. Crops like cowpea, green gram and soybean etc. were also in the similar range.

At Vasad (Gujarat) Nema et al. (1978) found cowpea as most effective crop with 'C' value of 0.32 followed by groundnut and greengram with 'C' values of 0.38 and 0.47, respectively.

Rao (1981) in his study from runoff plots under lateritic soil conditions of Kharagpur found best protection with Dub (Cynodon dactylon) with a 'C' value of 0.04 as compared to 0.17, 0.35, 0.28 and 0.38 for cowpea, maize, paddy and pigeon pea, respectively. Detailed review on 'C' factor under Indian condition has been done by Singh *et al.* (1981). But in most of the conditions cropping management factor (C) has been evaluated only from very mild slope and is based on first approximation in absence of crop stage data. Information is still lacking in this aspect from steep slopes.

Scope of further work

A good deal of work has been done in other countries as well as in India on runoff and erosion losses under different soils, crops and cropping systems with varying slopes and management practices leading to the development of various emperical equations for estimating rainfall erosion potential, soil erodibility factor, crop management factor slope gradient and conservation practice factor etc. for effective soil conservation planning. It is apparent from the review of literature that most of these studies are confined to low and milder slopes and less aggressive rainfall conditions. There is no precise information available on runoff and erosion losses and its effect on soil productivity with particular reference to high intensity rainfall, steep slope and existing cropping and management systems.

Under high rainfall conditions of north eastern hill region of India, adoption of shifting cultivation on very steep slopes (higher than 60 %) and even in marginal and submarginal lands with reduced Jhum cycle of 3 to 4 years has become one of the most menacing problems of major concern.

It is therefore envisaged that there is great scope of study soil, water and nutrient losses as well as plant growth studies in such high rainfall and steep slopes. These basic informations will help the future research workers in the development of appropriate conservation measures for checking erosion losses, estimating some of the parameters of universal soil loss equations taking into explicit account of rainfall pattern, soil characteristics and prevailing mixed cropping systems with almost zero tillage along with other improved crop and soil management practices.

3. MATERIALS AND METHODS

In the present investigation entitled "Production potential, runoff, soil and nutrient losses under different cropping systems and management practices on steep slopy 'Jhum' land", the details pertaining to materials used and the methods followed are given in this chapter under appropriate heads.

3.1 Location

The study was conducted at the Indian Council of Agricultural Research Farm in the premises of Soil Conservation and Training Institute, Burnihat (26°N, 91.5°E) in the East Khasi Hills of Meghalaya, India. The place is located about 90 km south of Shillong on the Shillong-Gauhati high way. The area lies at an altitude of 100 metre above mean sea level. The topography of the area is undulating and rolling type with steep slope gradient of 58 to 70 per cent which is the predominent slope representing majority of the areas in the region as whole.

3.2 Description of climate, soil and vegetation of the experimental site

3.2.1 Climate

The area is characterised by sub-humid tropical climate with wet and dry seasons extending from May to September and October to April, respectively. The average annual rainfall is around 1581 mm (Table 3.1). Nearly 82 % of the total annual rainfall is received during the months from May to September. June, July and August are the wettest months and December and January are the driest months.

Table 3.1 Monthly distribution of rainfall and temperature at experimental site

Month	Rainfall in mm			7 Years average (1976-1982)	Temperature Maximum °C				Temperature Minimum °C			
	1979	1980	1981		1980	1981	1982	Mean	1980	1981	1982	Mean
Jan	0.0	0.0	64.5	9.8	24.0	30.7	25.9	26.9	9.0	8.7	8.4	8.7
Feb	28.4	18.8	25.4	18.4	27.0	27.2	28.1	27.4	10.0	10.8	9.6	10.1
Mar	0.0	55.6	40.6	36.7	30.0	31.3	33.3	31.5	13.0	14.4	11.9	13.1
Apr	171.7	82.3	77.0	114.0	35.0	33.1	32.9	33.7	19.0	17.3	16.1	17.5
May	120.7	277.1	47.2	162.5	33.0	37.4	37.7	36.0	20.0	20.7	21.8	20.8
Jun	198.4	450.1	104.4	318.5	34.0	39.0	35.0	36.0	22.0	24.6	24.2	23.6
Jul	433.8	252.0	441.2	350.7	34.0	37.8	36.3	36.0	25.0	25.1	24.9	25.0
Aug	184.9	192.8	214.9	313.0	36.0	37.6	37.6	37.1	25.0	24.6	24.8	24.8
Sep	106.4	191.5	222.0	151.0	34.0	37.4	36.4	35.9	22.0	23.7	24.4	23.4
Oct	165.3	80.0	19.5	84.4	32.0	36.5	35.4	34.6	20.0	19.7	19.3	19.7
Nov	24.9	0.0	2.5	20.6	29.0	33.4	31.1	31.2	17.0	13.3	17.6	16.0
Dec	7.6	0.0	0.0	1.5	25.0	27.6	25.7	26.1	12.0	10.0	10.8	10.9
Total	1442.1	1600.2	1259.2	1581.1								

Table 3.2 Monthly distribution of frequency of falls of erosive rainfall amounts and events during the cropping seasons (1979 - 1981)

Months	Total rainfall in mm	Amount of erosive rainfalls in mm / day						
		5-15	15-25	25-35	35-45	45-55	Greater than 55	Total
1979								
Jun	198.4 (14)	24.6 (2)	64.3 (3)	58.4 (2)	Nil	Nil	Nil	147.3 (7)
Jul	433.8 (22)	42.1 (4)	40.4 (2)	Nil	37.9 (1)	Nil	194.3 (2)	314.7 (9)
Aug	184.9 (9)	Nil	Nil	26.2 (1)	Nil	Nil	57.2 (1)	83.3 (2)
Sep	106.4 (7)	Nil	Nil	Nil	Nil	54.6 (1)	Nil	54.6 (1)
Oct	165.3 (6)	Nil	Nil	Nil	Nil	48.8 (1)	Nil	48.8 (1)
Total	1088.8 (58)	66.8 (6)	104.7 (5)	84.6 (3)	37.9 (1)	103.4 (2)	251.5 (3)	648.7 (20)
1980								
May	277.1 (19)	30.7 (3)	41.4 (2)	27.9 (1)	78.7 (2)	Nil	Nil	178.8 (8)
Jun	450.1 (17)	20.3 (2)	24.1 (1)	99.4 (3)	35.6 (1)	48.3 (1)	121.2 (2)	348.8 (10)
Jul	252.0 (21)	19.3 (2)	43.2 (2)	58.4 (2)	Nil	Nil	58.4 (2)	179.3 (7)
Aug	192.8 (19)	7.9 (1)	16.5 (1)	Nil	Nil	50.8 (1)	Nil	75.2 (3)
Sep	191.5 (15)	Nil	68.1 (3)	29.7 (1)	Nil	Nil	Nil	97.8 (4)
Oct	80.0 (7)	Nil	Nil	26.7 (1)	Nil	Nil	Nil	26.7 (1)
Total	1443.5 (98)	78.2 (8)	193.3 (9)	242.1 (8)	114.3 (3)	99.1 (2)	179.6 (3)	906.6 (33)
1981								
Jun	104.4 (11)	20.1 (2)	16.0 (1)	Nil	Nil	Nil	Nil	36.1 (3)
Jul	441.2 (21)	19.1 (2)	70.1 (4)	59.7 (2)	Nil	50.8 (1)	156.2 (2)	355.9 (11)
Aug	211.9 (13)	Nil	50.0 (3)	34.0 (1)	Nil	53.4 (1)	Nil	137.4 (5)
Sep	222.0 (12)	12.7 (1)	21.6 (1)	Nil	Nil	Nil	68.3 (1)	102.6 (3)
Total	979.5 (57)	51.8 (5)	157.7 (9)	93.8 (3)	Nil	104.2 (2)	224.5 (3)	632.0 (22)

Figures in parenthesis indicate number of rainfall events.

The data on monthly distribution of erosive rainfall events (Table 3.2) indicate that the highest number of rainfall events (98) occurred in 1980 followed by (58) in 1979 and (57) in 1981 with corresponding rainfall amounts of 1600.2, 1442.1 and 1259.2 mm, respectively during the three years. The highest number of erosive rainfall events (33) was also recorded in 1980 followed by (22) in 1981 and (20) in 1979. The amount of rainfall under these erosive events accounted for 56.7, 50.2 and 45.0 per cent of the total rainfall amounts received during three years of 1980, 1981 and 1979, respectively.

It is evident from the rainfall data that frequency of occurrence of the erosive rains exceeding 25 mm per day is much higher in the month of June and July in 1979, May, June and July in 1980 and July, August and September in 1981.

The mean monthly maximum temperature ranges from 26.1°C in December to 37.1°C in August and the mean minimum temperature from 8.7°C in January to 25.0°C in July.

3.1.2 Soil

The soils of the experimental plots can be broadly classified as oxisol having plinthite nodules within one metre from the soil surface. The parent material consisted of sand stone. A thin layer of quarts is also not uncommon. Kaolinite and mica are dominating clay, minerals (Munna Ram <u>et al.</u> 1979). Internal drainage of the soil is quite good. Some of the physical and chemical properties of the soil are presented in Table 3.3.

Table 3.3 Physical and chemical properties of soil (0-15 cm depth) at experimental site

Physical properties					
Mechanical composition			Texture	Bulk density g/cm³	Water stable aggregates greater than 0.25 mm
Sand	Silt	Clay			
70.2	16.2	13.6	Sandy loam	1.18	43.8%

Chemical properties					
pH	Organic carbon (%)	Cation exchange capacity meq/100	Exchangeable cations (meq/100)		
			Calcium	Magnesium	Potassium
5.84	1.25	7.45	3.80	1.57	0.67

Table 3.4 Spatial distribution of plant species at experimental site before burning

Plant species		Density/ m^2	Percentage of total plant space
1. Imperata cylindrica	P. Beauv	1.31	34.6
2. Grewia elastica	Royle	1.14	29.7
3. Panicum khasianum	Munro	0.31	8.2
4. Eupatorium odratum	L.	0.25	6.5
5. Smilex sp		0.14	3.5
6. Ricinus communis		0.10	2.7
7. Scleria terrenstris (L) Fass		0.10	2.7
8. Capillipedium sp		0.08	2.2
9. Yilis sp		0.07	1.9
10. Litsaea sp		0.05	1.4
11. Solanum indicum L.		0.04	1.1
12. Callicarpa arborea		0.04	1.1
13. Mikania micrantha H.B.K.		0.04	1.1
14. Thysanolacna maxima Kunse		0.02	0.5
15. Miscellaneous		0.10	2.7

3.2.3 Vegetation

The area originally supported climax forest of sal (Shorea robusta) with its associates. But as a result of heavy exploitation of primary forest due to shifting cultivation during the last 40 years or so, the present vegetation around the study area consists mostly of degraded and shrub forests. When the area was taken up for constructing runoff plots for the study in 1977, the secondary forest vegetation was mostly dominated by Dendrocalamus hamiltonii (a bamboo species alongwith few scattered trees and shrub species which are given as follows :

a) Tree species

1. Cordia myxa
2. Chikrassia tabularis
3. Toona ciliata
4. Careya arborea
5. Callicarpa arborea
6. Cassia fistula
7. Dillenia pentagyna
8. Dillenia indica
9. Derris robusta
10. Duabanga sonneretioides
11. Emblica officinalis
12. Erythrina suberosa
13. Ficus glumerata
14. Gmelina arborea
15. Premina latifolia
16. Semecarpus anacardium
17. Schima wallichii
18. Sterculia villosa
19. Streeospermum chellenoides
20. Shorea robusta
21. Sapium baccatum
22. Oroxylum indicum
23. Macaranga denticulata
24. Legerstnoemia parviflora
25. Litsaea polyaltha
26. Bombax ceiba
27. Tetramelas nudiflora
28. Trewia nudiflora
29. Terminalia balerica
30. Vitex peduncularis

b) Under shrubs and bamboos and canes

1. Adhatoda vosica
2. Autidesma diandrum
3. Clerodendron infortunatum
4. Eupatorium odoratum
5. Ricinus communis
6. Flemengia brackata
7. Calamum tenus
8. Bamboosa pallida
9. Bamboosa toolda
10. Teinostachyum dullua
11. Dendrocalamus hamiltonii

3.3 Description of the experiment

In order to study "The production potential, runoff, soil and nutrients losses under different cropping systems and management practices under steep slopy Jhum land" field experiments were conducted with ten treatments comprising of cropping systems and management practices using runoff plots during three cropping seasons of 1979, 1980 and 1981.

3.3.1 Clearing, burning and construction of runoff plots

The experimental site was cleared manually by cutting and felling the trees and shrubs of existing secondary forest vegetation during 1977 for constructing the runoff plots. Ten runoff plots of 20 m x 2 m size were constructed on the cleared site having a mean slope of 65 per cent. The boundary of each runoff plot was enclosed with corrugated galvanised iron sheet by inserting it to a depth of 20 cm below the soil surface and allowing 20 cm above the ground level. Each runoff plot was provided with runoff collection taks which were installed at lower outlet of each plot. The work on the construction of runoff plots was completed by the end of 1977. After the completion of the work, all the ten runoff plots were left fallow for complete one year during 1978 and the natural vegetation was allowed to grow so that the plots could stabilize properly. Before assigning the treatments in 1979, observations were taken on secondary vegetation by putting the quadrats of 10 sq. metre at randomly at six places and counting the number of different species. The details of different species given in the Table 3.4 revealed that secondary vegetation was dominated by <u>Imperata Cylindrica</u> followed by <u>Grewia elastica</u>, <u>Panicum khasiana</u> and <u>Eupatorium odoratum</u>.

After this observation, the plots were cleared manually by cut slashing the secondary vegetation in the month of January, 1979 and allowed to dry till March, 1979. The weight of dry material of slash was taken for each runoff plot before burning which ranged from 15 to 40 kg per plot of 40 sq. metre, where it was less than 40 kg, the dry material was brought from out side so as to make the weight equal in each plot amounting to 10 t / ha. The burning was done on 5th April, 1979.

3.3.2 Treatment details

The ten treatments were assigned to 10 runoff plot. The details of treatments are given below.

T_1 - Grass cover

T_2 - Uncultivated bare fallow (Vegetation not allowed by the use of hand hoe, Khurpi

T_3 - Maize along the slope

T_4 - Maize across the slope

T_5 - Maize intercropped with sesamum, soybean and pigeon pea during 1979, 1980 and 1981, respectively

T_6 - Rice sole cropping

T_7 - Topo-sequential strip cropping (without any fertilizer)

T_8 - Topo-sequential strip cropping (with fertilizer @ 80 kg N + 60 kg P_2O_5 + 40 kg K_2O / ha)

T_9 - Mixed cropping (without any fertilizer)

T_{10} - Mixed cropping (with fertilizer @ 80 kg N + 60 kg P_2O_5 + 40 kg K_2O / ha)

3.3.3 Method of sowing

Under topo-sequential strip cropping system, cassava (*Manihot esculenta* Cranz) was planted in the upper most plot and the other crops in desending order of maize (*Zea mays* L) fox tail millet (*Setaria italica* (L.) Beauv.), sesamum (*Sesamum indicum* L.) soybean (*Glycine max* Merr.) each comprising of 10 per cent area and the remaining 50 per cent area down below was sown with sole rice (*Oryza sativa* L.)

The crops were sown manually in each season by dibbling 2 to 3 seeds per hole with dibbling stick except cassava which was planted by using stem cuttings having 6 to 8 eyes.

As regards seeding of mixed cropping treatments, the amount of seed rate worked out for the specified area of each crop in topo-sequential cropping was mixed together and sown 15 to 20 cm apart by dibbling method. Required number of cassava sets were planted randomly in the entire plot. Thin napier grass was planted through root slips.

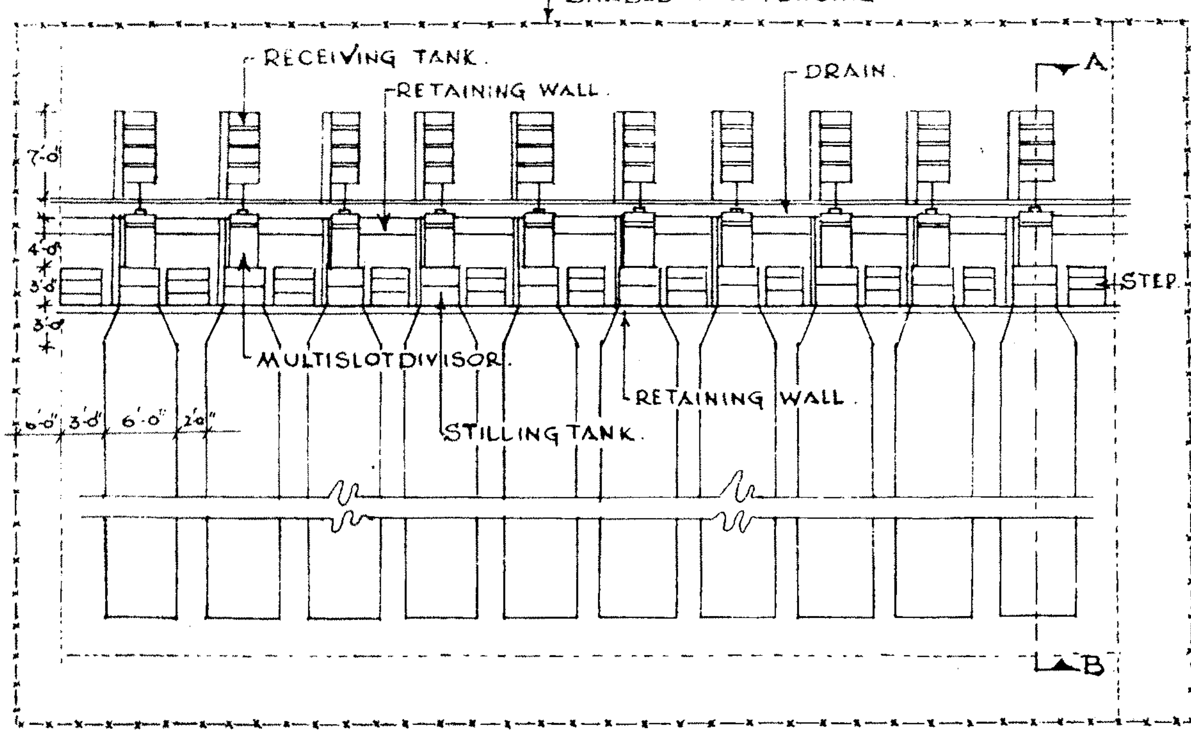
3.3.4 Method of fertilizer application

The plots with fertilizer treatments were applied with 80 kg N, 60 kg P_2O_5 and 40 kg K_2O / ha in the form of ammonium sulphate, single super phosphate and muriate of potash, respectively. The measured quantity of fertilizer for each plot was mixed together and applied in the dibbling holes made adjacent to the seeding holes so as to avoid direct contact of fertilizer with seeds. The calender of cultural operations are presented below :

Calender of cultural operations

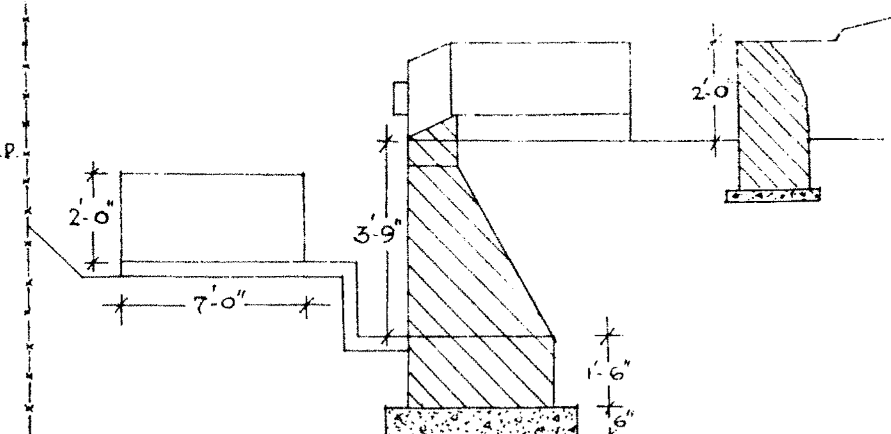
Particulars	1979	1980	1981	Remarks
1	2	3	4	5
1. Date of sowing pigeonpea	8.5.79	10.5.80	8.5.81 18.5.81	
2. Fertilizer application	8.5.79	10.5.80	8.5.81	By dibbling method adjacent to seeding hol[illegible]

RUNOFF PLOT WITH MULTISLOT DIVISORS



PLAN

SCALE :- 16' FEET TO AN INCH. FIG.1.



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ENGINEERING SECTION.
I.C.A.R. SHILLONG.

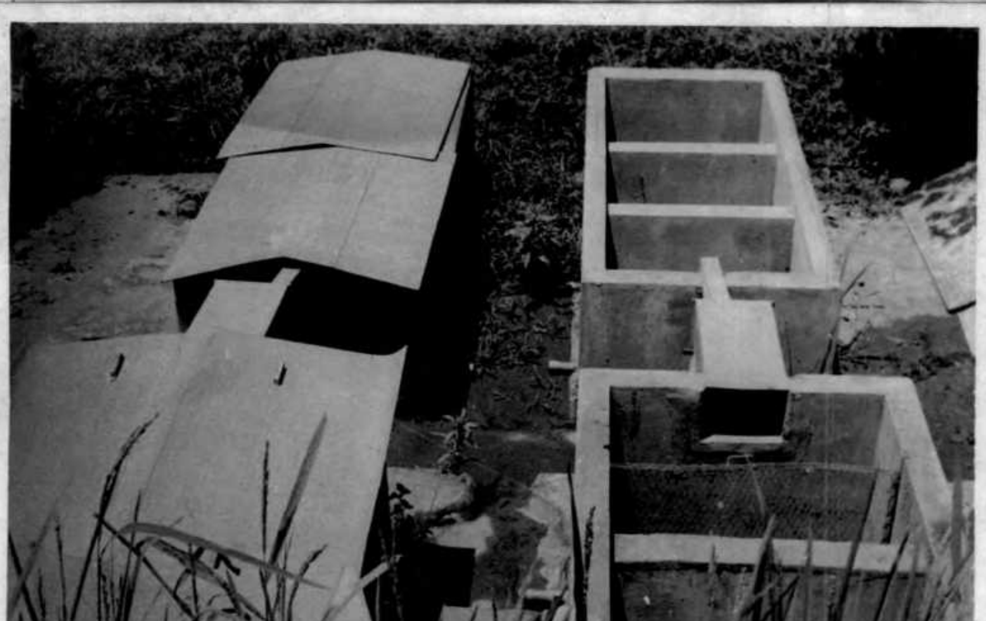


Plate 1 & 2 A view of runoff plot with collection system

1	2	3	4	5
3. Varieties of crops grown and spacing adopted				
Grass(Thin Napier)	20x10cm	20x10cm	20x10cm	
Cassava (Local)	100x100cm	100x100cm	100x100cm	
Maize (Ganga-5)	50x25cm	50x25cm	50x25cm	
Fox tail millet (Local)	20x10cm	20x10cm	20x10cm	
Rice(Local Chou-rengma)	20x10cm	20x10cm	20x10cm	
Sesamum (Local)	50x25cm	50x25cm	50x25cm	
Soybean (Local)	50x25cm	50x25cm	50x25cm	
Pigeonpea (Local)	50x25cm	50x25cm	50x25cm	
4. Establishment of crops (75% germination)				
Cassava	27.5.79	1.6.80	3.5.81	
Maize	13.5.79	17.5.80	13.5.81	
Fox tail millet	13.5.79	17.5.80	13.5.81	
Rice	13.5.79	17.5.80	13.5.81	
Sesamum	22.5.79	17.5.80	12.5.81	
Pigeonpea	-	-	24.5.81	
5. Date of weeding 1st	9.6.79	11.6.80	9.6.81	By kódali
Date of weeding 2nd	10.7.79	12.7.80	10.7.81	
6. Date of flowering				
Maize Tasselling	137.79	117.80	18.7.81	
Silking	19.7.79	17.7.80	24.7.81	
Rice Flowering	31.7.79	28.7.80	3.8.81	
7. Date of harvesting				
Cassava	10.11.79	10.11.80	25.11.81	
Maize	23.8.79	11.8.80	18.8.81	
Fox tail millet	25.8.79	7.11.80	8.10.81	
Rice	27.8.79	25.8.80	7.9.81	
Sesamum	15.10.79	18.10.80	14.10.81	
Pigeonpea	-	-	23.11.81	

....42..

1	2	3	4	5
Plant protection measures	-	-	-	As per practice in jhum cultivation, no plant protection measure was adopted

3.4 Collection of soil samples

Soil samples (0 - 15 cm depth) were collected before and after burning on 5.4.79 and 20.4.79, respectively and again on 4.1.82 after three years of cropping. Composite samples were drawn by combining the soils from top, middle and bottom from each runoff plots. Soils were air dried and ground on wooden planks with roller and passed through 2 mm seive for analysis. Ash samples were collected after burning. The soil samples were analysed for some physical constants, organic carbon, CEC and exchangeable cations, total P, K, Ca, Mg, Zn, Cu, Fe and Mn.

3.5 Measurement of runoff and soil losses

The runoff collection device, installed at the lower end of the slope, comprised of silting tank, multislot divisor (5 slots) and a series of tanks (Fig. 1). A view of the runoff plot along with the collection system is shown in plate No.1 & 2.

Runoff was measured every morning following a rainy day. A 500 ml of the sediment water runoff mixture was collected from each plot after thoroughly churning the collected material in the tank from every event of runoff occurrence. Separation of liquid and solid material could not be done because of large number of samples and therefore, the water was dried in oven at 60°C for determining the soil loss. The samples of eroded sediments were bulked monthwise and the composite sample was used for chemical analysis for estimating nutrient losses.

3.6 Determination of physical and chemical properties of soil

3.6.1 Particle size distribution

Particle size distribution was measured with the help of Bouyoucos (1936) hydrometer using sodium hexametaphosphate as dispersion agent.

3.6.2 Bulk density

It was determined as per clod method.

3.6.3 Water stable aggregates

Water stable aggregate analysis was performed by Yoder's sieve method as modified by Van Bavels methods as described by Balch (1965).

3.6.4 pH

Soil pH was determined with the help of pH meter in soil water ratio of 1 : 2 : 5 as described by Jackson (1958).

3.6.5 Organic carbon

Organic carbon was determined by Walkley and Black Wet oxidation method as described by Jackson (1958).

3.6.6 Cation exchange capacity

CEC was measured by leaching the soils with N neutral ammonium accetate solution by the method of schollenberger and Dreibelbis (1930) as described by Jackson (1958).

3.6.7 Exchangeable cations (Ca, Mg and K)

These cations were determined in the leachate of CEC. Ca and Mg were measured with the help of Atomic absorption spectrophotometer while K by Flame photometer.

3.6.8 Total nutrients in soils

1 g soil sample was digested with 10 ml 70 % perchloric acid and volume was made up to 50 ml. Total P in the extract was estimated by developing the colour with ammonium metavanadate Jackson, 1973) and total K by flame photometer. The rest of the elements (Ca, Mg, Zn, Cu, Fe and Mn) were determined with the help of Atomic absorption spectrophotometer.

3.6.9 Enrichment ratio

Enrichment ratio was worked out by dividing the concentration of the respective elements in eroded sediments by concentration of the element in soil from which runoff originated.

3.7 Bio-metrical observations

3.7.1 Percentage ground cover

The percentage of ground cover under each treatment was assessed at fortnightly interval beginning two weeks after sowing by visual observations using point quadrate frame of one square metre having one hundred holes each of 10 x 10 cm. The whole plot of 40 square metre was divided into 10 plots of 2 x 2 metre size from top to bottom. The quadrate was placed at random in all the ten plots and the percentage ground cover for each system was estimated by taking the average value.

3.7.2 Plant height

Ten plants from each sub-divided plots were randomly selected and tagged. Plant height was measured at 15 days interval starting from 15 days after sowing as per standard method adopted for each crop.

3.7.3 Number of tillers per plant

The observations on number of tillers in rice and millet were periodically recorded from the same tagged plants which were selected for height measurement.

3.7.4 Fresh and dry weight of plants

The fresh weights of tagged plants were taken after harvesting. For dry weight determination, the above ground portion of each tagged plant were cut and chopped into pieces and kept for sunhdrying. After sun drying, it was kept in the oven for 48 hours at 60°C. The constant oven dry weight was recorded for above and below ground portion (in case of cassava only) of the plants.

3.8 Yield components and yield

3.8.1 Plant stand

Observation on final stand of each crop was taken by counting the number of plant from one square metre area from ten places at randomly from top to bottom portion of the each runoff plot.

3.8.2 Barrenness percentage

In case of maize, barrenness percentage was worked out by counting the number of bearing and non-bearing plants.

3.8.3 Length of panicle

Length of panicles was measured in case of rice and millet crop from the ten sampled plants.

3.8.4 Number of grains / cob or panicle

The number of grains per cob and per panicle was counted for ten sampled cobs and panicles. In case of cassava, number of tubers per plant were also recorded.

3.8.5 Test weight

One hundred kernels in case of maize and one thousand grains in case of rice were counted and their weights were recorded.

3.8.6 Grain and tuber yield

Final grain yield per plot of 4 square metre area was recorded after proper sun drying and adjusted to 15 % moisture level. Grain yield of sampled plants recorded separately was added for calculating the yield per hectare. In case of cassava fresh weight of tubers were recorded and dry matter was expressed at 35 per cent of the fresh weight of tubers.

3.8.7 Stover and straw yield

The final weight of stover and straw yield per plot was recorded after proper sun drying upto constant weight.

3.9 Determination of some of the parameters of universal soil loss equation

The universal soil loss equation, developed by Wischmeir and Smith (1965) based on the statistical analysis of more than 10,000 plot years of runoff plot data, is an erosion model to predict the long time average soil losses from a specified land in a specified cropping and management system. The equation is $A = R\ K\ S\ L\ C\ P$ where A is the computed soil loss per unit area, R, an index of rainfall erosiveness, K, an index of soil erodibility, SL, a topographic index including both the angle and length of the slope and is expressed as the expected ratio of soil loss per unit area from a field slope to that from 22.13 metre length of uniform 9 per cent slope under identical condition, C, the crop management factor expressing the combined influence of vegetal cover and cultural practices, and P, an index showing the effectiveness of supporting erosion control practices on soil loss such as contouring strip cropping, terracing, farming, up and down slope.

3.9.1 Calculation of erosion index 'EI_{30}'

The rainfall factor (R) in the soil loss equation is the measure of erosivity i.e. the potential ability of rains to cause erosion and can be precisely estimated for a particular location by totalling erosion index values (EI_{30}) of all storms in a year. The erosion index is one hundredth of the product of the kinetic energy of rain storms and its maximum 30 minutes intensity (Wischmeir, 1959 and 1961). Since rainfall intensity data were not available, an alternate method as suggested by Raghunath et al., (1971) was followed for estimating the erosion index value (EI_{30}) from daily rainfall amounts by estimating EI_{1140} from the published table given by Raghunath *et al.*, (1971). From this estimated value of EI_{1440}, the EI_{30} was calculated by using the regression equation $EI_{30} = 7.65 + 24.26\ EI_{1440}$ computed by Raghunath *et al.*, (1982).

3.9.2 Calculation of soil erodibility factor 'K'

Soil erodibility factor is expressed as soil loss in tonnes / ha /EI unit on 9 per cent slope 22.13 m long under continuous cultivated fallow. But since in *Jhum* system of cultivation practically zero tillage is adopted, soil loss data from uncultivated bare fallow plot at 65 per cent slope of Burnihat was converted to 9 per cent slope as per following slope gradient equation suggested by Wischmeir and Smith (1978).

$$S = 65.41\ \sin^2 + 4.56\ \sin + 0.65 \text{ where}$$

S = Slope gradient factor and O = angle of the slope

3.9.3 Calculation of cropping management factor 'C'

The cropping management factor (C) in the soil loss equation is the expected ratio of soil loss from land cropped under specified conditions to the corresponding soil loss from clean tilled fallow on identical soil and slope and under the same rainfall. The cropping management factor 'C' was worked out as per method suggested by Rao (1981) and Singh *et al.*, (1981).

Ratios of soil from cropped plots to corresponding loss from uncultivated bare fallow plot were worked out periodwise and 'C' factor was calculated for these period as per following method.

$$\text{'C' value} = \frac{R\ 1\ \%\ \times\ \text{Soil loss}\ \%}{100 \times 100}$$

Percentage of monthly erosion index 'R' factor was worked out from the monthly erosion index value of E 11440 .

3.10 Statistical analysis of data

In view of limited resources and difficult terrain where the work was conducted, the experimental design followed was non-replicated hierarchichal design (Snedecor and Cochram 1967) Here an attempt has been made to partition the variability between plots within sampling time and between sampling time within plots. The standard errors of means have been provided in the tables to gauge the extent of differences between treatments in the light of the variabilities indicated by standard errors.

Inter-relationships of daily as well as monthly amount of rainfall, runoff and soil loss was computed on the basis of pooled data for 3 cropping seasons through computor. Likewise correlation and regression analysis was also performed between runoff and nutrient concentration in sediment, and soil loss and nutrient concentration to find out the relationship.

4. RESULTS

The results of the investigation have been presented in two broad classifications. In one case (4.1) the results of plant stand, growth behaviour yield and yield attributes of crops have been described and in the other part (4.2) the effect of different stages of cultivation as well as cropping systems on physico-chemical properties of soil and soil, water and nutrient losses have been presented. As has been stated earlier soybean crop put forth good vegetative growth, it flowered but pods were not formed so its yields could not be assessed and in subsequent year (1980) it was replaced with pigeon pea.

4.1 Effect of different systems of cropping and management practices on final stand of plants, growth, yield attributes and yield of different crops are presented herewith

4.1.1 Plant stand

The data on final stand of crops grown under varied systems of cropping and management practices are presented in Table 4.1.

4.1.1.1 Maize

There were well marked differences in plant stand of maize under different cropping systems in different years (Table 4.1). In 1979, the maximum stand was observed under the intercropping system of maize with sesamum (60,800 plants / ha) followed by maize along the slope (59,300 plants / ha) and maize across the slope (56,000 plants / ha). Plant stand was found to be comparatively less under topo-sequential (43,000 and 30,000 / ha) and mixed cropping systems (55,000 and 43,000 / ha) with and without fertilizer applications.

During the cropping season of 1980, the maximum plant stand was recorded under sole cropping of maize along the slope (70,500 / ha) closely followed by maize across the slope (70,300 / ha) and maize intercropped with soybean (65,000 / ha); under topo-sequential and mixed cropping system, the density of plants was comparatively less.

In 1981, maximum plant stand was recorded under sole cropping of maize across the slope (76,800 / ha) followed by maize intercropped with pigeon pea (75,000 / ha) and maize under topo-sequential cropping system receiving no fertilizer application (73,000 / ha). Plant stand was slightly less under mixed cropping system.

Fertilizer application in general was found to have slightly adverse effect on plant stand in topo-sequential system of cropping in all the three years and in mixed cropping during 1979 only (Table 4.1).

4.1.[illegible] Rice

In general the plant density of rice was higher during the cropping season of 1981 and 1980 than in 1979. There was no appreciable difference in the plant stand of rice in various systems of cropping except in mixed cropping system under which the plant stand of rice was found to be slightly less.

Fertilizer application slightly reduced the plant stand specially under strip system of cropping in all the 3 seasons and in mixed system of cropping in 1979 only.

Table 4.1 Plant stand of different crops grown under varied ~~of~~ cropping and management practices

Cropping systems	No. of plants / m^2		
	1979	1980	1981
1. Maize along	5.9	7.1	7.1
2. Maize across	5.6	7.0	7.7
3. Intercropped maize	6.0	6.5	7.5
4. Associated crops - sesamum/soybean/ pigeon pea	-	-	1.3
5. Rice (sole)	23.9	25.2	36.2
6. Topo-sequential cropping without fertilizer			
a) Cassava (10 % area)	0.1	0.1	0.1
b) Maize (10 %)area)	0.4	0.6	0.7
c) Fox tail millet (10 % area)	1.5	0.8	1.8
d) Sesamum (10 % area)	0.9	0.6	0.4
e) Soybean (10 % area)	-	-	-
f) Rice (50 % area)	12.4	12.3	13.9
7. Topo-sequential cropping with fertilizer			
a) Cassava (10 % area)	0.1	0.1	0.1
b) Maize (10 % area)	0.3	0.4	0.6
c) Fox tail millet (10 % area)	1.0	0.5	1.2
d) Sesamum (10 % area)	0.8	0.5	0.2
e) Soybean (10 % area)	0.6	1.9	-
f) Rice (50 % area)	9.6	11.8	11.9
8. Mixed cropping (without fertilizer)			
a) Cassava (10 % area)	0.1	0.1	0.1
b) Maize (10 % area)	0.6	0.3	0.6
c) Fox tail millet (10 % area)	0.7	0.7	1.8
d) Sesamum (10 % area)	0.7	0.4	1.3
e) Soybean (10 % area)	1.6	-	-
f) Rice (50 % area)	4.4	5.7	9.0
9. Mixed cropping (with fertilizer)			
a) Cassava (10 % area)	0.1	0.1	0.1
b) Maize (10 % area)	0.4	0.5	0.6
c) Fox tail millet (10 % area)	0.7	0.3	1.3
d) Sesamum (10 % area)	1.3	0.3	1.2
e) Soybean (10 % area)	1.0	-	-
f) Rice (50 % area)	3.1	12.8	9.6

4.1.3 Fox tail millet

Almost similar trend like rice was observed in plant stand of millet under different systems of cropping except that the plant stand of fox tail millet in 1980 was found to be quite low in all the systems of cropping.

4.1.4 Sesamum

Contrary to other crops, plant stand of sesamum was found to be maximum in mixed cropping system as compared to topo-sequential cropping system except in 1980 when the plant stand was found to be quite low. Fertilizer application resulted in slightly reduced stand of plants under topo-sequential cropping system but increased under mixed cropping system.

4.1.5 Cassava

There was no appreciable difference in final stand of cassava plants under different system of cropping and management practices.

4.2 Growth attributes

In general the growth rate of different crops was characterised by slow rate of increase at the beginning followed by a rapid increase and afterwards it ceased towards maturity. The time lag between planting and rapid increase phase ranged between 60 to 70 days in cassava and 45 to 60 days in maize, rice and millet.

4.2.1 Plant height

Maize : Maximum height of maize at maturity was attained under mixed and topo-sequential cropping systems except in 1980 when plant height decreased under mixed cropping system (Table 4.2).

slight increase in height was recorded when maize was sown across the slope. The maximum rate of growth, as determined in terms of growth in height of plants / cm, was observed after 40, 55, 70 and 110 days of planting during the cropping season of 1979, 1980 and 1981, respectively. The average rate of growth was considerably higher (2.13 and 1.87 cm / day) for topo-sequential and mixed cropping systems (2.09 and 1.73 cm / day) with and without fertilizer application as compared to other three cropping systems of maize i.e. maize along and across the slope or intercropped with sesamum, soybean and pigeon-pea which had an average growth rate of 1.55, 1.64 and 1.75 cm / day, respectively during the cropping season of 1979. Similar trend in growth rate was observed in 1980 and 1981 except that the growth rate of maize when intercropped with pigeon-pea was much slower (1.79 cm / day) in comparison with the growth rate of maize in other cropping systems.

Rice : The maximum plant height of rice at maturity was recorded under sole cropping as compared to topo-sequential or mixed system of cropping in all the three years. Sole rice showed faster growth than rice in topo-sequential or mixed cropping system in all the three years except in 1981 when there was no significant difference in the growth rate of rice under sole or mixed cropping systems (Table 4.2 to 4.4). Fertilizer application significantly increased the plant height under topo-sequential as well as mixed cropping systems with corresponding higher growth rate.

Fox tail millet : The plant height of fox millet increased slightly under mixed cropping system as compared to topo-sequential cropping system except during the crop season of 1979 when the

Table 4.2 Average plant heights in cm of different crops grown under varied systems of cropping and management practices at different timings of sampling

1979 Cropping systems	Average plant height (cm)				Absolute growth rate (cm/day)			
	Days after sowing				Days after sowing			
	40	55	70	110	40	55	70	110
Maize along	51.6	74.8	99.6	151.5	1.29	1.55	1.32	1.29
Maize across	57.4	82.0	103.5	154.2	1.44	1.64	1.37	1.27
Maize intercropped with sesamum	54.3	80.5	105.1	158.9	1.36	1.75	1.64	1.35
Maize Topo-sequential crop (-F)	50.6	78.6	99.6	151.2	1.27	1.87	1.40	1.29
Maize Topo-sequential crop (+F)	56.0	88.6	112.4	175.0	1.40	2.13	1.68	1.57
Maize in mixed cropping (-F)	47.3	73.3	98.8	142.1	1.18	1.73	1.37	1.21
Maize - mixed cropping (+F)	62.8	94.2	115.2	165.3	1.52	2.09	1.49	1.25
Mean	54.3	81.7	104.9	156.9				
S. Em ±	1.9	2.8	6.1	4.1				
Rice sole cropping	49.3	74.7	98.5	129.5	1.23	1.69	1.59	0.78
Rice Topo-sequential crop (-F)	43.2	70.8	92.0	119.4	1.08	1.84	1.41	0.69
Rice Topo-sequential crop (+F)	49.0	80.2	105.2	148.4	1.23	2.08	1.67	1.08
Rice mixed cropping(-F)	31.8	52.5	67.9	104.2	0.80	1.38	1.03	0.91
Rice mixed cropping(+F)	42.1	67.8	91.7	134.8	1.05	1.73	1.59	1.08
Mean	43.1	69.2	91.1	127.3				
S. Em ±	3.2	4.7	6.3	7.4				
Millet Topo-sequential crop (-F)	32.0	66.0	94.2	159.8	0.80	2.27	1.88	1.64
Millet Topo-sequential crop (+F)	39.2	83.6	110.0	176.6	0.98	2.96	1.76	1.67
Millet mixed cropping (-F)	15.3	43.3	68.2	136.2	0.38	1.83	1.66	1.45
Millet mixed cropping (+F)	16.0	50.2	79.0	147.9	0.40	2.28	1.92	1.72
Mean	25.6	60.8	87.9	155.1				
S. Em ±	5.9	9.0	9.1	8.6				

Table 4.2 (continued)

1979 Cropping systems	Average plant height (cm)				Absolute growth rate (cm/day)			
	Days after sowing				Days after sowing			
	40	55	70	110	40	55	70	110
Cassava Topo-sequential crop (-F)	47.5	69.0	106.4	282.5	1.19	1.43	2.47	0.95
Cassava Topo-sequential crop (+F)	56.2	77.5	121.2	330.0	1.41	1.42	2.91	1.12
Cassava mixed cropping (-F)	44.2	74.3	115.7	303.6	1.11	2.01	2.76	1.01
Cassava mixed cropping (+F)	45.6	82.2	132.2	356.6	1.14	2.44	3.33	1.21
Mean	48.4	75.8	118.9	318.2				
S. Em ±	2.7	2.8	5.4	16.1				
Sesamum Topo-sequential cropping (-F)	16.0	35.2	45.6		0.40	1.28	0.69	
Sesamum Topo-sequential cropping (+F)	20.0	56.4	74.6		0.50	2.43	1.21	
Sesamum mixed cropping (-F)	13.6	28.8	37.4		0.34	1.01	0.57	
Sesamum mixed cropping (+F)	15.9	39.1	50.6		0.44	1.55	0.77	
Mean	16.4	39.9	52.1					
S. Em ±	1.3	5.9	8.0					
Soybean Topo-sequential cropping (-F)	23.4	36.4	67.8		0.59	0.88	2.09	
Soybean Topo-sequential cropping (+F)	35.0	54.4	75.2		0.88	1.29	1.39	
Soybean mixed cropping (-F)	29.9	41.5	57.8		0.75	0.77	1.89	
Soybean mixed cropping (+F)	31.8	45.5	69.5		0.80	0.91	1.60	
Mean	30.0	44.4	67.6					
S. Em ±	2.4	3.8	3.6					

+F and -F stand for with and without fertilizer

Table 4.3 Average plant heights (in cm) of different crops grown under varied systems of cropping and management practices at different timings of sampling

1980 Cropping systems	Plant heights (cm)				Absolute growth rate (cm/day)			
	Days after sowing				Days after sowing			
	25	40	55	90	25	40	55	90
Maize along	57.0	92.9	115.4	162.0	2.28	2.39	1.50	1.33
Maize across	59.5	96.0	122.5	173.3	2.38	2.43	1.77	1.45
Maize inter-cropped with soybean	51.2	91.7	120.4	175.2	2.05	2.70	1.91	1.57
Maize topo-sequential cropping(-F)	53.2	92.6	114.0	161.6	2.13	2.63	1.43	1.36
Maize topo-sequential cropping(+F)	62.8	116.4	141.8	192.6	2.51	3.57	1.69	1.45
Maized mixed cropping (-F)	44.9	89.5	108.4	136.3	1.80	2.97	1.26	0.80
Maized mixed cropping (+F)	46.7	91.8	114.3	151.2	1.87	3.01	1.50	1.05
Mean	53.6	95.8	119.5	164.6	2.15	2.81	1.58	12.60
S. Em ±	2.5	3.5	4.1	6.8				

	Plant heights (cm)					Absolute growth rate (cm/day)				
	25	40	55	70	100	25	40	55	70	100
Rice sole cropping	49.6	83.0	95.7	106.6	114.6	1.98	2.23	0.85	0.73	0.27
Rice topo-sequential cropping(-F)	56.3	87.3	97.2	104.0	110.6	2.25	2.07	0.66	0.45	0.22
Rice topo-sequential cropping(+F)	62.4	104.0	126.8	133.6	142.3	2.50	2.77	1.52	0.45	0.29
Rice mixed cropping (-F)	46.2	67.9	88.9	97.0	103.6	1.85	1.45	1.40	0.54	0.22
Rice mixed cropping (+F)	60.8	85.9	109.6	115.1	124.3	2.43	1.67	1.58	0.37	0.31
Mean	55.1	85.6	103.6	111.3	119.1	2.20	2.04	1.20	0.51	0.26
S. Em ±	3.1	5.8	6.7	6.3	6.7					

Table 4.3 (Continued)

1980 Cropping systems	Plant heights (cm)				Absolute growth rate (cm/day)			
	Days after sowing				Days after sowing			
	40	55	70	100	40	55	70	100
Millet topo-sequential cropping (-F)	71.0	118.6	126.6	138.4	1.78	3.17	0.53	0.39
Millet topo-sequential cropping (+F)	84.8	159.0	170.0	184.8	2.12	4.95	0.73	0.49
Millet mixed cropping (-F)	62.4	112.8	125.4	145.6	1.56	3.36	0.84	0.67
Millet mixed cropping (+F)	65.4	117.7	132.4	154.9	1.64	3.49	0.98	0.75
Mean	70.9	127.0	138.6	155.9	1.78	3.74	0.77	0.58
S. Em ±	5.0	10.7	10.6	10.2				
	40	55	70	180	40	55	70	180
Cassava topo-sequential cropping (-F)	51.5	100.5	167.7	272.5	1.29	3.27	4.48	0.95
Cassava topo-sequential cropping (+F)	69.0	137.9	221.0	344.0	1.73	4.59	5.54	1.12
Cassava mixed cropping (-F)	64.8	129.6	211.0	324.0	1.62	4.32	5.43	1.03
Cassava mixed cropping (+F)	77.5	152.5	235.8	360.1	1.94	5.00	5.55	1.13
Mean	65.7	130.1	208.9	325.1	1.65	4.30	5.25	1.06
S. Em ±	5.4	10.9	14.6	19.0				
Sesamum topo-sequential cropping (-F)								
Sesamum topo-sequential cropping (+F)								
Sesamum mixed cropping (-F)								
Sesamum mixed cropping (+F)								
Mean								
S. Em ±								

+F and -F indicates with and without fertilizer

Table 4.4 Plant heights (in cm) of different crops grown under varied systems of cropping and management practices when sampled on different dates

1981 Cropping systems	Plant heights (cm) Days after sowing					Absolute growth rate (cm/day) Days after sowing				
	15	30	45	60	90	15	30	45	60	90
Maize along	16.4	43.4	73.5	112.5	139.5	1.09	1.80	2.01	2.60	0.90
Maize across	17.4	44.2	77.0	120.0	147.9	1.16	1.799	2.19	2.87	0.93
Maize inter-cropped with Pigeonpea	16.1	39.2	68.8	99.0	129.6	1.07	1.54	1.97	2.01	1.02
Maize Topo-sequential cropping (-F)	16.7	44.6	82.4	130.0	151.0	1.11	1.86	2.52	3.17	0.70
Maize Topo-sequential cropping (+F)	22.1	54.6	98.4	152.5	175.0	1.47	2.17	2.92	3.61	0.75
Mean	17.7	45.2	80.0	122.8	148.6					
S. Em ±	1.1	2.5	5.1	9.0	7.6					
Rice sole cropping	14.9	32.5	59.9	90.4		0.99	1.17	1.83	2.03	
Rice Topo-sequential cropping (-F)	15.5	32.0	51.4	83.1		1.03	1.10	1.29	2.11	
Rice Topo-sequential cropping (+F)	16.2	34.3	56.2	86.4		1.08	1.21	1.46	2.01	
Rice mixed cropping (-F)	11.5	29.6	56.8	89.6		0.77	1.21	1.81	2.19	
Rice mixed cropping (+F)	12.6	34.3	68.6	105.4		0.84	1.45	2.29	2.45	
Mean	14.1	32.5	58.6	91.0						
S. Em ±	0.9	0.9	2.9	3.8						
Millet Topo-sequential cropping (-F)	14.6	36.6	99.0	124.8		0.97	1.47	4.16	1.72	
Millet Topo-sequential cropping (+F)	18.8	46.4	109.6	137.2		1.25	1.91	4.21	1.84	
Millet mixed cropping (-F)	4.2	24.9	83.7	130.7		0.31	1.35	3.92	3.13	
Millet mixed cropping (+F)	9.7	34.1	93.0	138.4		0.65	1.63	3.93	3.03	
Mean	11.8	35.5	96.3	132.8						
S. Em ±	3.1	4.4	5.4	3.2						

Table 4.4 (Continued)

1981 Cropping systems	Plant heights (cm)					Absolute growth rate(cm/				
	Days after sowing					Days after sowing				
	15	30	45	60	90	15	30	45	60	90
Cassava Topo-sequential cropping (-F)	9.5	27.0	55.0	102.4	252.5	0.63	1.17	1.87	3.16	1.07
Cassava Topo-sequential cropping (+F)	12.0	29.9	58.5	111.5	262.5	0.83	1.19	1.95	3.53	1.08
Cassava mixed cropping (-F)	11.0	28.0	51.0	115.0	277.5	0.73	1.13	1.53	4.27	1.16
Cassava mixed cropping (+F)	14.0	32.7	59.7	131.7	292.5	0.93	1.25	1.80	4.80	1.15
Mean	11.6	29.4	56.1	115.2	271.3					
S. Em ±	0.9	1.3	1.9	6.1	8.8					
	15	30	45	60	160	15	30	45	60	160
Sesamum Topo-sequential cropping (-F)	8.8	17.8	59.0	117.8	266.8	0.59	0.60	2.75	3.25	1.49
Sesamum Topo-sequential cropping (+F)	9.4	20.0	62.2	125.4	280.8	0.63	0.71	2.81	3.55	1.55
Sesamum mixed cropping (-F)	7.5	16.2	53.5	114.9	265.2	0.50	0.58	2.49	4.09	1.50
Sesamum mixed cropping (+F)	9.8	25.8	65.8	128.3	286.9	0.65	1.07	2.67	4.17	1.59
Mean	8.9	19.9	60.1	121.6	274.9					
S. Em ±	0.5	2.1	2.6	3.1	5.3					
	15	30	45	60	200	15	30	45	60	200
Pigeon pea intercropped with maize	11.3	26.4	76.8	132.8	328.0	0.75	1.01	3.36	3.73	1.39

+F and -F stand for with and without fertilizer plants attained greater height under topo-sequential system of cropping than under mixed cropping system. Fertilizer application had appreciably increased the plant height of millet under both the systems of cropping in all the three years.

Cassava : The plant height of cassava was conspicuously more under mixed cropping systems (300, 324 and 277.5 cm) than under sole cropping (282.5, 272.5 and 252.5 cm in 1979, 1980 and 1981, respectively). Fertilizer application increased plant height under both the systems of cropping. The rate of increase in height was very slow upto 25 to 40 days, slightly increased upto 45 to 55 days and there after rapid increase in height was observed upto 60 to 70 days after planting.

Sesamum : The plant height of sesamum was more under topo-sequential cropping system than under mixed cropping system during the year 1979, whereas during the cropping season of 1981 no well marked difference occurred in plant height between the two cropping systems. The rate of growth was also slower under mixed cropping system than under the sole cropping system. Fertilizer application significantly increased the plant height under both the systems of cropping although the rate of increase was considerably higher under topo-sequential cropping system than under mixed cropping system.

Pigeon pea : The plant height of pigeon pea was slightly more under sole cropping than when intercropped with maize. Slight decrease in plant height was also recorded under fertilizer applied plots. The rate of increase in plant height was slow upto 30 days but thereafter rapid increase occurred upto 60 days after sowing.

4.2.2 Tillering in rice

No well marked difference in tillering was observed due to various systems of cropping except that fertilizer application had well pronounced effect on tillering of rice under both the cropping systems. Fertilizer application increased the total number of tiller per hill by 19 per cent in 1979 and by 13 per cent in subsequent two years of cropping whereas effective tillers per hill was increased by 29, 23 and 8 per cent under topo-sequential system of cropping and by 42, 58 and 32 per cent under mixed system of cropping when compared to plots receiving no fertilizer.

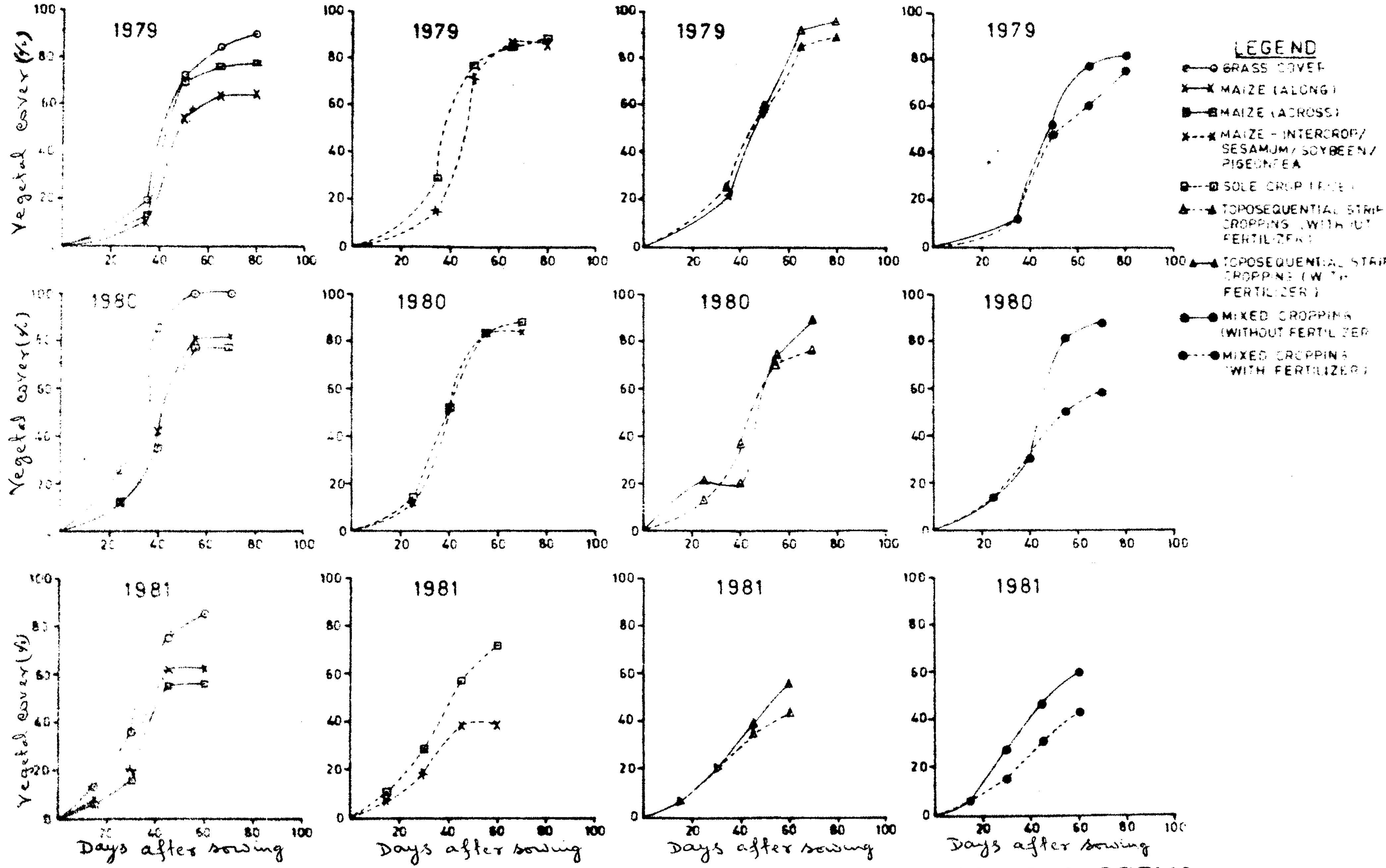
4.2.3 Vegetal cover

Marked differences were observed in vegetal ground cover provided by different crops under varied cropping systems. In general the development of ground cover was found to be maximum during the cropping season of 1980 as compared to other two years (Table 4.5).

As regards the effect of cropping systems on vegetal cover, the quickest cover was provided by the Napier grass followed by sole cropping of rice, maize intercropping systems and sole cropping of maize. Application of fertilizer helped in providing ground cover much earlier as compared to cropping systems receiving no fertilizer application. The rapid rate of increase occurred from 30 to 40 days after sowing to 45 to 55 days after sowing when more than 50 per cent of ground cover was provided by almost all the systems of cropping.

4.3 Biomass production

The data on total biomass production as influenced by



IG2 PERCENT VEGETAL COVER AS INFLUENCED BY DIFFERENT CROPPING SYSTEMS

Table 4.5 Percentage of vegetal ground cover under varied systems of cropping and management practices in different years at different dates of samplings

Year	Days after sowing	Grass cover	Maize along	Maize across	Maize inter-cropped	Sole rice	Topo-sequential Cropping -F	Topo-sequential Cropping +F	Mixed Cropping -F	Mixed Cropping +F
1979	40	19.0	10.6	13.3	15.8	25.5	20.9	23.9	12.0	12.1
	55	72.1	54.4	69.4	73.3	84.0	55.1	57.7	48.4	52.3
	70	84.7	63.8	79.9	86.5	89.8	70.5	90.3	70.9	77.7
	90	90.2	64.6	81.2	86.5	89.8	75.8	93.9	75.2	82.4
1980	25	26.3	12.7	13.3	11.5	14.8	13.9	21.0	14.0	14.0
	40	86.3	35.5	42.7	45.8	52.5	36.1	45.7	30.65	31.3
	55	100.0	74.6	82.8	84.8	88.1	70.0	84.2	50.1	82.7
	90	100.0	77.8	81.8	84.8	88.1	79.6	89.7	59.0	88.1
1981	15	13.3	8.0	6.7	7.3	10.5	6.2	6.6	5.7	6.4
	30	36.9	20.7	16.6	18.1	28.1	20.2	28.0	15.2	27.2
	45	85.7	62.6	55.8	59.4	57.4	35.1	38.6	31.3	46.0
	60	85.7	62.6	56.5	59.4	72.2	43.8	55.8	43.4	60.0

+F and -F indicates with and without fertilizer application different systems of cropping and management practices along with percentages of relative contribution of individual crop is given in Table 4.6. There was no well marked difference in biomass production of maize when sown either along (21.35 q / ha) or across the slope (22.13 q / ha) but the average production was reduced (19.68 q / ha) under intercropping system primarily because of the failure of intercrops in 1979 and 1980 but during the cropping season of 1981 when maize was intercropped with pigeon pea, the total biomass production of intercropping system was more (19.68 q / ha) because pigeon pea proved successful as intercrop. In general, the biomass production was maximum in the first year of cropping and there after it decreased in subsequent two years. The decrease was in order of 16 and 33 % with maize along the slope, 0 and 29 % with maize across the slope and 9.2 % with intercropping system in subsequent two years. The average production of biomass under sole rice was low (12.92 q / ha) as compared to other cropping systems. The magnitude of decrease in biomass production of sole rice was also much higher i.e. 38 and 82 % in subsequent in 1980 and 1981, respectively.

The average total production of biomass under mixed cropping system even without any fertilizer application was more (27.20 q / ha) than the average production of 22.16 q / ha under topo-sequential system of cropping as well as other cropping systems like sole cropping of maize along or across the slope, intercropping system and sole cropping of ride.

Fertilizer application increased higher biomass production under both the systems of cropping. There was increasing trend in biomass production in mixed cropping system with fertilizer

Table 4.6 Total biomass production in q / ha under different systems of cropping and management practices in different years

Cropping systems		1979	1980	1981	Mean
Grass cover					
Maize along		25.56	21.49	17.00	21.35
Maize across		24.86	24.90	17.53	22.13
Maize intercropped		20.96	19.04	19.05	19.68
Sole rice		21.61	13.31	3.83	12.92
Topo-sequential cropping (-F)					
1. Cassava (10 % area)		13.44	7.91	8.94	10.10
2. Maize (10 % area)		2.21	1.69	3.26	2.39
3. Rice (50 % area)		10.29	7.89	1.82	6.67
4. Millet (10 % area)		1.78	1.81	1.55	1.71
5. Sesamum (10 % area)		Failed	2.50	1.38	1.29
	Total	27.72	21.80	16.95	22.16
Topo-sequential cropping (+F)					
1. Cassava (10 % area)		17.00	15.63	11.48	14.70
2. Maize (10 % area)		2.92	2.04	3.71	2.89
3. Rice (50 % area)		16.22	13.34	5.38	11.65
4. Millet (10 % area)		2.00	1.97	1.55	1.84
5. Sesamum (10 % area)		Failed	2.75	1.63	1.46
	Total	38.14	35.73	23.75	32.54
Mixed cropping (-F)					
1. Cassava (10 % area)		15.44	24.55	9.13	16.37
2. Maize (10 % area)		3.08	1.07	2.64	2.26
3. Rice (50 % area)		2.03	7.11	Failed	4.57
4. Millet (10 % area)		1.04	0.56	1.52	1.04
5. Sesamum (10 % area)		Failed	0.25	8.63	2.96
	Total	21.59	33.54	21.92	27.20
Mixed cropping (+F)					
1. Cassava (10 % area)		18.06	29.80	21.02	22.96
2. Maize (10 % area)		6.66	1.24	6.00	4.63
3. Rice (50 % area)		4.81	6.64	Failed	3.82
4. Millet (10 % area)		2.64	1.18	2.02	1.95
5. Sesamum (10 % area)		Failed	0.65	12.25	4.30
	Total	32.17	39.51	41.29	37.66

+F and -F indicates with and without fertiliser application whereas under topo-sequential system of cropping decreasing trend in total production of biomass was observed.

As regards the relative contribution of individual crop in producing total biomass under topo-sequential and mixed cropping systems, cassava ranked first by contributing 45.58 % of the biomass folłowed by rice (30.09 %), maize (10.79 %), millet (7.72 %) and sesamum (5.82 %) under topo-sequential cropping system without fertilizer application as compared to the relative contribution of 60.18, 16.80, 10.88, 8.31 and 3.82 % of cassava, rice, sesamum, maize and millet, respectively under mixed cropping system without fertilizer application. More or less similar trend of variation was observed in fertilizer treated plots under both the systems of cropping.

4.5 Yield contributing characters and yield of different crops

4.5.1 Maize

Percentage of barren plants : In general percentage of barren plants was higher (46.7 %) in 1980 (Table 4.7) than in 1979 (29.84) and 1981 (28.8 %). As regards the influence of cropping systems, the mean percentage of barren plants was found to be minimum under topo-sequential (29.3 and 26.4 %) and mixed cropping systems (32.2 and 25.2 %) with and without fertilizer applications, respectively. The percentage of barrenness was high under maize planted across the slope (54.2 %) followed by intercropped maize (41.7 %) and maize planted along the slope (35.7 %).

Number of grains / cob : The average number of grains / cob was more (Table 4.7) in 1981 (208) than the cropping seasons of 1979 (146) and 1980 (142). As regards the influence of cropping

Table 4.7 Growth, yield attributing characters and yield of maize under varied systems of cropping and management practices

Characters	Years	Cropping systems: Maize along	Maize across	Maize inter-cropped	Topo-sequential cropping −F	Topo-sequential cropping +F	Mixed cropping −F	Mixed cropping +F	Mean	S.Em (±)
Final plant height (cm)	1979	151.5	154.2	158.9	151.2	175.0	142.1	165.3	156.9	4.1
	1980	162.0	173.3	175.2	161.6	192.5	136.3	151.2	164.6	6.8
	1981	139.5	147.9	129.6	151.0	175.0	140.0	160.0	149.0	5.7
	Mean	151.0	158.5	154.6	154.6	180.8	139.5	158.8	156.8	4.7
Plant stand/ m^2 at harvest	1979	5.9	5.6	6.1	4.3	3.0	5.5	4.3	4.9	0.4
	1980	7.0	7.0	6.5	6.0	4.0	3.3	4.5	5.5	0.6
	1981	7.0	7.7	7.5	7.3	6.0	5.5	6.0	6.7	0.3
	Mean	6.7	6.8	6.7	5.8	4.3	4.8	4.9	5.7	0.4
Barrenness %	1979	44.9	63.2	51.2	9.7	9.3	20.5	10.1	29.8	8.6
	1980	33.7	46.0	34.1	46.4	41.80	69.2	55.6	46.7	4.7
	1981	28.4	53.4	39.9	31.9	28.0	10.0	10.0	28.8	5.9
	Mean	35.7	54.2	41.7	29.3	26.4	33.2	25.2	35.1	3.8
Number of grains /cob	1979	168.9	162.0	126.7	140.0	200.0	80.0	142.5	145.7	14.2
	1980	186.1	185.5	171.9	100.0	223.0	61.5	66.0	142.0	24.5
	1981	163.9	160.8	147.3	299.8	360.0	110.2	212.8	207.8	34.1
	Mean	173.0	169.4	148.6	179.9	261.0	83.9	140.4	165.2	20.1
1000 grains weight (g)	1979	266.3	227.0	270.0	235.7	298.0	297.5	313.7	272.6	12.4
	1980	189.1	186.5	166.9	260.0	264.6	160.2	265.2	227.5	19.0
	1981	167.2	166.0	152.7	206.8	241.7	202.1	240.8	196.8	13.7
	Mean	207.5	193.2	196.5	234.2	268.1	253.3	273.2	232.3	12.7
Stover yield (q/ha)	1979	13.6	11.8	10.3	9.0	11.7	17.6	27.5	14.5	2.4
	1980	13.1	113.7	12.7	9.7	10.5	7.1	8.1	10.0	1.0
	1981	9.5	7.7	12.3	18.2	22.5	14.2	29.3	16.2	2.9
	Mean	12.1	11.1	11.8	12.3	14.9	13.0	21.6	13.8	1.4
Grain yield (q/ha)	1979	12.0	13.0	10.7	13.1	17.5	13.3	39.1	17.0	3.8
	1980	8.4	11.2	6.7	7.3	9.9	3.6	4.7	7.3	1.0
	1981	7.5	9.8	6.7	14.7	14.6	12.3	30.8	13.7	3.1
	Mean	9.3	11.3	7.9	11.6	14.0	9.7	24.7	12.6	2.1
Harvest index	1979	0.47	0.52	0.51	0.60	0.60	0.43	0.59	0.53	
	1980	0.39	0.45	0.33	0.43	0.48	0.34	0.35	0.40	
	1981	0.44	0.56	0.35	00.44	0.39	0.46	0.51	0.46	
	Mean	0.43	0.50	0.40	0.49	0.48	0.48	0.53		

systems, the average number of grains / cob was recorded to be maximum under topo-sequential cropping systems receiving fertilizer application (261) which was appreciably higher than the plots receiving no fertilizer application (180) followed by maize along (173) and maize across the slope (169). The number of grains / cob was appreciably reduced under mixed cropping without any fertilizer application (84) although fertilizer application increased the grain number (140) and this was at par with intercropped maize (149).

Test weight of grains : Averaged over cropping systems, 1000 grain weight was more (272.6 and 227.5 g) during the cropping seasons of 1979 and 1980, respectively) in two previous years than those recorded in 1981 (197 g).

The mean weight of 1000 grains was higher under mixed cropping system (268.1 and 234.2 g) followed by topo-sequential cropping systems (268.1 and 234.2 g) with and without fertilizer application. Thus, fertilizer application has increased the test weight under both the two systems.

Stover yield : Averaged over cropping systems, the stover yield was relatively more in 1981 (16.30 q / ha) and 1979 (14.49 q / ha) than in 1980 (10.67 q / ha). The average stover yield of maize did not differ widely under different systems of cropping except in case of fertilized plots under mixed cropping which recorded appreciably higher mean yield of 21.60 q / ha than in other cropping systems which ranged between 11.25 to 14.90 q / ha.

Averaged over cropping systems, the maximum grain yield of 16.95 q / ha was obtained during the cropping season of 1979 followed by 13.72 q / ha and 7.29 q / ha in 1981 and 1980, respectively. Maize in mixed cropping system with fertilizer application gave the maximum yield of 24.75 q / ha which was appreciably superior to the yield obtained under other cropping systems, the mean grain yield under which ranged between 7.92 to 11.58 q / ha. Fertilizer qpplication under topo-sequential system of cropping increased the grain yield by 50, 36 and 1 % in the cropping season of 1979, 1980 and 1981, respectively over other cropping systems. The percentage increase in yield of maize under mixed cropping system was particularly higher due to fertilizer application than topo-sequential cropping system.

Harvest index : The harvest index (grain yield divided by total plant dry weight harvest) values showed wide differences (Table 4.7) under different systems of cropping. The lowest harvest index (0.40) was recorded in the intercropped maize and the highest value was recorded under mixed cropping with fertilizer (0.53).

Correlation between grain yield and yield atributing characters

The simple correlation co-efficient between maize grain yield and some of the important yield contributing characters are given in Table 4.8. The data revealed that stover yield and 1000 grain weight showed significant positive correlation with yield whereas barrenness percentage exhibited highly significant negative correlation with grain yield. The value of R^2 (Co-efficient of determination of multiple regression equation) showed that 74 per cent of variations in grain yield was accounted for by the six characters included for study. The algebric signs of regression co-efficient values indicated that characters like stover yield (x_6).

Table 4.8 Simple correlation co-efficients between maize grain yield and yield attributing characters (Pooled data of 1979, 1980 and 1981)

Characters	x_2 Final plant stand	x_3 Barren-ness %	x_4 Kernel number	x_5 1000 grain weight	x_6 Stover yield	x_7 Grain yield
x_1 Plant height	-0.2294	-0.1259	0.5604*	0.2601	0.2101	0.2373
x_2 Final plant stand	-	0.1424	0.2769	-0.7587*	0.0671	-0.2014
x_3 Barrenness %	-	-	-0.2505	-0.1562	-0.5757**	-0.6205**
x_4 Kernel No.	-	-	-	-0.1833	0.4550*	0.2522
x_5 1000 grain weight	-	-	-	-	0.2462	0.4342*
x_6 Stover yield	-	-	-	-	-	0.8534**

Multiple regression equation:

$$Y = -2.471 + 0.038x_1 - 0.00007x_2 - 0.0702x_3 - 0.016x_4 + 0.0137x_5 + 1.093x_6$$

$R = 0.8619$; $R^2 = 0.74$

1000 grain (x_5) weight and plant height (x_1) in the order of weightage showed additive effects whereas barrenness percentage (x_3), grain numbers / cob (x_4) and plant stand (x_2) showed negative effects on grain yield.

Rice

Effective tillers / hill : In general, the number of effective tillers / hill was slightly more (Table 4.9) in 1980 (3.17 / hill) than in 1979 (2.53 / hill) and 1981 (2.12 / hill). No significant difference occurred in the number of effective tillers / hill among various cropping systems of rice except that under topo-sequential system of cropping it was slightly more.

Panicle length : Averaged over cropping systems, the maximum length of panicle (Table 4.9) was observed in 1979 (24.74 cm) followed by those in 1980 (21.06 cm) and 1981 (20.74 cm). There was no significant difference in panicle length of rice under different systems of cropping except that fertilizer application increased length of panicles under topo-sequential and mixed cropping systems.

Number of filled grains / panicle

The average number of filled grains per panicle (Table 4.9) was comparatively more in 1979 (101.10) and 1981 (102.43) than in 1980 (81.88). Fertilizer application had appreciably increased the average number of grains from 95.6 (in unfertilized plot) to 105.4 in fertilized plot under topo-sequential cropping, the corresponding figures in mixed cropping is 74 (in fertilized plot) and 94 (in fertilized plot).

Table 4.9 Growth, yield contributing characters and yield of rice as influenced by different systems of cropping and management practices

Characters	Years	Cropping systems					Mean	S.Em (±)
		Sole rice	Topo-sequential cropping		Mixed cropping			
			-F	+F	-F	+F		
Final plant height (cm)	1979	129.5	119.4	148.4	104.2	134.8	127.26	7.4
	1980	114.6	110.6	142.3	103.6	124.3	119.08	6.7
	1981	90.4	83.1	86.4	89.6	105.4	90.98	3.8
	Mean	111.5	104.4	125.7	99.1	121.5	112.40	5.0
Plant stand/m^2	1979	23.93	24.76	19.16	8.80	6.16	16.56	3.8
	1980	25.15	24.66	23.56	11.46	25.60	22.09	2.7
	1981	20.85	19.40	11.25	18.06	19.10	17.73	1.7
	Mean	23.31	22.94	17.99	12.77	16.95	18.80	2.0
Effective tillers/ hill	1979	3.10	3.06	2.36	2.32	1.83	2.53	0.2
	1980	2.62	3.25	3.80	3.91	2.28	3.17	0.3
	1981	1.98	2.20	2.38	1.75	2.31	2.12	0.1
	Mean	2.57	2.84	2.85	2.66	2.14	2.60	0.1
Panicle length(cm)	1979	24.5	24.2	24.7	25.2	25.1	24.74	0.2
	1980	21.3	21.7	22.9	18.5	20.9	21.06	0.7
	1981	20.8	20.8	22.8	19.8	20.3	20.75	0.6
	Mean	22.2	22.2	23.5	20.9	22.1	22.20	0.4
No. of filled grains/ panicle	1979	116.0	92.9	111.7	82.7	102.2	101.10	6.1
	1980	65.8	94.0	98.4	65.3	85.9	81.88	7.0
	1981	101.3	100.0	106.0	Failed	Failed	102.43	1.8
	Mean	94.4	95.6	105.4	74.0	94.1	97.70	5.1
1000 t grain weight (g)	1979	21.82	22.43	23.24	21.14	21.22	21.97	0.4
	1980	22.73	22.52	22.97	22.20	22.46	22.58	0.1
	1981	20.18	21.41	21.86	Failed	Failed	21.15	0.5
	Mean	21.58	22.12	22.69	21.67	21.84	22.00	0.2
Straw yield (q / ha)	1979	13.28	12.75	23.81	2.78	7.43	12.01	3.5
	1980	7.10	8.56	19.59	12.71	9.56	11.50	2.2
	1981	2.27	2.25	7.95	Failed	Failed	4.16	1.9
	Mean	7.55	7.85	17.12	7.75	8.50	9.80	1.8
Grain yield (q / ha)	1979	8.33	7.83	8.63	1.28	2.18	5.65	1.6
	1980	6.21	7.22	7.08	1.50	3.71	5.14	1.1
	1981	1.56	1.38	2.81	Failed	Failed	1.92	0.4
	Mean	5.37	5.48	6.17	1.39	2.95	4.30	0.9
Harvest index	1979	0.39	0.38	0.27	0.32	0.23	0.32	
	1980	0.47	0.46	0.27	0.11	0.28	0.32	
	1981	0.42	0.38	0.26	-	-	0.35	
	Mean	0.42	0.41	0.26	0.15	0.26		

Test weight of grains : There was no significant difference in 1000 grain weight of rice between various systems of cropping except that fertilizer application had slightly increased (Table 4.9) the 1000 grain weight under both the systems of cropping.

Straw yield : Averaged over cropping system, straw yield (Table 4.9) of rice was of the same order in 1979 (12.01 q / ha) and 1980 (11.50 q / ha) but it was appreciably reduced in 1981 (4.16 q / ha).

As regards the effect of different cropping systems on straw yield, there appeared to be no significant difference in average straw yield of rice under different systems of cropping except that treatments under topo-sequential system of cropping receiving fertilizer application had appreciably higher (17.12 q / ha) straw yield than the average straw yield of other systems ranging from 7.55 to 8.50 q / ha.

Grain yield : Averaged over cropping systems, the grain yield of rice during 1979 and 1980 was of the same order i.e. ~~12.01~~ 5.65 and ~~11.50 q~~ 5.14 / ha, respectively but during the year 1981 it was appreciably reduced to ~~4.16~~ 1.92 q / ha.

There was no appreciable difference in the average grain yield of rice under sole cropping (5.37), topo-sequential cropping with (6.17) and without fertilizer application (5.48 q / ha). But the grain yield of rice was appreciably reduced under mixed cropping system both with (2.95 q / ha) and without (1.39 q / ha) fertilizer application. The percentage increase in grain yield due to application of fertilizer was nominal in first year i.e. only 10 %, where there was no increase in second year but in third year of cropping there was spectacular increase of 104 % under topo-sequential system of cropping whereas under mixed system of cropping the increase in yield due to application of fertilizer was 70 and 147 % in first and second years, respectively but in the third year of cropping rice plants failed to produce any grain.

Harvest index : Averaged over cropping systems, there was no significant difference in harvest index in different years of cropping. But there was well marked difference in the harvest index of rice under different systems of cropping. The harvest index value was appreciably reduced from 0.41 to 0.26 in fertilized topo-sequential cropping but under mixed cropping the harvest index value increased from 0.15 in untreated plot to 0.26 under fertilized plot.

Correlation between grain yield and yield attributes of rice

The data on correlation co-efficient values indicated highly significant positive correlation of grain yield with straw yield and 1000 grain weight and significant positive correlation with plant height as well as plant stand (Table 4.10). The value of R^2 (co-efficient of determination) revealed that 82 per cent of variation in grain yield of rice was accounted for by these seven yield contributing characters. The algebric signs of multiple regression equation for predicting yield indicated that except plant height, all the other six characters showed additive effects on grain yield. The weightage of additive effect was in the order of 1000 grain weight (x_6), effective tillers / hill (x_3), number of filled grains per panicle (x_4), plant stand (x_2), straw yield (x_7) and 1000 grain weight (x_5) whereas the weightage of negative effect of plant height was considerably low (0.005).

Table 4.10 Simple correlation co-efficients between some of the important plant characters and yield of rice

Characters	x_2 Plant stand/m^2	x_3 Effective tillers/ plant	x_4 Panicle length (cm)	x_5 No. of tiller grains	x_6 1000 grain weight	x_7 Straw yield q/ha	Y Grain yield q/ha
x_1 Average plant height (cm)	0.209	0.212	0.505	0.218	0.595	0.786	0.670*
x_2 Plant stand/m^2	-	0.282	-0.214	0.036	0.441	0.248	0.657
x_3 Effective tillers/ plant	-	-	-0.282	-0.294	0.535	0.505	0.406NS
x_4 Panicle length (cm)	-	-	-	0.552	0.016	0.243	0.368NS
x_5 No. of filled grains/ panicle	-	-	-	-	-0.146	0.244	0.298
x_6 1000 grain weight in g	-	-	-	-	-	0.778	0.722**
x_7 Straw yield (q/ha)	-	-	-	-	-	-	0.721**

$$Y = 39.14 - 0.005x_1 + 0.233x_2 + 0.789x_3 + 0.654x_4 + 0.015x_5 + 0.942x_6 + 0.083x_7$$

$R = 0.906$

$R^2 = 0.82$

Fox tail millet

Length of ears : Averaged over cropping systems, no appreciable difference occurred in the average ear length (Table 4.11) of fox tail millet in different years of cropping. The differences in the ear length under topo-sequential and mixed cropping systems were not wider. But application of fertilizer increased the mean length of ears to 24.00 cm over 17.77 in unfertilized plots under topo-sequential cropping system; the corresponding figures under mixed cropping were 28.5 and 17.26 cm.

Straw yield : The mean straw yield of fox tail millet (Table 4.12) was of the same order during 1979 (12.12 q / ha) and 1981 (11.32 q / ha) but it was appreciably low in 1980 (8.53 q/ha). Under unfertilized condition, the mean straw yield was very low (6.80 q / ha) in mixed cropping system as against high yield of 11.52 q / ha obtained under topo-sequential cropping system. Application of fertiliser showed spectacular increase in straw yield under mixed cropping system than under topo-sequential cropping system. The percentage increase in straw yield due to application of fertiliser over control plot was 14, 35 and 31 per cent, in three successive years under mixed cropping system whereas under topo-sequential system of cropping the per cent increases were 9, 6 and 0 per cent in 1979, 1980 and 1981, respectively.

Grain yield : There was no appreciable difference (Table 4.11) in the grain yield of fox tail millet in different years of cropping. But as regards the effect of cropping systems, the grain yield was appreciably reduced under mixed cropping system (3.57 q / ha) as compared to the grain yield (5.58 q / ha) under topo-sequential cropping system, receiving no fertiliser. Under

Table 4.11 Growth, yield contributing characters and yield of fox tail millet as influenced by different systems of cropping and management practices

Plant characters	Years	Cropping systems: Topo-sequential cropping -F	Topo-sequential cropping +F	Mixed cropping -F	Mixed cropping +F	Mean	S. Em (±)
Final plant height (cm)	1979	159.8	176.6	136.2	147.9	155.13	8.63
	1980	138.4	184.8	145.6	154.9	155.93	10.20
	1981	124.8	137.2	130.7	138.4	132.78	3.15
	Mean	141.0	166.2	137.5	147.1	147.95	6.40
Plant stand/ m^2	1979	15.35	10.0	6.50	7.25	9.75	1.98
	1980	7.80	4.50	6.50	3.30	5.53	1.00
	1981	18.30	12.00	18.30	12.80	15.35	1.98
	Mean	13.78	8.83	10.43	7.78	10.21	1.31
Length of ears in cm	1979	18.20	26.00	17.20	19.70	20.28	1.98
	1980	17.90	23.60	17.77	21.60	20.22	1.43
	1981	17.20	22.40	16.80	20.20	19.15	1.32
	Mean	17.77	24.00	17.26	20.50	19.88	1.54
Straw yield (q / ha)	1979	12.00	13.13	6.74	16.60	12.12	2.04
	1980	11.55	12.24	3.50	6.84	8.53	2.01
	1981	11.00	10.80	10.15	13.33	11.32	0.69
	Mean	11.52	12.06	6.80	12.26	10.66	1.30
Grain yield (q / ha)	1979	5.75	6.88	3.63	9.75	6.50	1.27
	1980	6.50	7.50	2.08	5.00	5.27	1.18
	1981	4.50	4.63	5.00	6.87	5.25	0.55
	Mean	5.58	6.34	3.57	7.21	5.68	0.78
Harvest index	1979	0.32	0.34	0.35	0.37	0.35	
	1980	0.36	0.38	0.37	0.42	0.38	
	1981	0.29	0.30	0.33	0.34	0.32	
	Mean	0.32	0.34	0.35	0.38	0.35	

Table 4.12 Simple correlation co-efficients between some of the important plant characters and yield (Pooled data of 1979, 1980 and 1981) of fox tail millet

Characters	x_2 Plant stand /m^2	x_3 Length of ears in cm	x_4 Straw yield q / ha	Y Grain yield q/ha
x_1 Final plant height(cm)	-0.4876	0.7531	0.2085	0.4023
x_2 Plant stand/m^2	-	-0.3672	0.2570	-0.1109
x_3 Length of ears (cm)	-	-	0.3235	0.4090
x_4 Straw yield (q/ha) at 15 % moisture	-	-	-	0.9105*

Multiple regression equation

$Y = 0.993 + 0.0131x_1 - 0.1456x_2 - 0.1025x_3 + 0.5874x_4$

$R = 0.9727$

$R^2 = 0.9461$

fertilized condition the average grain yield was slightly more in mixed cropping system (7.21 q / ha) as against the grain yield of 6.34 q / ha under topo-sequential cropping.

Harvest index : The value of harvest index was slightly more (0.38) in 1980 than 1979 (0.35) and 1981 (0.32). The average value of harvest index was slightly more under mixed cropping systems (0.38 and 0.35) as compared to the values of 0.34 and 0.32 under topo-sequential system of cropping with and without fertiliser application, respectively.

Correlation between grain yield of fox tail millet and yield contributing characters

Only straw yield showed significant positive correlation with grain yield of fox tail millet. As indicated by R^2 values (co-efficient of determination) of multiple regression equation (Table 4.12), the percentage variability in grain yield accounted for by these four characters were more than 94 per cent. The algebric signs of regression co-efficient showed maximum additive effect of straw yield (x_4) followed by plant height (x_1) whereas the weightage of negative effect was more for plant stand (x_2) followed by ear length (x_3).

Cassava

Average number of tubers / plant

The average number of tubers per plant (Table 4.13) did not differ widely in different years of cropping. But systems of cropping had reflected influence on average number of tubers per plant. The average number of tubers per plant was appreciably higher under mixed cropping systems (11.33 and 8.16) as compared to topo-sequential system of cropping (5.19 and 5.86) with and without fertiliser applications.

Table 4.13 Growth, yield contributing characters and yield of cassava as influenced by different systems of cropping and management practices

Plant characters	Years	Cropping systems: Topo-sequential cropping −F	+F	Mixed cropping −F	+F	Mean	S. Em (±)
Average plant height in (cm)	1979	282.5	330.0	303.6	356.6	318.2	16.08
	1980	272.5	344.0	324.0	360.0	325.1	19.02
	1981	252.5	262.5	277.5	292.5	271.3	18.98
	Mean	269.2	312.2	301.7	336.4	304.9	13.93
Average number of tubers/plant	1979	8.25	5.75	9.25	8.75	8.00	0.78
	1980	3.67	4.33	9.75	12.25	7.50	2.09
	1981	5.67	5.50	5.50	13.00	7.42	1.86
	Mean	5.86	5.19	8.16	11.33	7.64	1.39
Mean tuber weight/plant (kg)	1979	0.348	0.630	0.338	0.418	0.343	0.09
	1980	0.266	0.462	0.357	0.371	0.364	00.04
	1981	0.247	0.300	0.260	0.268	0.269	0.01
	Mean	0.287	0.464	0.318	0.352	0.355	0.04
Dry matter yield of plants (q/ha)	1979	33.75	43.13	45.00	52.50	43.60	3.85
	1980	45.00	86.25	123.75	138.75	98.44	20.96
	1981	40.41	57.00	42.25	88.12	56.70	11.15
	Mean	39.72	62.12	70.00	93.12	66.24	11.02
Tuber yield (q/ha)	1979	287.50	362.44	312.50	365.94	332.09	15.81
	1980	97.50	200.00	347.85	455.00	275.09	78.97
	1981	140.00	165.00	143.12	348.75	199.22	50.15
	Mean	175.00	242.48	267.82	389.90	268.80	44.87
Dry matter yield of tubers at 35% moisture (q/ha)	1979	100.63	126.85	109.38	128.08	116.24	6.73
	1980	34.13	70.00	121.75	159.25	96.28	27.64
	1981	49.00	57.75	50.09	122.06	69.73	17.55
	Mean	61.25	84.86	93.74	136.46	94.08	15.70
Harvest index	1979	0.75	0.75	0.71	0.71	0.73	
	1980	0.43	0.45	0.50	0.53	0.48	
	1981	0.55	0.50	0.55	0.58	0.55	
	Mean	0.58	0.57	0.59	0.61		

Table 4.14 Simple correlation co-efficients between plant characters and tuber yield of cassava

Characters	x_2 Average tuber number	x_3 Mean tuber weight in kg	x_4 Dry matter yield q/ha	Y Grain yield q/ha
x_1 Plant height(cm)	0.3802	0.672*	0.571	0.747**
x_2 Average tuber number	-	-0.092	0.586	0.811**
x_3 Mean tuber yield	-	-	0.059	0.484
x_4 Dry matter yield of plant (q/ha)	-	-	-	0.552

Multiple regression equation

$Y = -271.45 + 0.458x_1 + 31.00x_2 + 486.62x_3 - 0.139x_4$

$R = 0.982 \quad R^2 = 0.9654$

Dry matter yield of plants excluding tubers

The average dry matter of plants was significantly more in 1980 (98.44 q / ha) than in 1979 (43.60 q / ha) or 1981 (56.70 q / ha). The dry matter yield of plants was appreciably higher under mixed system of cropping (93.12 and 70.00 q / ha) as compared to topo-sequential system of cropping with and without fertilizer application (62.12 and 39.72).

Tuber yield

Averaged over cropping systems, maximum tuber yield was obtained in 1979 (332.09 q / ha) followed by the year 1980 (275.09 q / ha) and 1981 (199.22 q / ha).

As regards the effect of cropping system, the mean tuber yield was significantly more under mixed cropping system (389.90 and 267.82 q / ha) as compared to the average yield of 242.48 and 175.00 q / ha under topo-sequential system of cropping with and without fertilizer application. The percentage increase in tuber yield due to fertilizer application was 46 and 40 per cent in mixed and topo-sequential cropping system.

Harvest index

Averaged over cropping systems, the value of harvest index was maximum (Table 4.14) in 1979 (0.73) followed by 0.55 in 1981 and 0.48 in 1980 (0.40).

As regards the effect of cropping systems there was negligible difference in the value of harvest index due to different cropping systems.

Correlation between yield and yield characters

The plant height and average number of tubers per plant exhibited highly significant positive correlation with tuber yield. As revealed by R^2 values (co-efficient of determination) all the four characters included for study accounted for more than 96 per cent variation in tuber yield of cassava. The algebric signs of regression co-efficient showed maximum additive effect of mean tuber weight (x_3) followed by average number of tubers per plant (x_2) and plant height (x_1) whereas the dry matter yield showed negative effect on tuber yield of cassava.

4.2 Effect of different stages of shifting cultivation and cropping systems on soil properties, runoff, soil and nutrient losses

4.2.1 Stages of shifting cultivation and soil properties

A perusal of data summarised in Table 4.15 revealed considerable changes in physical and chemical properties of soil as affected by different stages of shifting cultivation. The sand percentage decreased from 70.2 to 55.5 per cent after three years of cropping. Bulk density of soil decreased slightly from 1.18 to 1.13 g / cm^3 as a result of burining but increased slightly to 1.16 g / cm^3 after three years of cropping. The soil aggregate fraction larger than 0.25 mm also increased due to burning.

The organic carbon content increased from 1.25 to 1.38 per cent but afterwards decreased to 1.23 per cent. Burning caused rise in soil pH value from 5.65 to 6.95 which declined to 5.32, even slightly below the original level after three years of cropping.

Burning of soil also caused substantial increases in almost all the major and micro-nutrients but these nutrients tended to decrease after 3 years of cropping. The cation exchange capacity increased by 27 per cent with burning but again decreased by 17 per cent after 3 years of cultivation. Among the exchangeable cations, there was maximum increase (185 %) in exchangeable magnesium closely followed by increases of 88 and 40 per cent in exchangeable potassium and calcium, respectively; corresponding decreases in exchangeable magnesium, potassium and calcium after 3 years of cultivation were 23, 39 and 13.4 per cent, respectively.

Total phosphorus, potash, calcium and magnesium increased by 24, 15, 50 and 10 per cent, respectively with burning whereas the

Table 4.15 Physical and chemical properties of soil (0 - 15 cm depth) as influenced by different stages of shifting cultivation

Particulars		Before burning	After burning	After 3 years of cropping
Physical properties				
Mechanical	Sand	70.2	-	55.5
Composition	Silt	16.2	-	18.3
	Clay	13.6	-	26.3
Texture		Sandy loam		
Bulk density (g/cm^3)		1.18	1.13	1.16
Water stable aggregate (greater than 0.25 mm)		43.8	60.8	47.7
Chemical properties				
pH		5.74	6.95	5.32
Organic carbon (%)		1.25	1.53	1.23
Cation exchange capacity ~~(CEC)~~ (meq/100g)		7.57	9.47	6.16
Exchangeable cations (meq/100)				
Calcium		3.78	5.31	3.29
Magnesium		1.57	4.48	1.21
Potassium		0.67	1.26	0.41
Total nutrients				
Phosphorus P (ppm)		158.40	195.80	123.30
Potassium K (%)		0.33	0.38	0.25
Calcium Ca (%)		0.22	0.33	0.18
Magnesium Mg (%)		0.42	0.46	0.38
Iron Fe (%)		4.20	3.00	5.30
Manganese Mn (ppm)		576.00	636.00	534.00
Zinc Zn (ppm)		75.50	86.00	67.80
Copper Cu (ppm)		23.20	24.30	20.80

percentages of decrease in these elements after 3 years of cropping were 22, 24, 14 and 9.5 per cent, respectively. Increases of 12, 9 and 4.5 per cent were also observed in case of zinc, manganese and copper, respectively with burning which again decreased by 10.2, 7.3 and 10.3 per cent after 3 years of cropping. In contrast to these three micro-nutrients, the total iron content decreased from 4.21 to 3.0 per cent with burning but again increased to 5.3 per cent after 3 years of cultivation.

4.2.2 Cropping systems and soil properties

The data on the influence of different cropping systems on some of the physical and chemical properties of soil are presented in Table 4.16. In general different cropping systems resulted in slight decrease in bulk density and increase in organic carbon content of the soil after three years of cropping. The maximum increase in organic carbon content of soil was observed under grass cover from 1.29 % to 1.46 % with corresponding decrease in bulk density of soil from 1.16 to 1.11 g / cm^2 after three years of cropping.

Slight variations were also observed in chemical concentrations of soil nutrients due to different systems of cropping although there were no appreciable differences among themselves. The concentration of almost all the nutrients decreased appreciably after three years of cultivation but the maximum decrease was observed under bare fallow plot.

4.2.3 Runoff and soil losses in relation to erosive rainfall

The data on percentage contribution of erosive rainfall in causing runoff and soil loss given in Table 4.17 indicate that runoff

Table 4.16 Effect of different systems of cropping and management practices on some physical and chemical properties of soil

Parti-culars	Timing	Grass cover	Bare fa-llow	Maize along	Maize across	Maize inter-cropped	Sole rice	Topo-sequential cropping -F	Topo-sequential cropping +F	Mixed cropping -F	Mixed cropping +F
Bulk density (g/cm^3)	BB	1.16	1.23	1.28	1.18	1.14	1.24	1.20	1.10	1.15	1.16
	AB	1.14	1.19	1.10	1.14	1.14	1.22	1.07	1.07	1.10	1.15
	AC	1.12	1.33	1.00	1.16	1.13	1.18	1.13	1.18	1.02	1.16
pH	BB	5.50	5.50	6.10	6.10	5.60	5.10	5.60	6.60	5.80	5.50
	AB	6.00	6.80	8.20	7.10	7.70	6.70	7.80	6.90	6.20	6.10
	AC	5.10	5.20	5.50	5.40	5.50	5.60	5.50	5.10	5.00	5.30
Organic carbon (%)	BB	1.29	1.17	1.32	1.17	1.29	1.25	1.35	1.45	1.14	1.05
	AB	1.53	1.42	1.78	1.50	1.70	1.30	1.65	1.80	1.33	1.29
	AC	1.46	0.99	1.07	1.26	1.38	1.42	1.30	1.07	1.26	1.10
C.E.C. (meq/100)	BB	7.4	6.1	8.1	7.7	7.6	7.5	7.5	8.5	7.9	7.4
	AB	8.2	10.2	10.7	10.4	9.3	8.0	11.5	9.6	8.7	8.1
	AC	6.7	4.7	5.8	6.2	6.2	6.8	5.2	6.2	7.4	6.4
Total P (ppm)	BB	150	137	200	137	187	137	187	187	137	125
	AB	250	187	287	137	187	212	187	187	187	137
	AC	137	137	125	112	112	112	137	137	112	112
Total K (ppm)	BB	3020	2760	3600	2980	2760	3380	3950	3480	3580	3440
	AB	3450	2900	3950	3900	3950	4000	4050	3950	3800	3580
	AC	2860	2185	2530	2875	2645	2875	1955	2070	2530	2300
Total Ca (ppm)	BB	2240	2200	2620	2880	2460	2500	1760	1770	2200	1820
	AB	2360	3020	4110	4220	3660	2700	2930	3700	3120	2700
	AC	2200	1660	2000	1640	1640	2000	1720	1420	1940	1680
Total Mg (ppm)	BB	3976	3822	4570	4026	4889	4713	4169	4532	3949	3800
	AB	4820	4086	5307	4235	5291	5164	4966	4350	4070	3894
	AC	3481	3388	3965	3542	4312	4092	3740	3954	3910	3794
Ex. K (ppm)	BB	308	272	300	308	264	224	200	352	200	200
	AB	328	384	484	664	648	420	768	540	360	300
	AC	156	138	138	175	138	147	147	200	184	168
Ex. Ca (ppm)	BB	684	704	800	672	720	700	755	952	883	688
	AB	856	880	1464	992	1176	968	1272	1000	1104	904
	AC	684	648	566	732	646	664	624	752	656	608
Ex. Mg (ppm)	BB	184	176	184	168	184	176	200	224	192	192
	AB	352	448	688	576	688	608	592	512	464	448
	AC	128	120	152	160	128	136	120	168	200	144

BB = Before burning; AB = After burning;
AC = After 3 years of cropping
+F and -F stands for with and without fertilizer

Table 4.17 Percentage contribution at different frequency intervals of rainfall amounts causing runoff and soil loss under bare fallow

Year	Frequency intervals of erosive rainfall/ day in mm	Erosive rainfall amount in mm	% of total erosive rainfall	Runoff in mm	% of total runoff	Soil loss in t/ha	% of total soil loss
1979	5 - 15	66.81	10.29	29.28	30.76	4.74	27.75
	15 - 25	104.64	16.13	5.07	5.33	1.09	6.14
	25 - 35	84.58	13.04	8.05	8.46	1.24	6.97
	35 - 45	37.85	5.83	2.80	2.94	2.39	13.44
	45 - 55	103.38	15.93	16.77	17.62	4.23	23.75
	55	281.46	38.76	33.23	34.90	3.91	21.95
	Total	648.73		95.20		17.80	
1980	5 - 15	78.18	8.62	20.48	7.10	1.75	6.24
	15 - 25	193.29	21.32	65.78	22.81	4.48	15.97
	25 - 35	242.14	26.71	59.72	20.70	8.40	29.97
	35 - 45	114.30	12.61	40.68	14.10	1.69	6.02
	45 - 55	99.06	10.93	44.72	15.50	8.43	30.06
	55	179.58	19.81	57.12	19.80	3.29	11.73
	Total	906.55		288.50		28.04	
1981	5 - 15	51.81	8.19	23.94	11.28	24.59	11.96
	15 - 25	157.72	24.96	40.47	19.10	36.89	17.94
	25 - 35	93.73	14.83	42.81	20.30	41.53	20.20
	45 - 55	104.15	16.48	46.41	21.88	40.65	19.77
	55	224.54	35.53	58.27	27.50	61.95	30.13

and soil loss were greatly influenced by the daily rainfall amount. In general the rainfall amount greater than 25 mm per day was found to be more conducive in causing runoff and soil loss as compared to lower rainfall amounts below 25 mm per day. The rainfall amounts greater than 25 mm per day constituted the highest (67 to 73 %) percentage of total erosive rainfall and caused maximum runoff and soil loss amounting 64 to 79 and 67 to 78 per cent of total runoff and soil loss, respectively. The lower rainfall below 25 mm per day constituted about 30 per cent of total erosive rainfall and accounted for only 30 to 36 per cent and 22 to 33 per cent of total runoff and soil loss, respectively.

4.2.4 Cropping systems and runoff

Effect of different vegetal cover on runoff and runoff co-efficient is given in Tables 4.18 and 4.19. In general the highest water loss through runoff occurred during the cropping season of 1980 (188.2 mm) followed by 1981 (150.2 mm) and 1979 (66.1 mm) which accounted for 13.0, 14.3 and 5.5 per cent of total rainfall during the three cropping seasons, respectively. Averaged over treatments, monthly runoff followed the same trend as that of rainfall pattern i.e. higher the rainfall in the month, higher was the runoff. July was the month recording highest runoff during 1979 and 1981 whereas in 1981 June resulted in the maximum runoff. As regards the influence of various treatments, uncultivated bare fallow plot resulted in maximum runoff values of 95.2 mm, 288.5 mm and 211.9 mm with corresponding percentages of runoff co-efficients of 7.9, 20.0 and 20.2 during the cropping seasons of 1979, 1980 and 1981, respectively. The grass cover recorded the least runoff of 57.6 mm (4.8 %), 24.1 mm (1.7 %) and 25.2 mm (2.4 %) and thereby

Table 4.18 Effect of vegetative cover offered by different cropping systems and management practices on runoff during different months

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		7.8	34.8	4.2	5.4	5.4	57.6
Bare fallow		9.5	64.6	5.5	5.1	10.5	95.2
Maize along		8.1	48.6	11.5	33.2	10.4	81.8
Maize across		4.9	33.8	6.6	2.9	5.8	51.0
Maize intercropped		5.2	40.7	6.8	3.2	9.5	65.4
Sole rice		7.3	37.6	5.6	4.6	2.1	57.2
Topo-sequential -F		10.3	45.3	8.5	3.7	8.1	75.9
Topo-sequential +F		10.0	41.0	4.5	3.9	3.6	63.0
Mixed -F		5.8	32.2	5.8	4.1	2.4	50.3
Mixed +F		8.9	36.3	9.0	3.9	2.7	60.8
Mean		7.8	41.5	6.8	4.0	6.0	66.1
S. Em ±		0.62	3.04	0.72	0.26	1.62	4.54
1980							
Grass cover	6.5	8.9	4.6	2.7	1.4	0	24.1
Bare fallow	41.9	112.1	63.2	34.1	32.3	4.9	288.5
Maize along	39.7	103.9	47.4	29.7	30.1	2.4	253.7
Maize across	43.6	84.7	45.5	38.0	23.7	2.8	238.3
Maize intercropped	45.7	92.7	38.9	30.1	19.7	2.2	229.3
Sole rice	32.7	79.5	28.8	10.7	14.2	0	168.9
Topo-sequential -F	29.1	98.8	41.8	10.9	6.4	1.7	188.7
Topo-sequential +F	29.7	90.0	32.7	14.1	3.5	1.5	171.5
Mixed -F	23.1	91.9	25.3	9.0	3.2	2.4	154.9
Mixed +F	25.3	86.4	33.1	10.2	8.9	3.1	167.0
Mean	31.7	84.9	36.1	19.0	14.3	2.2	188.2
S. Em ±	3.85	8.97	4.91	3.98	3.63	0.33	23.04
1981							
Grass cover		0	7.6	13.2	4.4		25.2
Bare fallow		12.0	97.3	66.8	35.8		211.9
Maize along		14.2	92.9	51.6	28.3		187.0
Maize across		10.0	92.9	51.0	27.0		180.9
Maize intercropped		18.5	107.0	59.9	39.6		225.0
Sole rice		10.7	78.7	45.6	20.5		155.5
Topo-sequential -F		11.8	86.1	40.9	17.7		156.5
Topo-sequential +F		14.1	88.6	36.3	16.3		155.3
Mixed -F		8.7	75.0	34.1	9.9		127.7
Mixed +F		10.2	73.9	40.4	12.5		137.0
Mean		11.0	80.0	47.0	21.2		150.2
S. Em ±		0.97	8.68	4.73	3.58		17.58

Table 4.19 Influence of cropping systems on runoff co-efficient in different months of the year.

Treatments	May	June	Jul.	Aug.	Sep.	Oct	Total
1976							
Grass cover	3.93	8.0	2.2	5.1	3.3		4.76
Bare fallow	4.8	14.9	3.0	4.8	6.3		7.87
Maize along	4.1	11.2	6.2	3.0	6.3		6.76
Maize across	2.5	7.8	3.6	2.7	3.5		4.22
Maize intercropped	2.6	9.4	3.7	3.0	5.7		5.41
Sole rice	3.7	8.7	3.0	4.3	1.3		4.73
Topo-sequential -F	5.2	10.4	4.6	3.5	4.9		6.27
Topo-sequential +F	5.0	9.4	2.4	3.7	2.2		5.21
Mixed -F	2.9	7.4	3.1	3.8	1.4		4.16
Mixed +F	4.5	8.4	4.8	3.7	1.7		5.46
1980							
Grass cover	2.9	2.0	1.8	1.4	0.7	-	1.67
Bare fallow	18.4	24.9	25.1	17.7	16.9	6.1	19.99
Maize along	17.5	23.1	18.8	15.4	15.7	3.6	17.57
Maize across	19.2	18.8	18.1	19.7	12.4	3.5	16.91
Maize intercropped	20.1	20.6	15.4	15.6	10.3	2.8	15.89
Sole rice	14.4	17.7	11.4	5.5	7.4	8.	11.70
Topo-sequential -F	12.8	22.0	16.6	5.6	3.3	2.2	13.07
Topo-sequential +F	13.1	20.0	13.0	7.3	1.8	1.9	11.88
Mixed -F	10.2	20.4	10.0	4.7	1.7	3.0	10.73
Mixed +F	11.2	19.2	13.1	5.3	4.6	3.8	13.04
1981							
Grass cover		-	1.7	6.1	2.0		2.40
Bare fallow		11.5	22.1	31.1	16.1		20.20
Maize along		13.6	21.0	24.0	12.8		17.82
Maize across		9.5	21.0	23.7	12.1		17.24
Maize intercropped		17.7	24.2	27.9	17.8		21.44
Sole rice		10.2	17.8	21.2	9.2		14.82
Topo-sequential -F		11.3	19.5	19.0	7.9		14.92
Topo-sequential +F		13.5	20.1	16.8	7.4		14.80
Mixed -F		8.3	17.0	15.9	4.5		12.17
Mixed +F		9.7	16.8	18.8	5.6		13.06

causing an appreciable reduction in runoff by 39.5, 91.6 and 88.1 per cent over bare fallow in the cropping seasons of 1979, 1980 and 1981, respectively. The other cropping systems found to more effective in reducing the runoff were sole crop of rice which resulted in a reduction of 39.9, 41.5, 26.6 per cent followed by mixed cropping with percentages reduction in runoff of 36.1, 42.1, 29.1 per cent and topo-sequential cropping systems with corresponding reduction of 20.3, 34.6 and 26.1 per cent over bare fallow treatment. Fertilizer application as management practices in the last two cropping systems proved to be slightly better in reducing runoff as compared no application of fertilizer. Maize along and across the slope contributed large quantity of runoff and was only next to bare fallow treatment. Maize along the slope was able to reduce the runoff by only 14.1, 12.1, 11.8 per cent whereas maize when intercropped with legume was found to be at par with sole cropping of maize. On the basis of three cropping seasons data, the general trend of runoff under various cropping systems and management practices revealed that there was reduction in runoff in descending order as bare fallow, maize along and across the slope as well as intercropped, topo-sequential cropping with fertilizer, sole crop of rice, mixed cropping with fertilizer and grass cover.

4.2.5 Cropping systems and soil loss

The data on soil loss during 1979 to 1981 are presented in Table 4.20. The minimum soil loss of 13.4 t / ha was recorded during the cropping season of 1979 which increased to 19.7 and 149.1 t / ha in 1980 and 1981, respectively. As regards the monthly soil loss in July it was the highest soil loss of 8.1, 71.7 t / ha during 1979 and 1981 whereas in 1980, June recorded the maximum soil loss of

Table 4.20 Effect of vegetative cover offered by different cropping systems and management practices on soil loss (t / ha)

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		0.54	5.13	1.03	1.15	0.11	8.32
Bare fallow		2.08	10.18	2.31	3.95	0.28	17.80
Maize along		0.59	7.25	3.12	1.19	0.27	12.42
Maize accross		0.53	4.80	2.51	1.15	0.14	9.13
Maize intercropped		0.40	13.80	1.13	0.73	0.32	16.38
Sole rice		0.74	6.33	1.76	1.75	0.10	10.68
Topo-sequential -F		0.94	5.74	5.14	1.12	0.21	13.15
Topo-sequential +F		1.50	6.09	1.59	1.39	0.17	10.74
Mixed -F		0.63	14.40	2.41	2.04	0.21	19.69
Mixed +F		0.83	7.23	4.19	2.75	0.39	15.39
Mean		0.78	8.10	2.52	1.76	0.22	13.38
S. Em ±		0.10	1.11	0.42	0.31	0.03	1.21
1980							
Grass cover	0.84	1.27	0.34	0.20	0.03	0	2.58
Bare fallow	1.57	17.24	4.76	2.43	1.64	0.40	28.04
Maize along	2.08	14.57	1.93	1.38	5.78	0.14	25.88
Maize across	1.30	14.66	3.57	1.26	2.30	0.20	23.29
Maize intercropped	2.10	12.61	2.34	4.64	0.78	0.09	22.56
Sole rice	1.49	7.99	2.28	1.00	1.93	0	14.69
Topo-sequential -F	1.83	13.29	2.13	2.03	1.14	0.01	20.43
Topo-sequential +F	0.94	10.10	3.36	0.28	0.65	0.10	15.43
Mixed -F	1.12	19.04	2.11	0.89	0.85	0.19	24.20
Mixed +F	1.11	15.45	1.83	0.38	0.84	0.34	19.95
Mean	1.44	12.62	2.47	1.45	1.59	0.15	19.72
S. Em ±	0.14	1.62	0.38	0.42	0.51	0.04	2.32
1981							
Grass cover		0	3.30	14.14	2.91	20.35	20.35
Bare fallow		19.29	90.34	66.94	29.04		205.61
Maize along		21.53	92.05	56.97	21.39		191.94
Maize across		11.76	95.42	61.54	24.18		192.90
Maize intercropped		29.76	96.42	51.68	34.48		212.34
Sole rice		8.20	75.92	48.11	14.32		146.55
Topo-sequential -F		20.91	81.52	35.26	13.92		151.61
Topo-sequential +F		17.11	62.19	38.54	14.81		132.65
Mixed -F		15.29	61.72	35.97	6.94		119.92
Mixed +F		11.08	57.99	38.14	10.40		117.61
Mean		15.49	71.69	44.73	17.24		149.15
S. Em +		2.03	8.69	4.91	3.14		18.15

12.6 t / ha. In all the three years of cropping the maximum soil loss of 17.8, 28.0 and 205.6 t / ha was recorded under bare fallow treatment. The other cropping systems which appreciably reduced the soil loss was sole crop of rice, topo-sequential and mixed cropping systems. The percentage reductions in soil loss over bare fallow was 40.0, 47.6 and 28.7 per cent in 1979, 1980 and 1981, respectively under sole crop of rice, 39.7, 45.0 and 35.5 per cent under topo-sequential cropping with fertilizer in three successive years and 26.1, 27.1 and 26.3 per cent in 1979, 1980 and 1981, respectively under topo-sequential cropping without fertilizer application. Mixed cropping without fertilizer resulted in a reduction of 0, 13.7 and 41.7 % whereas mixed cropping with fertilizer application further reduced the soil loss by 13.5, 28.9 and 42.8 per cent over bare fallow treatments.

4.2.6 Relationship between rainfall, runoff and soil loss

Linear regression analyses of the relationships between rainfall and runoff and rainfall and soil loss, from pooled data of three seasons, were carried out to evaluate the efficiency of different types of vegetal covers under varied types of croppings, as per the method suggested by Hillel, (1967) and Frasier (1975). The linear regression equation (following Hillels notation) is $R = A + BP$ where R is runoff per storm, P is storm size and A and B are the co-efficients of the linear regression equation. The threshold values i.e. minimal rainfall necessary to produce runoff obtained from the P axis intercept (i.e. A/B) is denoted P_o. The co-efficient B represents the runoff efficiency after the threshold rainfall has been exceeded.

The linear regression equations based on pooled results of three years for individual rainfall events and runoff of amount, rainfall and soil loss and runoff and soil loss are given in Table 4.21 whereas the relationship between monthly rainfall and runoff, monthly rainfall and soil loss and runoff and soil loss has been presented in Fig. 3, 4 and 5, respectively.

4.2.6.1 Rainfall and runoff

The threshold rainfall to initiate runoff was found to be minimum (2.65 mm) under bare fallow treatment as against the maximum threshold retention value of 5.59 mm for grass cover treatment. The rainfall efficiency to initiate runoff after threshold as expected, was maximum (B = 0.20) for bare fallow plot and the lowest (B = 0.046) for grass cover, indicating thereby the high rate of infiltration under grass cover. For the other treatments the values for threshold retention and runoff efficiency lie in between the two extreme values of bare fallow and grass cover treatments. Amongst cropping systems, sole cropping of rice followed by topo-sequential and mixed cropping with and without fertiliser application were found to be more efficient in reducing runoff as compared with widely spaced crop of maize along the slope or intercropped maize, although maize when planted across the slope was more efficient than the other two treatments.

4.2.6.2 Rainfall and soil loss

The rainfall efficiency in initiating soil loss was lowest (B = 0.011) in case of grass cover and highest in case of bare fallow plot (B = 0.091), although threshold retention value was slightly lower (2.79 mm) under grass cover as compared to that of bare fallow

Table 4.21 Regression analyses of the relationship between runoff (mm) and daily rainfall amount (mm) (pooled data of 1979, 1980 and 1981)

Regression equation		r	r^2	Threshold value	F value attributable to the regression	SE of regression coefficient (±)
(n=219)	$Y_1 = -0.256+0.046\,b$	0.57	0.32	5.59	104.59**	0.022
	$Y_2 = -0.531+0.200\,b$	0.64	0.40	2.65	147.19**	0.023
	$Y_3 = -0.713+0.192\,b$	0.67	0.45	3.72	178.54**	0.022
	$Y_4 = -0.607+0.171\,b$	0.65	0.42	3.55	155.45**	0.011
	$Y_5 = -0.836+0.198\,b$	0.66	0.43	4.21	164.53**	0.020
	$Y_6 = -0.571+0.142\,b$	0.64	0.41	4.02	152.06**	0.011
	$Y_7 = -0.720+0.163\,b$	0.70	0.49	4.41	205.73**	0.018
	$Y_8 = -0.730+0.155\,b$	0.69	0.48	4.70	201.24**	0.003
	$Y_9 = -0.525+0.126\,b$	0.60	0.35	4.15	118.77**	0.012
	$Y_{10} = -0.614+0.141\,b$	0.67	0.45	4.35	178.67**	0.005
	Regression analyses of the relationship between soil loss (t/ha) and rainfall (mm)					
(n=219)	$Y_1 = -0.030+0.011\,b$	0.36	0.13	2.79	31.43**	0.003
	$Y_2 = -0.327+0.091\,b$	0.41	0.17	3.58	43.92**	0.002
	$Y_3 = -0.376+0.088\,b$	0.42	0.18	4.27	46.34**	0.004
	$Y_4 = -0.509+0.095\,b$	0.43	0.18	5.36	49.35**	0.095
	$Y_5 = -0.291+0.089\,b$	0.42	0.18	3.26	46.76**	0.004
	$Y_6 = -0.401+0.073\,b$	0.40	0.16	5.47	41.44**	0.004
	$Y_7 = -0.119+0.053\,b$	0.40	0.16	2.25	42.18**	0.001
	$Y_8 = -0.330+0.072\,b$	0.45	0.20	4.58	53.71**	0.004
	$Y_9 = -0.324+0.066\,b$	0.46	0.21	4.89	58.04**	0.004
	$Y_{10} = -0.317+0.063\,b$	0.45	0.21	5.05	56.17**	0.005

Table 4.21 (Continued)

Regression equation		r	r^2	Threshold value	F value attributable to the regression	SE of regression coefficient ($\pm$)
	Regression analyses of the relationship between soil loss (t/ha) and runoff (mm)					
(n=219)	Y_1 = 0.048+0.195 b	0.52	0.27	0.25	81.38**	0.007
	Y_2 = 0.012+0.420 b	0.59	0.35	0.03	118.64**	0.004
	Y_3 = 0.081+0.406 b	0.55	0.30	0.20	94.75**	0.008
	Y_4 = 0.038+0.459 b	0.55	0.30	0.08	94.10**	0.027
	Y_5 = 0.101+0.442 b	0.63	0.40	0.23	143.85**	0.009
	Y_6 =−0.096+0.510 b	0.62	0.38	0.19	132.94**	0.002
	Y_7 = 0.155+0.302 b	0.54	0.29	0.52	89.29**	0.004
	Y_8 =−0.008+0.474 b	0.66	0.43	0.02	163.23**	0.056
	Y_9 = 0.036+0.468 b	0.69	0.48	0.08	197.57**	0.017
	Y_{10} =−0.047+0.448 b	0.68	0.46	0.11	184.93**	0.038

Y_1 = Grass cover; Y_2 = Bare fallow; Y_3 = maize along;

Y_4 = maize across; Y_5 = maize intercropped; Y_6 = sole rice;

Y_7 = Topo-sequential −F; Y_8 = Topo-sequential +F

Y_9 = Mixed cropping −F; Y_{10} = Mixed cropping +F;

** Significant at 1%; n = Number of observations

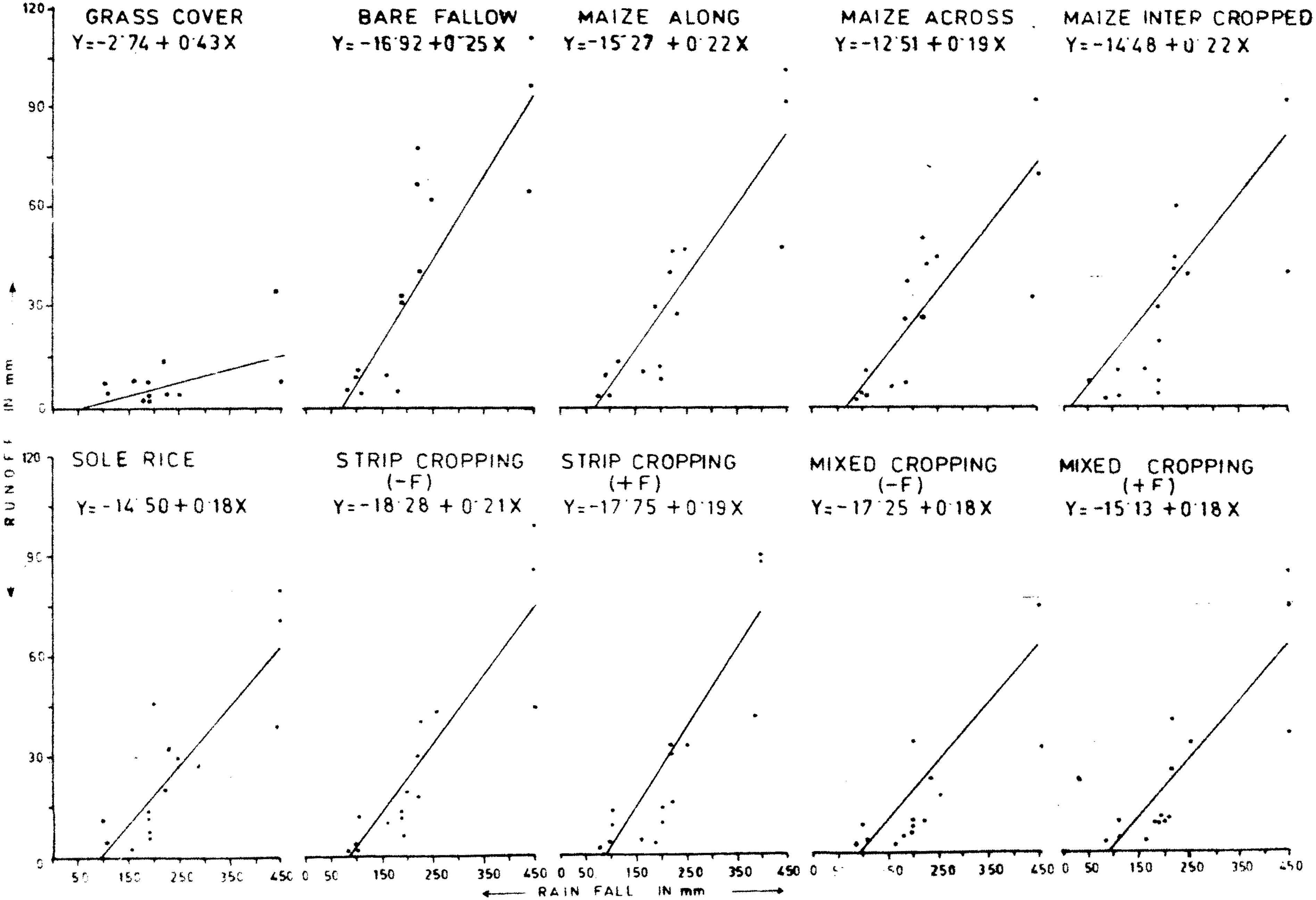


FIG.3. RELATIONSHIP BETWEEN MONTHLY RAINFALL AND RUNOFF

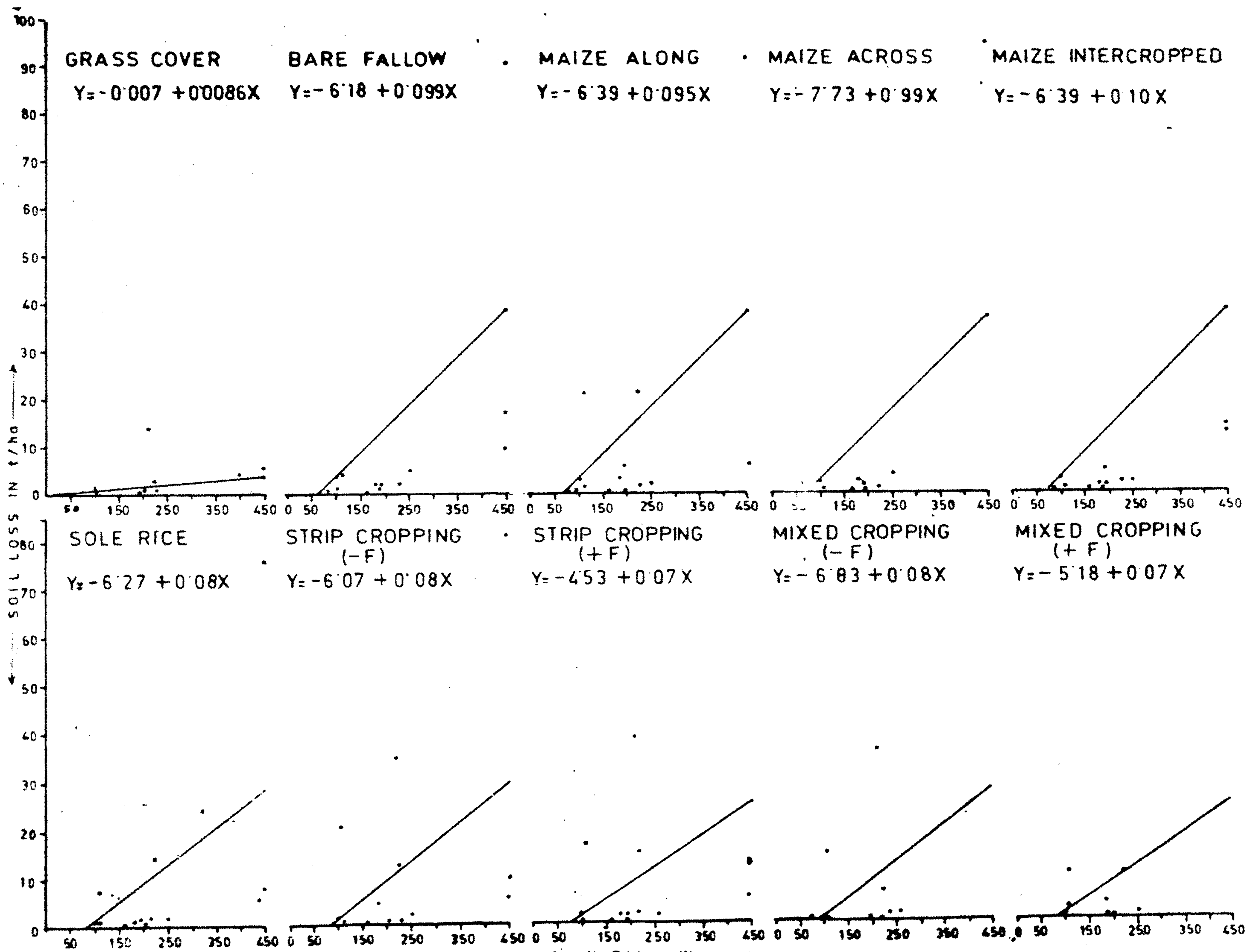


FIG.4. RELATIONSHIP BETWEEN MONTHLY RAIN FALL AND SOIL LOSS

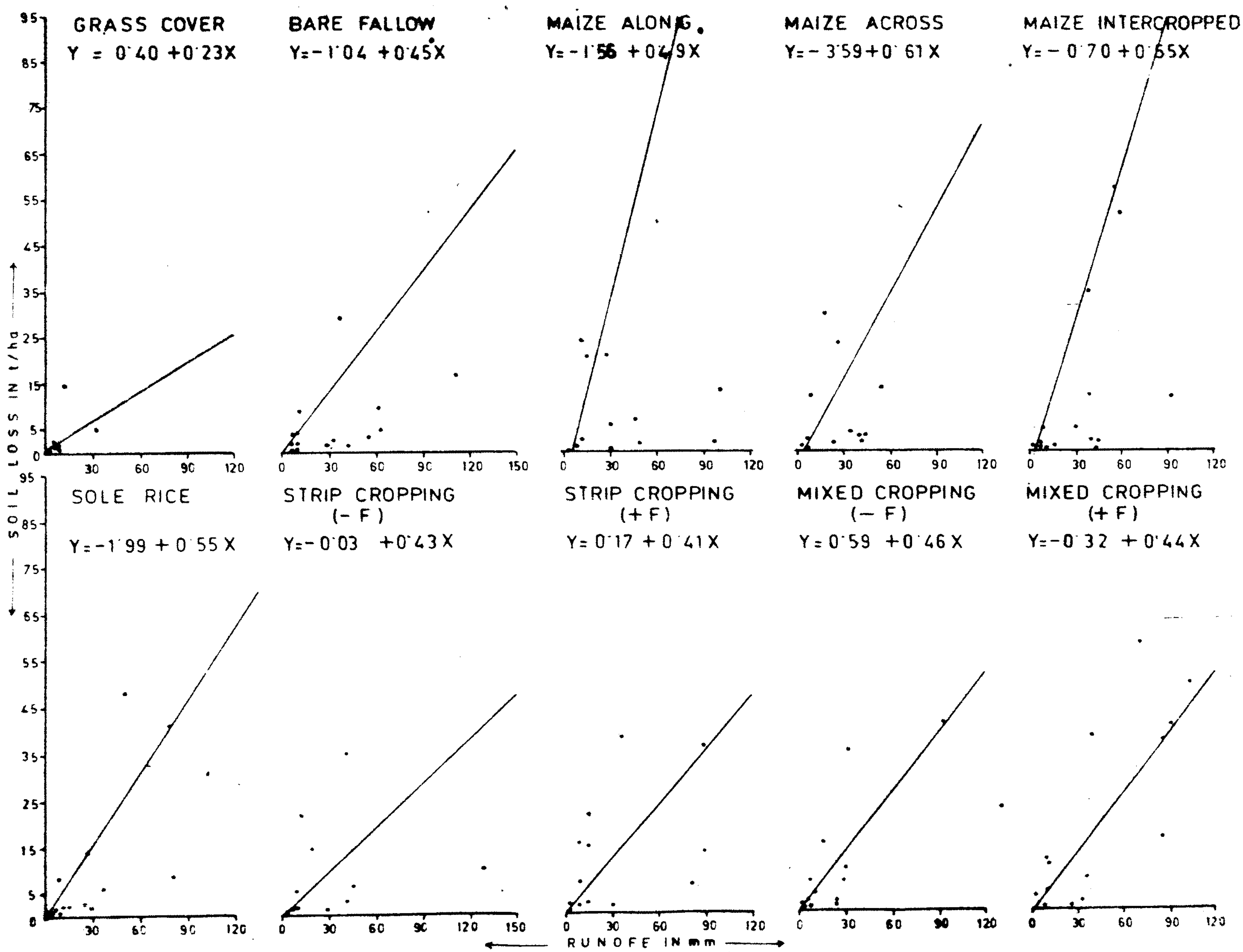


FIG 5. RELATIONSHIP BETWEEN MONTHLY RUNOFF AND SOIL LOSS

plot (3.58 mm). The effectiveness of different cropping systems in arresting soil loss was more or less similar to the relationship of rainfall and runoff.

4.2.6.3 Runoff and soil loss

The runoff efficiency, after threshold retention in causing soil loss, was lowest (0.195) for grass cover with high threshold retention value of 0.25 mm; under bare fallow the threshold retention value was lowest (0.03 mm) and the runoff efficiency was high (0.42). No appreciable difference was observed in the values of runoff efficiency in other cropping systems except under the unfertilised topo-sequential cropping system, which showed low runoff efficiency value (0.30) and high threshold retention value (0.52 mm). Under bare fallow there was maximum soil loss per mm of runoff, whereas it was minimum under grass cover.

4.2.7 Enrichment ratio

Except total magnesium and manganese the mean (over the years). Enrichment Ratio of the sediments for almost all the nutrient studied, were higher than unity (Table 4.22), indicating thereby that substantial losses of these nutrients in the eroded material have taken place over the years. Averaged over treatments, the maximum value of enrichment ratio was obtained for total copper (6.4) followed by exchangeable K (3.9), total calcium (3.6), total Zn (3.4) and exchangeable calcium (2.3). The enrichment ratios for other nutrients ranged from 1.09 to 1.95. Grass cover, sole cropping of rice, mixed and topo-sequential cropping systems were found to be quite effective in reducing the enrichment ration.

Table 4.22 Nutrient enrichment ratio of eroded sediment as influenced by different systems of cropping and management practices in different years

Nutri-ents	Year	Cropping systems										Mean
		Grass cover	Bare fal-low	Mai-ze along	Maize across	Mai-ze inter-cropped	Sole rice	Topo-se-quential		Mixed cropping		
								-F	+F	-F	+F	
Organic carbon (%)	1979	1.20	1.47	1.33	1.38	1.52	1.23	1.14	1.14	1.17	1.57	1.31
	1980	1.23	1.36	1.27	1.31	1.16	1.22	1.02	1.19	1.43	1.66	1.29
	1981	0.93	1.09	1.05	1.06	1.05	1.02	0.84	0.79	1.04	1.24	1.01
	Mean	1.12	1.31	1.22	1.25	1.24	1.16	1.00	1.04	1.21	1.49	1.20
Total P	1979	3.17	3.65	2.31	2.99	2.54	3.41	2.51	2.81	3.28	4.30	3.10
	1980	1.83	2.41	1.61	2.06	1.62	1.85	1.55	1.61	2.11	2.48	1.97
	1981	0.78	0.95	0.75	0.89	0.71	0.77	0.60	0.68	0.82	1.29	0.82
	Mean	1.93	2.34	1.56	1.98	1.62	2.01	1.55	1.70	2.07	2.69	1.95
Total K	1979	1.31	1.61	1.19	1.20	1.87	1.17	0.91	1.95	1.09	1.49	1.31
	1980	1.92	2.45	2.03	1.84	2.15	1.72	1.44	2.12	1.85	2.25	1.97
	1981	1.85	2.24	1.72	2.39	2.93	1.97	1.44	1.91	1.72	2.07	1.99
	Mean	1.69	2.10	1.65	1.81	2.32	1.62	1.27	1.76	1.55	1.94	1.77
Total Ca	1979	3.63	6.21	4.21	4.39	4.42	3.53	5.35	7.11	3.30	5.77	4.39
	1980	2.33	2.87	2.58	2.89	2.34	1.85	2.91	3.39	2.51	4.13	2.78
	1981	3.13	3.60	3.06	3.29	3.37	2.68	3.11	3.83	2.52	4.95	3.35
	Mean	3.03	4.23	3.28	3.50	3.38	2.69	3.79	4.78	2.78	4.95	3.64
Total Mg	1979	0.69	0.78	0.65	0.67	0.71	0.65	0.57	0.62	0.60	0.88	0.83
	1980	0.64	0.69	0.60	0.60	0.55	0.51	0.58	0.58	0.63	0.74	1.06
	1981	1.40	1.34	1.27	1.33	1.13	1.07	1.16	1.12	1.12	1.39	1.23
	Mean	0.91	0.94	0.84	0.87	0.80	0.74	0.77	0.77	0.78	1.00	0.84
Exchan-geable K	1979	2.34	4.84	2.83	2.06	2.54	2.60	3.40	2.32	2.25	3.03	2.82
	1980	6.01	10.29	5.21	3.80	9.97	8.18	5.71	4.45	9.62	13.99	7.72
	1981	0.81	1.36	1.14	0.85	1.19	0.96	1.29	0.77	1.18	1.44	1.23
	Mean	3.05	5.50	3.06	2.24	4.57	3.91	3.47	2.51	4.35	6.15	3.88

Table 4.22 (Continued)

Nutrients	Year	Cropping systems: Grass cover	Bare fallow	Maize along	Maize across	Maize intercropped	Sole rice	Topo-sequential -F	Topo-sequential +F	Mixed cropping -F	Mixed cropping +F	Mean
Exchangeable Ca	1979	3.92	4.19	3.44	3.13	2.98	2.01	3.13	3.59	1.88	2.79	3.10
	1980	2.07	2.43	2.12	2.10	2.67	2.17	2.03	2.13	1.87	2.97	2.26
	1981	1.64	1.75	1.63	1.56	1.83	1.78	1.47	1.36	1.38	2.07	2.81
	Mean	2.54	2.79	2.40	2.26	2.49	1.99	2.21	2.36	1.71	2.61	2.34
Exchangeable Mg	1979	0.74	0.94	1.08	1.04	1.12	0.86	0.74	0.76	0.88	0.84	0.84
	1980	0.99	1.11	1.25	1.10	1.08	0.93	0.72	0.91	0.90	1.19	1.02
	1981	0.89	1.39	1.56	1.46	1.70	1.52	1.14	1.31	1.11	1.30	1.35
	Mean	0.94	1.15	1.30	1.20	1.30	1.10	0.87	0.99	0.89	1.11	1.09
Total Zn	1979	3.63	3.19	2.77	3.33	2.68	2.87	2.49	3.76	2.20	4.70	3.16
	1980	3.20	3.36	4.33	4.31	3.00	3.77	4.14	3.86	3.27	3.81	3.71
	1981	4.45	3.04	3.42	4.16	2.56	3.37	4.00	3.31	4.15	4.69	3.71
	Mean	3.76	3.20	3.52	3.93	2.75	3.34	3.54	3.64	3.21	3.30	3.42
Total Cu	1979	8.35	6.45	8.17	7.58	7.44	8.38	9.13	7.71	7.36	6.80	7.74
	1980	11.35	11.53	9.63	9.98	8.81	8.92	9.47	7.52	9.72	7.17	9.41
	1981	5.04	4.61	5.40	5.56	5.27	4.87	5.82	6.24	5.67	5.10	5.35
	Mean	8.25	7.53	7.73	7.71	7.17	7.39	8.14	7.16	7.58	6.36	7.50
Total Mn	1979	1.01	0.98	0.83	0.86	0.58	0.78	0.81	0.87	0.77	0.64	0.69
	1980	0.97	0.74	0.79	0.93	0.71	0.66	0.75	0.79	0.77	0.81	0.79
	1981	1.03	1.04	0.87	0.94	0.72	0.82	0.86	0.85	0.84	0.89	0.89
	Mean	1.00	0.92	0.83	0.91	0.69	0.75	0.81	0.84	0.83	0.78	0.84
Total Fe	1979	1.02	0.98	1.00	0.90	1.05	0.99	0.99	1.01	0.87	0.99	0.98
	1980	0.97	1.04	1.10	0.90	1.00	0.88	0.95	0.93	0.98	0.93	0.97
	1981	1.39	1.30	1.30	1.15	1.37	1.30	1.32	1.29	1.29	1.29	1.30
	Mean	1.13	1.11	1.13	0.98	1.14	1.06	1.09	1.08	1.05	1.07	1.08

4.2.7.1 Runoff and concentration of nutrients

Analysis of the correlation co-efficients (Table 4.22.1) drawn between runoff and concentration of nutrients in the sediments revealed that there was significant positive correlation between runoff and concentration of organic carbon, total potassium, total exchangeable magnesium, total manganese and total iron; in case of other nutrients the relationships were positive but not significant.

4.2.7.2 Soil loss and concentration of nutrients

Analysis of the correlation between soil loss and nutrient concentration in the sediment indicated non-significant (Table 4.22.2) relationship except in case of total magnesium and total iron concentration in the sediment in the base soil. So no attempt was made to find out the relationship between soil loss and nutrient concentrations.under other cropping systems.

4.2.7.3 Correlation between concentration of organic carbon and other nutrients

Correlation between concentration of organic carbon and other nutrients indicated a highly significant relationship (Table 4.22.3).

4.2.8 Effect of different cropping systems and management practices on nutrient losses in eroded sediments

4.2.8.1 Organic carbon

The data on organic carbon loss in sediments are presented in Table 4.23. The loss of organic carbon in the eroded material was comparatively small 189.9 kg / ha during the first year but in second year it increased to 347.1 kg / ha and in third year it was as high as 1892.7 kg / ha. In 1979, the maximum loss occurred

Table 4.22.1 Relationship between concentration of nutrient elements in eroded soil and monthly runoff (mm) for bare fallow treatment (Pooled for 1979, 1980 and 1981)

Nutrients		Regression equation			r
Organic carbon (%)	Y=	0.641	+	0.0137 x	0.563**
Total K (ppm)	Y=	266.972	+	5.1238 x	0.524*
Total Mg (ppm)	Y=	1509.843	+	31.1410 x	0.545*
Total Mg (ppm)	Y=	84.433	+	1.5630 x	0.480*
Total Mn (ppm)	Y=	235.2670	+	3.2925 x	0.499*
Total Fe (%)	Y=	1.9524	+	0.0384 x	0.625**

* significant at 5%; ** significant at 1%

Table 4.22.2 Relationship between concentration of nutrient element in eroded soil and monthly soil loss

Nutrients		Regression equation			r
Total Mg (ppm)	Y=	1787.229	+	53.910 x	0.683**
Total Fe (%)	Y=	2.626	+	0.043 x	0.504*

Table 4.22.3 Relationship between concentration of nutrient element and organic carbon (%) in soil under bare fallow treatment

Nutrients		Regression equation			r
Total P (ppm)	Y=	100.079	+	137.826 x	0.572*
Total K (ppm)	Y=	46.015	+	356.632 x	0.889**
Total Ca (ppm)	Y=	122.094	+	991.943 x	0.528*
Total Mg (ppm)	Y=	817.509	+	1573.354 x	0.671**
Exch K (ppm)	Y=	23.506	+	528.924 x	0.550*
Exch Ca (ppm)	Y=	6.339	+	1126.528 x	0.786**
Exch Mg (ppm)	Y=	22.229	+	104.052 x	0.778**
Total Zn (ppm)	Y=	49.770	+	113.858 x	0.822**
Total Cu (ppm)	Y=	12.772	+	113.146 x	0.732**
Total Mn (ppm)	Y=	91.121	+	231.143 x	0.853**
Total Fe (%)	Y=	0.958	+	2.070 x	0.819**

Table 4.23 Monthly losses of organic carbon in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		10.14	99.52	8.56			118.22
Bare fallow		25.16	202.58	19.16			246.90
Maize along		11.80	134.85	44.62			191.27
Maize across		9.81	85.92	29.52			125.25
Maize intercropped		8.80	269.10	19.38			297.28
Sole rice		11.62	120.90	20.33			152.85
Topo-sequential -F		18.33	98.12	49.38			165.83
Topo-sequential +F		30.45	107.54	18.26			156.25
Mixed -F		11.34	233.09	13.74			258.17
Mixed +F		18.59	130.86	37.33			186.78
Mean		15.60	148.25	26.03			189.88
S. Em ±		2.32	20.11	4.31			18.81
1980							
Grass cover	16.20	21.70	4.82	2.13	0.21	-	45.06
Bare fallow	38.90	311.88	71.46	51.41	20.55	1.72	495.92
Maize along	37.58	244.61	33.81	30.50	79.12	0.81	426.43
Maize across	28.12	233.08	59.93	25.41	29.52	0.75	376.81
Maize intercropped	50.98	223.02	38.64	80.50	8.89	0.36	402.39
Sole rice	32.41	131.79	35.13	13.25	16.76	-	229.34
Topo-sequential -F	39.13	219.20	49.52	32.37	10.42	0.13	350.77
Topo-sequential +F	27.13	198.02	57.37	5.27	10.86	0.36	299.01
Mixed -F	30.42	364.86	33.81	15.40	10.35	1.10	455.94
Mixed +F	31.65	308.84	28.83	6.80	10.26	3.00	389.38
Mean	33.25	225.70	41.33	26.30	19.69	0.82	347.10
S. Em ±	2.92	30.80	5.99	7.69	7.05		41.29
1981							
Grass cover		-	39.60	169.68	34.92		244.20
Bare fallow		231.48	1084.08	903.69	392.04		2611.29
Maize along		322.95	1242.68	769.10	282.35		2617.08
Maize across		158.76	1145.04	738.48	290.16		2332.44
Maize intercropped		446.40	1301.67	620.16	465.48		2833.71
Sole rice		110.70	979.37	577.32	184.73		1852.12
Topo-sequential -F		250.92	978.24	423.12	133.63		1785.91
Topo-sequential +F		230.99	746.28	520.29	155.51		1653.07
Mixed -F		299.35	722.12	431.64	62.46		1445.57
Mixed +F		176.17	695.88	514.89	109.20		1496.14
Mean		215.77	893.50	572.38	211.05		1892.69
S. Em ±		31.49	116.52	65.71	44.98		241.87

in the month of July which amounted for 78 per cent of the total loss during the year whereas in 1980 and 1981 the maximum loss was recorded in the month of June and July and July and August which accounted for 76.9 and 77.4 per cent of total loss in two successive years, respectively.

Among the different cropping systems tried, the grass cover proved to be most effective in reducing the loss of organic carbon through erosion followed by sole cropping of rice, strip cropping and mixed cropping systems. Grass cover reduced the organic carbon losses by 52, 91 and 91 per cent in three successive years over bare fallow treatment, under strip cropping without any fertilizer application there were reductions of 33, 29 and 32 per cent and that of with fertilizer application reductions of 37, 40 and 37 per cent in three successive years, respectively. It is further, interesting to note that mixed cropping with fertilizer application was able to reduce the organic carbon losses by 24, 21 and 43 per cent in 1978, 1980 and 1981, respectively but mixed cropping without any fertilizer application reduced the loss of organic carbon in the first two years by 24 and 21 per cent whereas in the third year, it caused appreciable reduction (43 per cent). Planting of maize across the slope, although was able to reduce soil loss by 49 and 24 per cent in the first and second year of cropping but it reduced the loss by only 11 per cent in the third year of cropping.

4.2.8.2 Total phosphorus

It is evident from the data given in Table 4.24 that 1981 proved to be more hazardous in causing maximum loss of phosphorus 19.85 kg / ha as compared to the losses of 6.3, and 5.6 kg / ha

Table 4.24 Monthly losses of total P in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		0.34	2.44	0.33	-		3.11
Bare fallow		0.79	5.09	1.04	1.28		8.20
Maize along		0.38	3.63	1.48	0.27		5.76
Maize across		0.33	1.92	1.00	0.24		3.49
Maize intercropped		0.28	6.89	0.51	0.33		8.01
Sole rice		0.46	2.83	0.57	0.57		4.43
Topo-sequential -F		0.69	3.16	1.67	0.36		5.88
Topo-sequential +F		1.16	3.49	0.75	0.66		6.06
Mixed -F		0.38	7.19	1.08	0.92		9.57
Mixed +F		0.60	4.70	1.99	1.31		8.60
Mean		0.54	4.13	1.04	0.59		6.31
S. Em ±		0.09	0.57	0.17	0.13		0.70
1980							
Grass cover	0.20	0.32	0.10	0.03	0.10	-	0.75
Bare fallow	0.44	4.82	1.30	0.78	0.57	0.19	8.10
Maize along	0.37	3.86	0.53	0.36	2.31	0.07	7.50
Maize across	0.30	3.88	8.98	0.27	0.69	0.08	6.20
Maize intercropped	0.52	3.78	0.69	1.74	0.20	0.03	6.96
Sole rice	0.35	2.24	0.60	0.25	0.45	-	3.89
Topo-sequential -F	0.49	3.92	0.75	0.51	0.33	0.02	6.02
Topo-sequential +F	0.26	3.23	0.93	0.07	0.18	0.04	4.71
Mixed -F	0.28	4.75	0.55	0.22	0.23	0.09	6.12
Mixed +F	0.31	4.32	0.49	0.11	0.24	0.15	5.62
Mean	0.35	3.51	0.69	0.43	0.53	0.07	5.59
S. Em ±	0.03	0.43	0.10	0.16	0.21	0.02	0.66
1981							
Grass cover		-	0.37	1.58	0.36		2.31
Bare fallow		2.64	10.12	9.17	3.98		25.91
Maize along		5.38	12.61	10.65	0.79		29.43
Maize across		2.20	13.07	7.69	0.89		23.85
Maize intercropped		5.57	13.21	7.08	2.14		28.00
Sole rice		1.44	8.50	3.61	8.89		14.44
Topo-sequential -F		2.61	11.17	4.37	0.86		19.01
Topo-sequential +F		3.20	8.52	4.82	0.92		17.46
Mixed -F		2.29	8.46	4.50	0.26		15.51
Mixed +F		1.66	10.84	9.54	0.52		22.56
Mean		2.70	9.69	6.30	1.16		19.85
S. Em ±		0.46	1.20	0.94	0.89		2.54

during 1979 and 1980, respectively. In July there was maximum loss of total phosphorus(4.13 and 9.69 kg / ha accounting for 65 and 49 per cent of the total loss during 1979 and 1981, respectively). In 1980, the maximum loss occurred in June which amounted to 63 per cent of the total loss in the year. With regard to the effect of various cropping systems and management it followed similar trend of variation as was observed in case of the losses of organic matter; the total phosphorus loss, however, much lesser than any other nutrients.

4.2.8.3 Total potassium

An apprisal of the data in Table 4.25 suggested that potassium loss increased rapidly from first year (45.42 kg / ha) to third year (1025.27 kg / ha). In July there was maximum loss to the extent of 32.77 kg and 494.36 kg / ha amounting to 72 and 48 per cent of the total losses of 1979 and 1981, respectively. As regards the effect of cropping systems on potassium loss 23.76 to 114.01 the losses ranged from 43 kg / ha under grass cover to 62.4 to 1688.26 kg / ha under intercropped maize.

4.2.8.4 Total calcium

A perusal of the data in Table 4.26 shows that the total calcium loss was highest during 1981 and followed by 1979 and 1980. Again the loss was closely related to the pattern of soil loss. Grass cover was found to be most efficient in reducing the calcium loss. High calcium loss was obtained in bare fallow followed by maize intercropping system.

Table 4.25 Monthly losses of total K in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		2.71	17.44	3.61			23.76
Bare fallow		7.04	38.19	7.15			52.38
Maize along		3.29	29.03	10.14			42.46
Maize across		2.36	15.60	7.51			25.47
Maize intercropped		3.08	55.09	4.23			62.40
Sole rice		3.78	23.55	5.30			32.63
Topo-sequential -F		4.30	22.38	12.86			39.54
Topo-sequential +F		7.84	27.34	5.16			48.54
Mixed -F		3.31	64.75	4.82			72.88
Mixed +F		6.14	34.34	13.63			54.11
Mean		4.39	32.77	7.44			45.42
S. Em ±		0.61	5.08	1.12			5.00
1980							
Grass cover	6.18	7.93	1.97	0.61	0.10	-	16.73
Bare fallow	18.84	118.89	26.68	19.10	6.74	1.53	188.78
Maize along	22.75	90.96	11.94	10.17	20.21	0.71	156.74
Maize across	12.84	79.96	18.40	7.53	6.92	0.67	126.32
Maize intercropped	23.60	81.80	11.71	28.57	2.56	0.35	148.59
Sole rice	15.83	47.92	11.41	4.98	4.62	-	84.76
Topo-sequential -F	21.13	75.72	18.82	8.65	3.02	0.17	127.51
Topo-sequential +F	15.31	60.62	22.38	1.71	2.57	0.55	103.14
Mixed -F	14.05	104.52	15.56	5.79	2.48	0.87	143.27
Mixed +F	18.13	92.65	15.32	2.65	2.94	1.66	133.35
Mean	16.86	76.10	15.42	8.98	5.22	0.65	122.92
S. Em ±	1.65	9.92	2.16	2.75	1.79	0.16	14.84
1981							
Grass cover		-	11.29	80.60	22.12		114.01
Bare fallow		109.95	514.93	381.56	220.70		1227.14
Maize along		122.72	524.68	432.97	121.92		1202.29
Maize across		67.03	725.19	467.70	183.77		1443.69
Maize intercropped		169.63	732.79	392.77	393.07		1688.26
Sole rice		31.16	432.74	365.64	136.04		965.58
Topo-sequential -F		79.46	619.55	200.98	79.34		979.33
Topo-sequential +F		97.53	472.64	219.68	112.56		902.41
Mixed -F		87.15	469.07	273.37	26.37		855.96
Mixed +F		84.21	440.72	289.86	59.28		874.07
Mean		84.88	494.36	310.51	135.52		1025.27
S. Em ±		11.85	63.97	37.93	35.09		132.89

Table 4.26 Monthly losses of total Ca in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		6.09	38.47	6.80			51.36
Bare fallow		21.66	112.03	23.08			156.77
Maize along		6.60	91.63	28.47			126.70
Maize across		4.72	40.79	17.20			62.71
Maize intercropped		5.00	153.21	10.00			168.21
Sole rice		7.60	48.66	15.03			71.29
Topo-sequential -F		11.46	50.92	37.94			100.32
Topo-sequential +F		21.46	68.35	19.25			109.06
Mixed -F		3.34	123.89	18.69			147.92
Mixed +F		8.71	72.30	46.13			127.14
Mean		9.75	83.23	22.16			112.15
S. Em ±		2.11	12.40	3.86			12.83
1980							
Grass cover	4.54	4.76	1.15	0.51	0.23	-	11.19
Bare fallow	10.01	86.16	24.36	16.98	15.21	1.96	171.04
Maize along	8.26	103.74	9.07	7.39	46.92	1.37	176.75
Maize across	7.06	65.95	15.77	6.47	15.57	1.24	112.06
Maize intercropped	14.95	59.85	10.83	37.89	3.64	0.51	127.67
Sole rice	9.65	32.95	9.98	4.36	7.22	-	64.16
Topo-sequential -F	8.96	58.12	14.84	14.00	4.98	0.24	101.14
Topo-sequential +F	6.59	46.73	18.24	2.14	3.13	0.68	77.51
Mixed -F	6.75	78.39	9.07	7.79	2.99	1.21	106.20
Mixed +F	8.65	77.21	8.78	4.11	4.73	3.68	107.16
Mean	8.54	61.39	12.21	15.21	10.46	1.09	105.49
S. Em ±	0.88	8.95	2.01	3.86	4.36	0.31	[illegible].39
1981							
Grass cover		-	16.57	126.98	20.54		164.09
Bare fallow		120.76	505.90	736.34	255.55		1618.55
Maize along		156.31	605.69	507.03	199.35		1468.38
Maize across		77.85	438.93	412.32	164.42		1093.52
Maize intercropped		238.67	757.86	516.80	251.70		1765.03
Sole rice		42.64	552.70	440.69	74.46		1110.49
Topo-sequential -F		114.59	510.31	224.25	52.90		902.05
Topo-sequential +F		96.10	455.23	311.40	91.82		954.55
Mixed -F		84.09	382.66	233.80	27.76		728.31
Mixed +F		70.91	463.92	533.96	79.04		1147.83
Mean		100.19	468.48	406.36	121.75		1095.28
S. Em ±		17.61	118.95	57.61	28.17		146.19

4.2.8.5 Total magnesium

In contrast to the calcium loss, the amount of magnesium loss (Table 4.27) was highest in the third year (825.6 kg / ha) and lowest (31.57 kg / ha) in the first year. In July there was maximum loss (about 72 and 49 percentages of total losses in 1979 and 1981, respectively. In 1980 the maximum loss was in June. Grass cover was found to be the best in reducing the magnesium loss, followed by sole cropping of rice.

4.2.8.6 Exchangeable potassium

A critical study of data (Table 4.28) indicated that loss of exchangeable potassium in soil sediment was much lower, as compared to total potassium loss. The loss of exchangeable potassium was lowest (7.88 kg / ha) during first year but in subsequent years it increased to 36.54 and 45.17 kg / ha, respectively. More than 75 and 50 per cent of the total loss occurred in July during 1979, and 1981, respectively whereas in 1980 the loss more than 70 per cent of the total loss occurred in June. Among the various cropping systems tried grass cover resulted in maximum conservation of exchangeable potassium and this was followed by sole cropping of rice. Bare fallow registered maximum loss.

4.2.8.7 Exchangeable calcium

A perusal of data (Table 4.29) revealed that pattern of losses of exchangeable calcium was similar to total calcium. Loss was minimum during first year and very high during third year. The loss in July were more than 72 and 43 per cent of total loss in 1979 and 1981 whereas it was only 15 per cent in 1980. In 1980, maximum

Table 4.27 Monthly losses of total Mg in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		1.78	13.08	0.39			17.25
Bare fallow		4.48	26.21	5.89			36.58
Maize along		2.25	19.76	7.57			29.58
Maize across		1.76	12.60	5.46			19.82
Maize intercropped		1.68	42.44	3.53			47.65
Sole rice		2.59	17.25	5.15			24.99
Topo-sequential -F		1.86	15.07	12.85			29.78
Topo-sequential +F		4.95	18.73	3.30			26.98
Mixed -F		1.31	42.12	5.12			48.55
Mixed +F		3.98	21.15	9.43			34.56
Mean		2.66	22.84	6.07			31.57
S. Em ±		0.41	3.48	1.09			3.17
1980							
Grass cover	2.23	3.08	0.84	0.55	0.07	-	6.77
Bare fallow	4.40	42.67	13.57	7.47	11.18	0.87	73.16
Maize along	6.86	38.25	5.21	3.76	14.02	0.36	68.46
Maize across	4.06	37.02	8.39	2.74	4.89	0.43	57.53
Maize intercropped	9.24	33.10	6.03	11.48	1.33	0.22	61.40
Sole rice	4.58	19.78	5.53	2.30	3.23	-	35.42
Topo-sequential -F	2.98	25.25	8.65	4.82	1.14	0.23	43.07
Topo-sequential +F	6.27	36.22	6.34	0.67	2.17	0.02	51.69
Mixed -F	3.70	47.60	4.75	2.07	1.54	0.50	60.16
Mixed +F	4.22	45.19	4.44	0.95	1.53	1.16	57.49
Mean	4.85	32.82	6.38	3.68	3.41	0.38	51.52
S. Em ±	0.65	4.27	0.73	1.10	1.51	0.11	6.09
1981							
Grass cover		-	-	75.38	16.87		92.25
Bare fallow		63.73	465.61	409.00	173.02		1111.36
Maize along		69.45	538.68	377.08	161.58		1146.79
Maize across		37.08	575.48	356.00	156.80		1125.36
Maize intercropped		99.49	598.76	294.58	237.12		1229.95
Sole rice		24.29	390.30	269.13	92.62		776.34
Topo-sequential -F		67.20	436.86	199.22	70.16		773.44
Topo-sequential +F		57.01	345.34	219.06	83.60		705.01
Mixed -F		52.99	244.58	164.38	28.13		590.08
Mixed +F		41.76	326.36	294.97	42.34		705.43
Mean		51.30	402.20	265.88	106.22		825.60
S. Em ±		6.76	34.15	32.63	22.94		108.81

Table 4.28 Monthly losses of exchangeable K in kg / ha in different years as influenced by varied cropping systems

Treatments	Jun	Jul	Aug	Sep	Total
1979					
Grass cover	0.66	3.02	0.36		4.04
Bare fallow	2.75	10.18	0.92		13.85
Maize along	0.59	5.98	2.26		8.83
Maize across	0.40	3.12	1.26		4.78
Maize intercropped	0.29	10.35	0.62		11.26
Sole rice	-	4.20	0.88		5.08
Topo-sequential -F	0.87	4.31	1.87		7.05
Topo-sequential +F	1.67	5.55	0.68		7.90
Mixed -F	-	7.75	0.87		8.62
Mixed +F	-	5.42	1.94		7.36
Mean	0.72	5.99	1.17		7.88
S. Em ±	0.24	0.83	0.20		0.95
1980					
Grass cover	2.32	0.64	-	-	2.96
Bare fallow	50.00	12.85	1.92	1.29	66.06
Maize along	27.32	5.21	1.46	3.62	37.61
Maize across	21.26	6.52	1.01	1.40	30.19
Maize intercropped	35.31	3.89	15.92	-	55.12
Sole rice	19.18	3.71	2.11	2.29	27.29
Topo-sequential -F	12.12	8.23	0.08	0.41	20.84
Topo-sequential +F	20.93	6.76	1.70	0.78	30.17
Mixed -F	34.75	8.11	1.00	0.77	44.63
Mixed +F	39.40	8.97	0.85	11286	50.48
Mean	26.26	6.49	2.61	1.18	36.54
S. Em ±	4.43	1.07	1.47	0.30	6.98
1981					
Grass cover	-	1.24	3.59	0.34	5.17
Bare fallow	9.07	37.49	26.11	6.01	78.68
Maize along	9.90	42.80	18.06	2.70	73.46
Maize across	5.41	20.13	15.69	2.95	44.18
Maize intercropped	13.84	42.91	10.23	5.17	72.15
Sole rice	2.87	16.40	8.90	1.60	29.77
Topo-sequential -F	8.05	25.84	6.21	2.09	42.19
Topo-sequential +F	6.84	19.71	6.94	2.73	36.22
Mixed -F	4.22	20.74	6.47	1.04	32.47
Mixed +F	3.88	23.20	8.54	1.83	37.45
Mean	6.41	25.05	11.07	2.65	45.17
S. Em ±	1.06	4.09	2.24	0.56	7.30

Table 4.29 Monthly losses of exchangeable Ca in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Total
1979						
Grass cover		2.45	9.23	1.57		13.25
Bare fallow		5.28	20.16	4.57		30.01
Maize along		2.31	19.29	5.24		26.84
Maize across		1.71	7.39	3.87		12.97
Maize intercropped		1.15	24.29	2.03		27.47
Sole rice		-	8.99	2.46		11.45
Topo-sequential -F		3.72	10.33	6.78		20.83
Topo-sequential +F		8.79	13.89	3.34		26.02
Mixed -F		-	32.26	2.60		34.86
Mixed +F		-	16.63	6.45		23.08
Mean		2.54	16.25	3.89		22.68
S. Em ±		0.75	2.51	0.58		2.51
1980						
Grass cover	1.18	1.57	0.54	-	-	3.29
Bare fallow	2.50	23.79	8.95	3.71	3.54	42.49
Maize along	4.24	19.23	3.55	1.95	10.87	89.84
Maize across	2.12	18.18	5.28	1.43	3.62	30.63
Maize intercropped	5.23	20.18	4.19	8.35	-	37.95
Sole rice	2.34	11.03	3.67	1.60	2.75	21.31
Topo-sequential -F	1.24	13.53	6.22	0.38	1.18	22.55
Topo-sequential +F	4.43	18.61	4.90	4.04	2.24	34.22
Mixed -F	1.58	29.32	3.88	1.46	1.54	37.78
Mixed +F	2.56	25.65	3.73	0.76	1.85	34.55
Mean	2.74	18.10	4.49	2.37	2.76	30.47
S. Em ±	0.45	2.51	0.68	0.74	0.89	7.22
1981						
Grass cover		-	3.60	14.17	3.61	21.92
Bare fallow		25.66	102.99	71.31	38.33	238.29
Maize along		30.79	115.06	78.62	24.81	249.28
Maize across		13.52	81.11	73.85	23.94	192.42
Maize intercropped		38.99	123.42	69.25	45.86	277.52
Sole rice		10.58	92.62	63.99	16.18	183.37
Topo-sequential -F		24.88	61.96	33.49	18.93	139.26
Topo-sequential +F		21.39	77.74	47.02	21.77	167.92
Mixed -F		20.79	45.67	46.40	10.41	123.27
Mixed +F		15.29	55.09	58.73	18.93	148.04
Mean		20.69	75.93	55.73	22.28	177.13
S. Em ±		2.71	11.35	6.45	3.90	23.25

loss took place in June. The loss of exchangeable calcium was minimum under grass. Strip and mixed cropping was able to check the losses better than other systems of cropping.

4.2.8.8 Exchangeable magnesium

Exchangeable magnesium loss (Table 4.30) followed similar trend of variation to losses that of total Mg loss; it was lowest during first year and increased in subsequent years. Like all other nutrients, major quantity (75 and 43 per cent) was lost during July in 1979 and 1981. But this loss was only 16 per cent in July of 1980. The loss of exchangeable magnesium in 1980 was found to be maximum (55 per cent) in the month of June. The loss of exchangeable magnesium in soil sediment was very low under grass cover. The loss, however, from plot under maize crop grown across slope, was low when compared with maize along the slope. The losses were reduced almost by fifty per cent in strip cropping and mixed cropping, as compared to bare fallow.

4.2.8.9 Total zinc

The loss of zinc was found to be comparatively lower than the losses of iron and manganese. The extent of zinc loss was lower during first year but it increased considerably high in third year (Table 4.31). The proportionate loss was higher (65 and 47 %) during the July in 1979 and 1981 but in 1980 major portion of loss (56 %) was in June. In 1981 the loss started from June and extend upto September. Among the various conservation cropping systems the grass cover reduced the loss of total zinc considerably whereas in bare fallow treatment the loss increased by 2 to 8 times to that under grass cover. The loss under rice cropping was about 60 per cent

Table 4.30 Monthly losses of exchangeable Mg in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Total
1979						
Grass cover		0.09	0.66	0.12		0.57
Bare fallow		0.25	1.47	0.28		2.00
Maize along		0.15	1.26	0.54		1.95
Maize across		0.13	0.63	0.37		1.13
Maize intercropped		0.09	2.59	0.24		2.92
Sole rice		-	1.05	0.24		1.29
Topo-sequential -F		0.19	0.79	0.52		1.50
Topo-sequential +F		0.35	0.90	0.21		1.46
Mixed -F		-	2.42	0.20		2.62
Mixed +F		-	1.59	0.43		2.02
Mean		0.13	1.34	0.32		1.78
S. Em ±		0.03	0.22	0.05		0.22
1980						
Grass cover	0.17	0.18	0.07	-	-	0.42
Bare fallow	0.40	2.48	1.44	0.35	0.21	4.88
Maize along	0.92	1.92	0.47	0.22	0.98	4.51
Maize across	0.48	1.79	0.70	0.12	0.33	3.42
Maize intercropped	0.63	1.71	0.42	0.82	-	3.58
Sole rice	0.40	1.05	0.41	0.14	0.20	2.20
Topo-sequential -F	0.24	1.38	0.50	0.02	0.07	2.21
Topo-sequential +F	0.68	2.02	0.37	0.24	0.23	3.54
Mixed -F	0.39	2.28	0.41	0.08	0.10	3.26
Mixed +F	0.50	3.03	0.36	0.06	0.11	4.06
Mean	0.48	1.78	0.52	0.21	0.22	3.21
S. Em ±	0.07	0.25	0.11	0.07	0.08	0.42
1981						
Grass cover	-	0.	0.63	2.54	0.67	3.84
Bare fallow		5.98	18.07	13.39	7.84	45.28
Maize along		9.47	20.25	14.81	4.92	49.45
Maize across		4.35	19.09	11.69	5.32	40.45
Maize intercropped		11.90	23.14	11.89	13.10	60.03
Sole rice		3.20	17.46	10.10	3.44	34.20
Topo-sequential -F		7.11	13.86	6.35	3.06	30.38
Topo-sequential +F		8.04	13.68	8.09	3.99	33.80
Mixed -F		3.82	11.73	6.83	1.53	23.91
Mixed +F		3.77	12.18	8.77	2.29	27.01
Mean		5.76	15.01	9.45	4.62	34.83
S. Em ±		0.91	1.98	1.17	1.14	4.91

Table 4.31 Monthly losses of total Zn in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		0.17	1.03	0.25			1.45
Bare fallow		0.34	1.99	0.55			2.88
Maize along		0.11	1.60	0.66			2.37
Maize across		0.15	0.89	0.48			1.52
Maize intercropped		0.13	2.30	0.19			2.62
Sole rice		0.19	1.52	0.26			1.97
Topo-sequential -F		0.25	1.16	0.68			2.09
Topo-sequential +F		0.53	1.37	0.43			2.33
Mixed -F		0.14	2.59	0.43			3.16
Mixed +F		0.26	1.64	2.30			4.20
Mean		0.23	1.61	0.62			2.46
S. Em ±		0.04	0.17	0.19			0.26
1980							
Grass cover	0.16	0.26	0.10	0.05	0.01	-	0.58
Bare fallow	0.36	3.86	1.33	0.72	0.33	0.11	6.71
Maize along	0.48	2.70	0.66	0.48	2.03	0.04	6.39
Maize across	0.29	3.37	1.06	0.49	0.75	0.04	6.00
Maize intercropped	0.51	2.31	0.62	1.07	0.28	0.02	4.81
Sole rice	0.48	1.48	0.73	0.30	0.55	-	3.54
Topo-sequential -F	0.25	1.87	1.76	0.13	0.24	0.02	4.27
Topo-sequential +F	0.62	2.76	0.62	0.61	0.30	0.00	4.91
Mixed -F	0.38	5.05	0.74	0.24	0.24	0.04	6.69
Mixed +F	0.27	3.32	0.54	0.19	0.14	0.12	4.58
Mean	0.38	2.70	0.82	0.43	0.49	0.04	4.85
S. Em ±	0.04	0.42	0.15	0.10	0.18	0.01	0.59
1981							
Grass cover		-	0.96	3.87	1.03		5.86
Bare fallow		3.68	18.07	14.86	8.65		45.26
Maize along		5.43	18.96	10.77	5.78		40.94
Maize across		3.88	13.55	17.48	7.88		42.79
Maize intercropped		4.85	15.14	8.22	12.41		40.62
Sole rice		1.95	17.16	9.81	4.91		33.83
Topo-sequential -F		5.90	40.03	6.28	4.70		57.00
Topo-sequential +F		3.76	15.24	10.17	3.91		33.08
Mixed -F		4.17	27.84	13.92	2.54		48.47
Mixed +F		5.56	12.70	11.75	4.32		34.33
Mean		3.92	17.97	10.71	5.62		38.22
S. Em ±		0.39	3.23	1.28	1.04		4.28

of bare fallow. Maize cropping was found to be most inefficient in checking the loss of zinc.

4.2.8.10 Total copper

Copper loss (Table 4.32) was lowest (2.05 kg / ha) during the first year and it increased to as high as 18.56 kg / ha in the third year. The maximum loss of 1.43 and 10.0 kg / ha occurred in the month of July during 1979 and 1981 whereas in 1980 the maximum loss (2.50 kg / ha) was recorded in the month of June. Grass cover reduced the loss of copper appreciably in all the three years of cropping. Among arable cropping sole rice followed by topo-sequential and mixed cropping were found effective in controlling the soil during second and third year of cropping but in the first year arable cropping was not found effective in checking the copper loss.

4.2.8.11 Total manganese

Loss of manganese (Table 4.33) under grass cover was minimum. The loss was also minimum during first year which increased manifold during third year. During first and third year July rains enhanced manganese loss. But in second year rain in June caused more than 90 per cent of the total loss. As expected manganese loss under bare fallow was maximum. Cropping with maize caused high loss of manganese, almost similar to bare fallow. Strip cropping recorded comparatively lower amount of loss of manganese than other cropping systems.

4.2.8.12 Total iron

Critical analysis of data in table 4.34 show that the loss of iron increased by two and six fold during 1980 and 1981 as compared to the losses in 1979. It followed the pattern of soil loss similar to other nutrients.

Table 4.32 Monthly losses of total Cu in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		0.07	1.06	0.25			1.38
Bare fallow		0.19	1.17	0.35			1.71
Maize along		0.12	1.41	0.59			2.12
Maize across		0.06	0.91	0.49			1.46
Maize intercropped		0.07	2.59	0.19			2.85
Sole rice		0.10	1.36	0.40			1.86
Topo-sequential -F		0.20	1.12	0.87			2.19
Topo-sequential +F		0.20	1.23	0.31			1.74
Mixed -F		0.10	2.48	0.48			3.06
Mixed +F		0.11	0.94	1.05			2.10
Mean		0.12	1.43	0.50			2.05
S. Em ±		0.02	0.19	0.09			0.17
1980							
Grass cover	0.15	0.22	0.12	0.08	0.01	0	0.58
Bare fallow	0.33	3.88	1.93	1.11	0.31	0.04	7.60
Maize along	0.47	2.48	0.90	0.29	1.19	0.02	5.35
Maize across	0.21	4.32	1.16	0.26	0.45	0.03	6.43
Maize intercropped	0.62	2.31	0.62	0.98	0.15	0.01	4.69
Sole rice	0.28	1.54	0.78	0.12	0.36	0	3.08
Topo-sequential -F	0.19	2.30	1.14	0.03	0.13	0.01	3.80
Topo-sequential +F	0.31	2.30	0.61	0.27	0.19	0	3.68
Mixed -F	0.25	3.14	1.01	0.18	0.16	0.03	4.77
Mixed +F	0.18	2.47	0.47	0.07	0.16	0.04	3.39
Mean	0.30	2.50	0.87	0.34	0.31	0.08	4.34
S. Em ±	0.05	0.36	0.15	0.12	0.11	0.02	0.62
1981							
Grass cover		-	0.43	1.53	0.32		2.28
Bare fallow		2.35	10.84	5.62	2.85		21.66
Maize along		2.84	16.66	5.87	2.18		27.55
Maize across		1.98	10.97	6.65	2.37		21.97
Maize intercropped		3.30	17.36	3.62	5.00		29.28
Sole rice		1.01	8.65	4.38	1.72		15.76
Topo-sequential -F		3.41	8.32	3.77	1.63		17.13
Topo-sequential +F		2.93	9.27	4.09	2.19		18.48
Mixed -F		1.61	11.54	3.60	1.05		17.80
Mixed +F		2.01	6.03	4.58	1.09		13.71
Mean		2.14	10.00	4.37	2.04		18.56
S. Em ±		0.25	1.54	0.46	0.40		2.39

Table 4.33 Monthly losses of total Mn in kg / ha in different years as influence by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		0.29	2.49	0.39			3.16
Bare fallow		0.70	4.48	0.87			6.05
Maize along		0.32	3.54	1.26			5.12
Maize across		0.32	2.16	0.97			3.44
Maize intercropped		0.14	6.36	0.66			7.16
Sole rice		0.36	3.14	0.83			4.33
Topo-sequential -F		0.60	3.16	2.17			5.92
Topo-sequential +F		0.90	3.01	0.68			4.58
Mixed -F		0.18	7.55	0.93			8.66
Mixed +F		0.35	3.51	1.16			5.02
Mean		0.41	3.94	0.99			5.35
S. Em ±		0.08	0.55	0.15			0.53
1980							
Grass cover	0.38	0.58	0.16	0.05	0.01	-	1.18
Bare fallow	0.71	7.16	1.98	1.07	0.90	0.14	12.41
Maize along	0.75	6.73	0.91	0.68	2.48	0.05	11.60
Maize across	0.63	7.26	1.54	0.76	1.36	0.09	11.64
Maize intercropped	1.15	6.43	1.03	2.19	0.18	0.04	11.01
Sole rice	0.74	3.28	0.98	0.40	0.62	-	6.01
Topo-sequential -F	0.49	5.56	1.52	0.13	0.32	0.05	8.07
Topo-sequential +F	1.01	5.91	1.30	0.83	0.57	0.02	9.65
Mixed -F	0.55	8.65	0.87	0.42	0.33	0.12	10.94
Mixed +F	0.45	7.26	0.76	0.19	0.38	0.19	9.23
Mean	0.69	0.59	1.11	0.67	0.72	0.70	9.17
S. Em ±	0.08	0.74	0.16	0.20	0.23	0.02	1.08
1981							
Grass cover		-	1.50	6.50	1.41		9.41
Bare fallow		10.22	42.00	35.14	15.98		103.34
Maize along		12.92	42.34	30.48	9.20		94.94
Maize across		5.82	47.71	31.38	14.27		99.18
Maize intercropped		15.33	46.76	19.38	18.10		99.57
Sole rice		3.73	40.24	26.22	7.59		77.78
Topo-sequential -F		12.13	44.84	20.98	7.24		85.19
Topo-sequential +F		8.38	27.98	19.65	7.03		63.04
Mixed -F		8.33	33.95	18.88	3.26		64.42
Mixed +F		6.04	31.89	18.88	4.73		61.54
Mean		8.29	35.92	22.75	8.88		75.84
S. Em ±		1.16	4.35	2.62	1.75		8.96

Table 4.34 Monthly losses of total Fe in kg / ha in different years as influenced by varied cropping systems

Treatments	May	Jun	Jul	Aug	Sep	Oct	Total
1979							
Grass cover		27.6	201.1	41.2			269.9
Bare fallow		47.5	364.4	83.1			495.1
Maize along		24.8	279.1	126.9			430.9
Maize across		25.4	199.2	100.4			325.0
Maize intercropped		18.8	558.9	45.7			623.5
Sole rice		37.5	227.9	63.4			328.8
Topo-sequential -F		39.9	244.0	205.6			489.5
Topo-sequential +F		62.6	247.9	66.8			379.9
Mixed -F		14.8	612.0	102.4			729.2
Mixed +F		39.0	305.1	163.4			507.5
Mean		34.1	323.9	99.9			457.9
S. Em ±		4.56	46.45	16.68			45.02
1980							
Grass cover	37.3	58.4	10.4	8.4	1.3	-	115.9
Bare fallow	70.6	848.2	174.7	106.9	71.3	13.4	1285.2
Maize along	101.9	692.0	79.1	68.6	237.0	5.5	1184.2
Maize across	69.5	702.2	126.7	54.2	92.0	8.0	1052.7
Maize intercropped	108.1	586.4	94.1	199.5	16.8	3.6	1008.5
Sole rice	71.5	247.7	85.9	37.7	55.0	-	497.9
Topo-sequential -F	50.3	378.7	135.1	12.3	18.2	3.7	598.3
Topo-sequentiao +F	96.1	478.4	83.5	80.6	30.2	0.4	769.2
Mixed -F	59.9	742.6	79.5	35.6	25.5	8.1	951.2
Mixed +F	56.6	567.0	72.6	16.5	27.5	12.4	752.7
Mean	72.2	530.1	94.1	62.0	57.4	5.5	821.5
S. Em ±	7.34	77.07	13.87	18.28	21.77	1.32	111.14
1981							
Grass cover			211.2	820.1	160.1		1191.4
Bare fallow		983.8	4607.3	3882.5	1452.0		10925.6
Maize along		1098.0	5154.8	2848.5	1138.7		10235.0
Maize across		576.2	5343.5	3630.9	1402.4		10953.0
Maize intercropped		1398.7	4917.4	2945.8	2310.2		11572.1
Sole rice		401.8	3947.8	2549.8	887.8		7787.2
Topo-sequential -F		1087.3	4157.5	2009.8	849.1		8103.7
Topo-sequential +F		906.8	3358.3	2081.2	784.9		7131.2
Mixed -F		795.1	3394.6	1978.4	360.9		6529.0
Mixed +F		587.2	3015.5	2326.5	582.4		6511.6
Mean		783.5	3810.8	2507.4	992.4		8094.0
S. Em ±		97.31	472.83	279.74	196.40		980.32

As usual loss of iron was maximum under bare fallow. Intensity of vegetal cover restricted soil loss and this also reduced loss of iron.

4.2.9 Estimation of some parameters of universal soil loss equation

4.2.9.1 Rainfall erosivity factor 'R'

Monthly and yearly erosion index values of experimental site for the three years (1979 - 81) are presented in Table 4.35. The erosion index values (EI_{30}) were 1306.04, 902.71 and 803.62 t / ha / year in 1979, 1980 and 1981, respectively with 7 years average value of 1159.94. (Fig.6.)

On an average 98 per cent of erosion index values were concentrated over the period from April to October and 79 per cent during the seasonal rainfall period from June to September. The erosion index is maximum in July except in 1980 where it was maximum in the month of June.

4.2.9.2 Soil erodibility factor 'K'

The average soil erodibility factor based on three years data was worked out to be 5 kg / ha / unit of rainfall factor.

4.2.9.3 Crop management factor 'C'

The grass cover offered maximum protection (Table 4.37) with a very low value of 'C' (0.133). Intercropping of maize, followed by maize planted along the slope and across the slope gave lowest 'C' values and they were 1.056, 0.921 and 0.857, respectively.

Mixed cropping and sole cropping of rice followed by topo-sequential cropping were quite effective in reducing the soil loss with 'C' values ranging from 0.568 to 0.664.

Table 4.35 Monthly distribution of rainfall and erosion index values at Burnihat during 1979 - 81

Rain-fall	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979												
Rain-fall	0	28.4	0	171.7	120.7	198.4	433.8	184.9	106.4	165.3	24.9	7.6
EI_{1440}	0	0.3	0	5.7	2.0	3.8	24.3	5.6	3.8	6.9	0.3	0
EI_{30}	0	7.1	0	139.6	70.0	92.2	592.6	136.9	92.2	168.5	7.1	0
EI(%)	0	0.5	0	10.7	5.4	7.1	45.4	10.5	7.1	12.9	0.5	0
Cumulative (EI (%)	0	0.5	0.5	11.2	16.6	23.7	69.0	79.5	86.6	99.5	100.0	100.0
1980												
Rain-fall	0	18.8	55.6	82.3	277.1	450.1	252.0	192.8	191.5	80.0	0	0
EI_{1440}	0	0.1	0.6	0.9	5.8	17.5	6.4	3.9	3.5	1.1	0	0
EI_{30}	0	3.2	13.7	20.8	141.8	428.0	155.6	96.1	85.6	27.8	0	0
EI(%)	0	0	1.5	2.3	14.6	44.0	16.1	9.8	8.8	2.8	0	0
Cumu-lative EI(%)	0	0	1.5	3.8	18.4	62.4	78.5	88.3	97.1	99.9	0	0
1981												
Rain-fall	64.5	24.4	40.6	77.6	47.2	104.4	441.2	214.9	222.0	19.5	2.5	0
EI_{1440}	0.8	0.2	0	0.4	0.1	0.9	18.7	4.6	7.2	0	0	0
EI_{30}	18.6	3.9	0	10.3	1.2	21.5	458.6	112.9	176.6	0	0	0
EI(%)	2.3	0.5	0	1.3	0.2	2.7	57.0	14.0	22.0	0	0	0
Cumu-lative EI (%)	2.3	2.8	2.8	4.1	4.3	7.0	64.0	78.0	100.0			
Average for 3 years (1979-1981)												
Rain-fall	21.5	24.2	48.1	110.3	148.3	250.0	375.7	197.5	173.3	88.3	9.1	2.5
EI_{1440}	0.3	10.2	0.2	2.3	2.9	7.4	16.5	4.7	4.8	2.7	0.1	0
EI_{30}	6.1	4.7	4.7	57.0	71.0	180.6	402.4	115.3	118.1	64.5	2.5	0
EI(%)	0.6	0.5	0.5	5.5	6.9	17.5	39.1	11.2	11.4	6.3	0.2	0
Cumulative EI (%)	0.6	1.1	1.6	7.1	14.0	31.5	70.7	81.9	93.4	99.8	100.0	

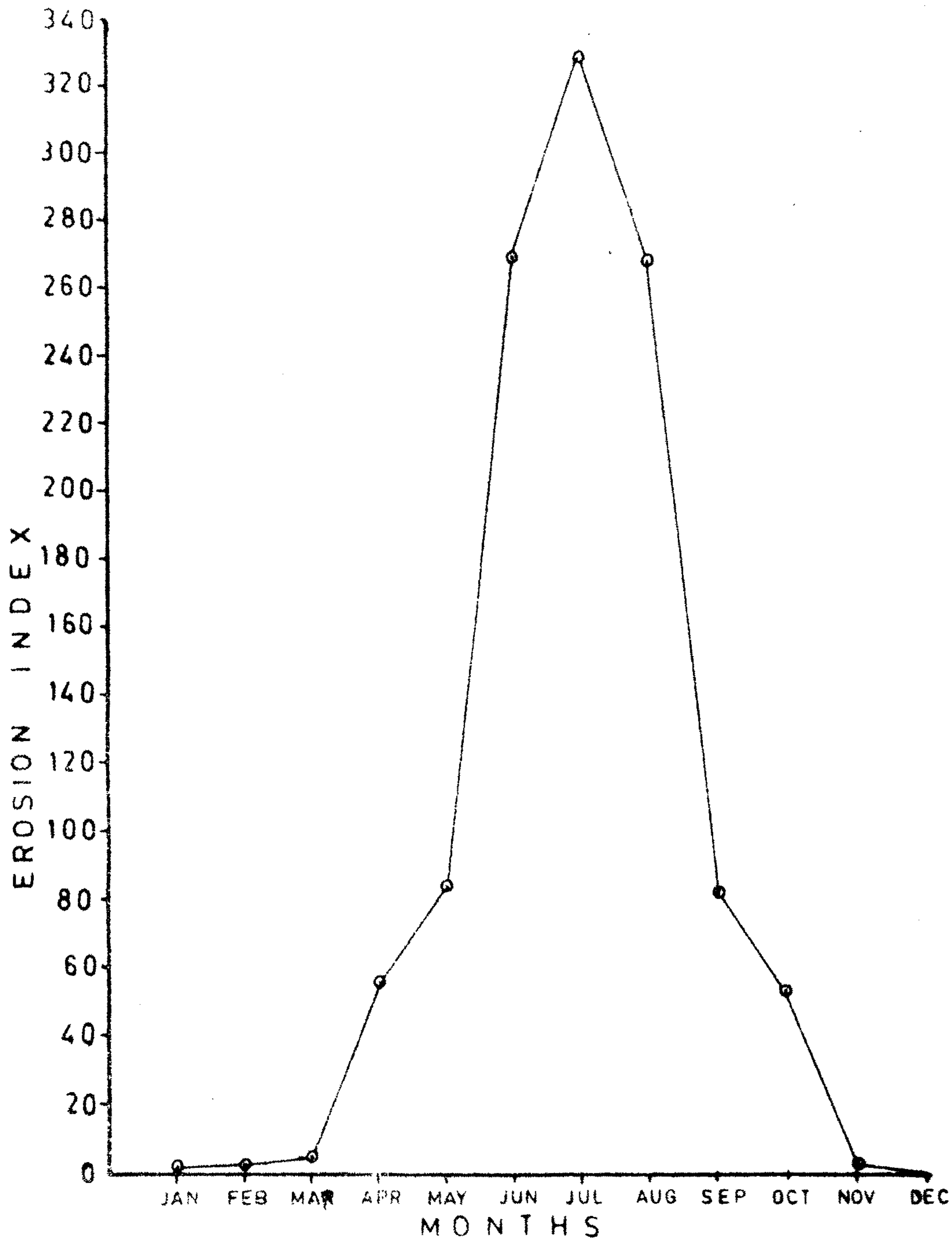


FIG.6. AVERAGE EROSION INDEX (1976-81) IN DIFFERENT MONTHS AT BURNIHAT, SHILLONG.

Table 4.36 Estimation of soil erodibility factor 'K' in different years

Year	Rainfall factor (R)	Observed soil loss (A^o) from bare fallow (kg/ha/year)	Slope gradient factor(s) for 65 % slope	Adjusted soil loss (A) (kg/ha/year)	Estimated 'K' (kg/ha/unit R)
1979	1306.20	17.8000	20	890.00	0.68
1980	972.60	28.040	20	1402.00	1.44
1981	803.60	205.610	20	10280.50	12.79
Mean	1027.46	83.817	20		5.00 kg or 0.005 t/ha

The soil loss under bare fallow at 9 per cent slope as per estimated rainfall and erodibility factor will be (A = R x K) i.e. 1004.12 x 0.005 = 5.02 tonnes / ha / year.

Table 4.37 Crop management factor 'C' for different systems of cropping

Particulars	Crop stage periods: From sowing to 23 days after sowing 8th May to 31st May	From 1st June to 30th June	From 1st July to 31st July	From 1st Aug. to 31st Aug.	From 1st Sept. onwards	Total
Av. 'R' for 3 yrs.	71.04	180.62	402.36	115.34	457.55	1226.91
R % of total R	5.79	14.72	32.79	9.40	37.30	100
Soil loss ratio (%)						
Grass cover	53.85	4.78	8.32	21.43	12.91	100
Bare fallow						
Maize along	132.69	79.53	96.15	85.77	81.48	
Maize across	82.69	71.61	98.60	91.12	79.18	
Maize intercropped	134.62	113.72	106.93	80.16	103.14	
Sole rice	96.15	44.98	80.31	70.99	51.23	
Topo-sequential cropping -F	59.62	84.93	86.09	56.76	45.28	
Topo-sequential cropping +F	117.31	84.77	66.89	58.81	49.62	
Mixed cropping -F	71.15	92.90	74.32	54.79	28.79	
Mixed cropping +F	71.15	72.73	63.69	59.61	41.63	
	$C \text{ value} = \frac{(R\ \% \times \text{Soil loss}\ \%)}{100 \times 100}$					
Grass cover	0.031	0.007	0.027	0.020	0.048	0.133
Bare fallow						
Maize along	0.077	0.144	0.315	0.081	0.304	0.921
Maize across	0.048	0.105	0.323	0.086	0.295	0.857
Maize intercropped	0.078	0.167	0.351	0.075	0.385	1.056
Sole rice	0.002	0.066	0.263	0.067	0.191	0.589
Topo-sequential cropping -F	0.035	0.125	0.282	0.053	0.169	0.664
Topo-sequential cropping +F	0.068	0.125	0.219	0.055	0.185	0.652
Mixed cropping -F	0.041	0.137	0.244	0.052	0.108	0.582
Mixed cropping +F	0.041	0.107	0.209	0.056	0.155	0.568

5. DISCUSSION

In northern region, comprising the States of Assam, Manipur, Meghalaya, Nagaland, Tripura, Arunachal Pradesh and Mizoram, about 2.7 million hectares of land are under 'Jhum' cultivation. 'Jhuming' or shifting cultivation consists of clearing a patch of forest on steep slopes after cutting and burning of the vegetation and allowing the felled material to dry up and burn. The patch so cleared on steep slope is worked out by manual labour, the seeds are mostly dibbled by dibbling sticks (or in other words go through the process of minimum tillage). In most cases more than one kind of seeds are sown in mixed cropping pattern. The crops are taken for 2 to 3 years on the patch and then the site is abandone, the cultivators shift to another new location. The cycle of this shifting has now come to 3 to 5 years in Meghalaya due to the increase in pressure of population. As has been reviewed earlier, no work on the water, soil and nutrient losses as influenced by different cropping systems, at such steep slopes has been conducted. The results of the present investigation simulating the practices followed by shifting cultivators, have provided good scope to discuss the results along with the informations already available on less slopy areas with relatively lower precipitation and to throw light on the problems and prospects of stable agriculture in this part of the country.

5.1 Cropping systems their productivity and sustenance in production

One of the important pre-requisites of any cropping system is that it should be economically viable and stable in production. The yield data given in Table 5.1 indicated a gradual fall in the

Table 5.1 Percentage decrease (-) or increase (+) in yield of different crops under different systems of cropping and management practices

Crops		Percentage decrease (-) or increase (+) over 1979	
		1980	1981
Maize	Across	- 14	-25
	Along	- 30	-37
	Intercropped	- 37	-37
	Topo-sequential -F	- 44	+12
	Topo-sequential +F	- 43	-17
	Mixed cropped -F	- 73	- 8
	Mixed cropped +F	- 88	-21
Rice	Sole cropped	- 25	-81
	Topo-sequential -F	- 8	-82
	Topo-sequential +F	- 18	-67
	Mixed cropped -F	+ 17	Failed
	Mixed cropped +F	+ 32	Failed
Fox tail millet	Topo-sequential -F	+ 13	-22
	Topo-sequential +F	+ 9	-33
	Mixed cropped -F	- 43	+38
	Mixed cropped +F	- 49	-30
Cassava	Topo-sequential -F	- 65	-51
	Topo-sequential +F	- 45	-54
	Mixed cropped -F	+ 34	-54
	Mixed cropped +F	+ 24	- 5

Table 5.2 Monetary values (Rs./ha) of production per hectare of land under different systems of cropping and management practices in steep slopes

Years	Maize along	Maize across	Maize inter-cro-pped	Sole rice	Strip Cropping		Mixed Cropping	
					-F	+F	-F	+F
1979	1989	1983	1599	833	2262	3198	3791	4899
1980	1256	1680	954	621	1453	1769	2571	3207
1981	1327	1125	1251	156	933	1084	1331	2256
Mean	1547	1586	1268	536	1549	2017	2564	3454

yield level of crops with the passage of time irrespective of the cropping systems tried although the magnitude of yield decline varied with different crops in different years.

The extent of yield decreases in maize in the second and third year were 30 and 37 % when planted along slope, 14 and 25 % when planted across the slope, 37 and 37 % when intercropped, and 43 and 17 % under topo-sequential cropping with fertilizer application, respectively. The yield decline in case of rice was not so high in second year but it was extremely high (67 to 82 per cent) in the third year and it failed even to produce any grain under mixed cropping system. In fox tail millet under topo-sequential system of cropping, there was an increase of 9 to 13 per cent in grain yield in second year but in third year, the yield decreased by 33 and 22 per cent with and without fertilizer application. In fox tail millet when grown under mixed cropping, the yield decline in second year was 43 per cent but it increased by 38 per cent in third year without fertilizer application. With fertilizer the yield decline was 49 and 30 per cent in second and third year, respectively. Cassava performed well under mixed cropping situation when the tuber yield rather increased by 24 and 11 per cent in second year with and without fertilizer but in the third year the yield decreased by 5 and 54 per cent. The decline in yield of crops with the passage of time is attributed to depletion of soil fertility and degradation of soil structure as a result of erosion losses of water, soil and nutrients as is clearly evident from the data given in the results section on erosion losses vide Table 4.18 to 4.34. Similar results have been reported by several research workers (Abuzeid 1973, Lal <u>et al</u>., 1975, Borthakur <u>et al</u>.,1979 and Mahapatra and Patnaik, 1982). Pendleton (1954) in a very sandy soil

Trinidad noted that it was rather impossible to raise a second crop due to depletion of soil fertility. Repley et al., (1961) reported that under unfertilized condition, artificial removal of 7.5 and 15 cm of top soil caused a decrease in the yield of barley by 21 and 58 per cent, respectively, averaged over a ten year period whereas under fertilized condition yield reductions were 19 and 46 per cent, respectively. The experiments conducted in North Carolina State University (1973 and 1974) revealed that there was correlation between yield decline of continuously grown upland rice in Tursi Maguas, Peru with decrease in the exchangeable potassium and increase in alluminium saturation. Sanchez (1976) also found high correlation between fertility depletion and yield decline from low base status Ultisols and Oxisols. Langdale et al., (1979) obtained corn yields of 2226, 4674 and 6429 kg / ha on severely eroded, moderately eroded and uneroded alluvial soil, respectively averaged over 3 years. Khybri et al., (1980) reported that on an average every centimeter of top soil removal there was 76 kg / ha reduction in the grain yield of corn. Frye et al., (1982) obtained 12 and 21 per cent lower corn yield under eroded condition as compared to eroded soil. They also reported higher clay content; higher bulk density, lower organic carbon content and lower water holding capacity in the surface layer of eroded soil.

Fertilizer application although resulted in higher yield of different crops to the extent of 10 to 40 per cent, yet the responses were much more in crops under mixed cropping (45 to 155 per cent). However, its application did not arrest the gradual fall of yield in such steep slopes and it appeared that cropping can not be prolonged for more than three years. The results are in conformity with the findings of Vieweg and Wilms (1974), who pointed out that after six years of cropping, yields fell to zero despite reasonable dressing of NPK on a light soils in the Kilombero valley of Tanzania. In a study on the role of fertilizer in the improvement of shifting cultivation Adetunji and Agboola (1973) concluded that with the use of fertilizers, higher yields have been obtained and maintained although not for an indefinite period. As such the scope of arable cropping after two to three years does not appear to be sound. Like wise sole cropping of rice should not be encouraged even after two years of cropping. Among the different systems tried when judged from economic point of view as well as meeting the food requirement and risk minimization point of view mixed cropping appeared to be more promising. Under fertilized condition mixed cropping was found to be superior to topo-sequential cropping thereby indicating better fertilizer use efficiency. Sole cropping of rice (Table 5.2) was least profitable (Rs.536 / ha).

5.2 Cropping systems and the changes in soil properties at different stages of shifting cultivation

The results indicated marked influence of different stages of cultivation and cropping systems on physical and chemical properties of soil (Table 4.15 and 4.16). The reduction in sand per cent from 70 to 55 in the run off plots after three years of cropping may be attributed to the transportation of soil particles, even of sand fraction from losely bound soil aggregates. This resulted in exposure of sub-surface soil which contained more of clay and silt particles than the surface 1 - 2 cm of the soil.

Burning and cropping although tended to decrease the bulk density of soil, the difference was not so well marked over the years. This was due to the fact that cropping period was too short to expect large differences.

Increase in organic carbon content from 1.25 to ~~1.38~~ 1.53 per cent after burning may be due to the inclusion of charcoal particles in organic carbon estimation. Moreover burning, in the process of shifting cultivation, may not destroy soil organic matter because soil temperature during burning does not remain high enough for sufficiently long time to cause complete combustion. Similar results were reported by Nye and Greenland (1964), and Seubert (1975).

Burning resulted in an increase of soil pH. Since soil reaction is dependent on base status of soil, as such increase in soil pH after burning may be attributed to increase in base status (Ca^{++}, Mg^{++} and K^{+}) of the soil. These findings corroborate with the results of Zinke <u>et al</u>., (1970), Awasthi <u>et al</u>., (1981) and Ellis et al., (1982). Decrease in pH after 3 years of cropping is due to the reduction in exchangeable Ca^{++}, Mg^{++} and K^{+} through their losses due to erosion. Further, due to increase in pH of soil and hence pH dependent charges, cation exchange capacity (CEC) of soil increased after burning. Similar results have also been reported by several workers (Sanchez, 1976; Zinke <u>et al</u>., 1970 and Ellis <u>et al</u>., 1982).

Burning resulted in considerable increase in the total content of P, K, Ca, Mg, Zn, Mn and Cu and exchangeable Ca, K and Mg. These changes were associated with increase in ash content after burning. However, iron content decreased slightly by 1.2 per cent. Most of these nutrients except ~~from~~ iron were found to decrease after three years of cropping and the decrease was appreciably high under bare fallow treatment. It was mainly due to their removal through erosion and uptake by the plants. However, most of the cropping systems resulted in small increases in organic carbon content which may be attributed to the addition of plants stubbles / residues, leaf fall and decomposition of roots etc.

5.2 Runoff and rainfall

Runoff, besides many other factors like slope, soil characteristics and management factor, is greatly influenced by rainfall characteristics viz.: amount, intensity and duration. In view of the limitations of the availability of data on rainfall intensity and their duration, attempt was made to analyse the rainfall data in terms of frequency intervals of different amounts of rainfall in six ranges i.e. 5 - 15 mm, 15 - 25 mm, 25 - 35 mm, 35 - 45 mm, 45 - 55 mm and greater than 55 mm to know their contribution in influencing runoff under bare fallow treatment. The results showed that in general the rainfall amount greater than 25 mm per day was more conducive in causing runoff and constituted the highest (67 to 73) percentage of total amount of erosive rainfall; rainfall amount below 25 mm per day constituted about 30 - 35 per cent of the total erosive rainfall (Table 4.17). The erosive rainfall was taken as the daily rainfall amount in 24 hours which caused runoff and soil loss. The rainfall amount as low as 5 mm per day caused erosion in such steep slopes. There were also few high intensity rains recorded, with daily amount exceeding 100 mm per day. The rainfall amount greater than 25 mm per day accounted for 64 to 79 per cent of total runoff and 67 to 78 per cent of total soil loss under bare fallow treatment, whereas the rainfall amount below 25 mm per day accounted for only 19 to 27 per cent of the total runoff and 6 to 28 per cent of total soil loss.

In order to find out the relationship between runoff and rainfall under different vegetal cover provided by varied cropping systems and management practices, regression analyses were carried out between daily as well as monthly runoff and rainfall amounts based on pooled data of three years. The data showed highly significant association between runoff, and rainfall amount (Fig. 7, 8 and 9). The rainfall amount accounted for 32 to 49 per cent variation in runoff. The threshold rainfall to initiate runoff was foun to be maximum under bare fallow plot (2.71 mm) as compared to the maximum threshold retension value of 5.6 mm under grass cover (Tabl 4.21). The regression co-efficient indicating the rainfall efficiency in causing runoff was maximum (0.20) in bare fallow plot and the lowest (0.05) in grass plot. Under grass cover the amounts of water lost as runoff were 57.6, 24.1 and 25.2 mm or 4.8, 1.7 and 2.4 per cent of the total rainfall as against the maximum runoff values of 95.2, 288.5 and 211.9 mm under bare fallow with corresponding runoff co-efficient values of 7.9, 20.7 and 20.2 per cent during the cropping seasons of 1979, 1980 and 1981, respectively. Among arabl croppings, sole cropping of rice followed by mixed and topo-sequential cropping with and without fertilizer application proved to be more effective systems in reducing runoff as judged from their lowe rainfall efficiency values which ranged from 0.12 to 0.16 with threshold retension values of 4.02 to 4.70 mm. The water lost as runoff under these systems ranged between 50.3 to 75.9 mm, 154.9 to 188.7 mm and 137 to 156.5 mm representing 4.2 to 6.3, 11.1 to 13.5 and 12.2 to 14.9 per cent of total rainfall during the croppin seasons of 1979, 1980 and 1981, respectively. These differential responses of cropping systems in influencing runoff are attributed to better rainfall interception and improvement in infiltration capacity of soil because of dense canopy and good tillering habit

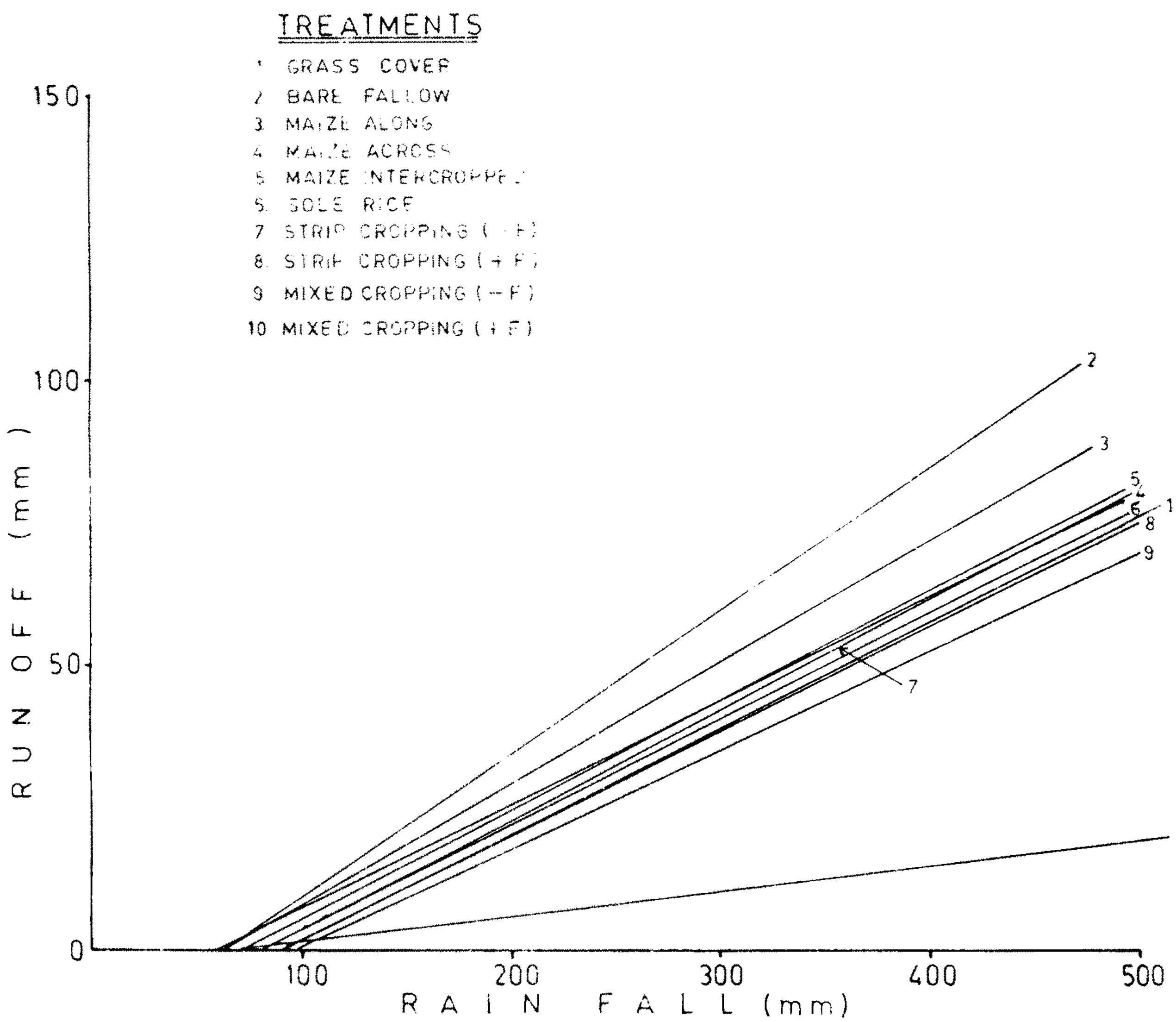


Fig.7 Estimated Relationship Between Monthly Rain Fall and Run-Off

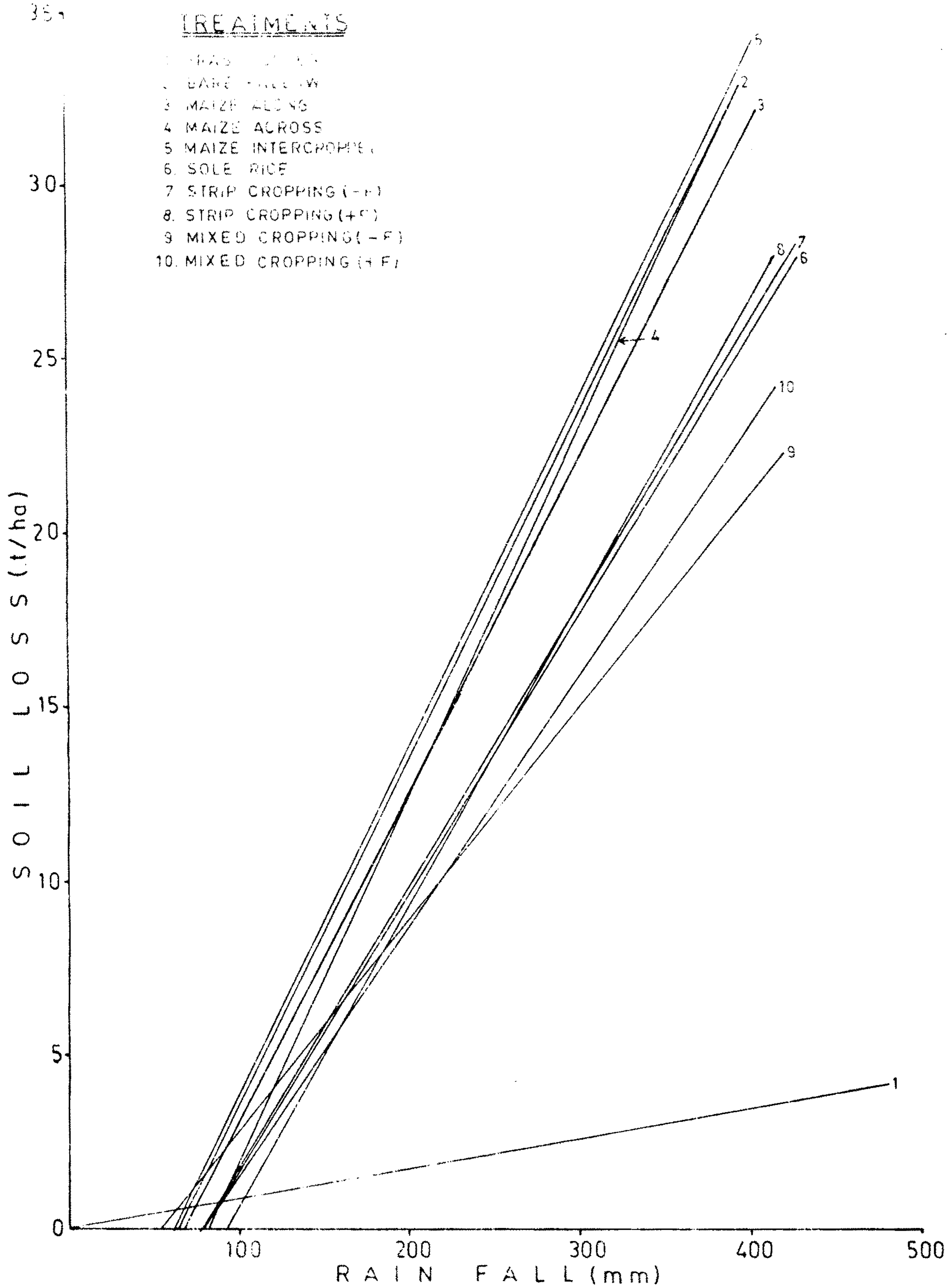


Fig.8. Estimated Relationship Between Monthly Rain Fall and Soil Loss

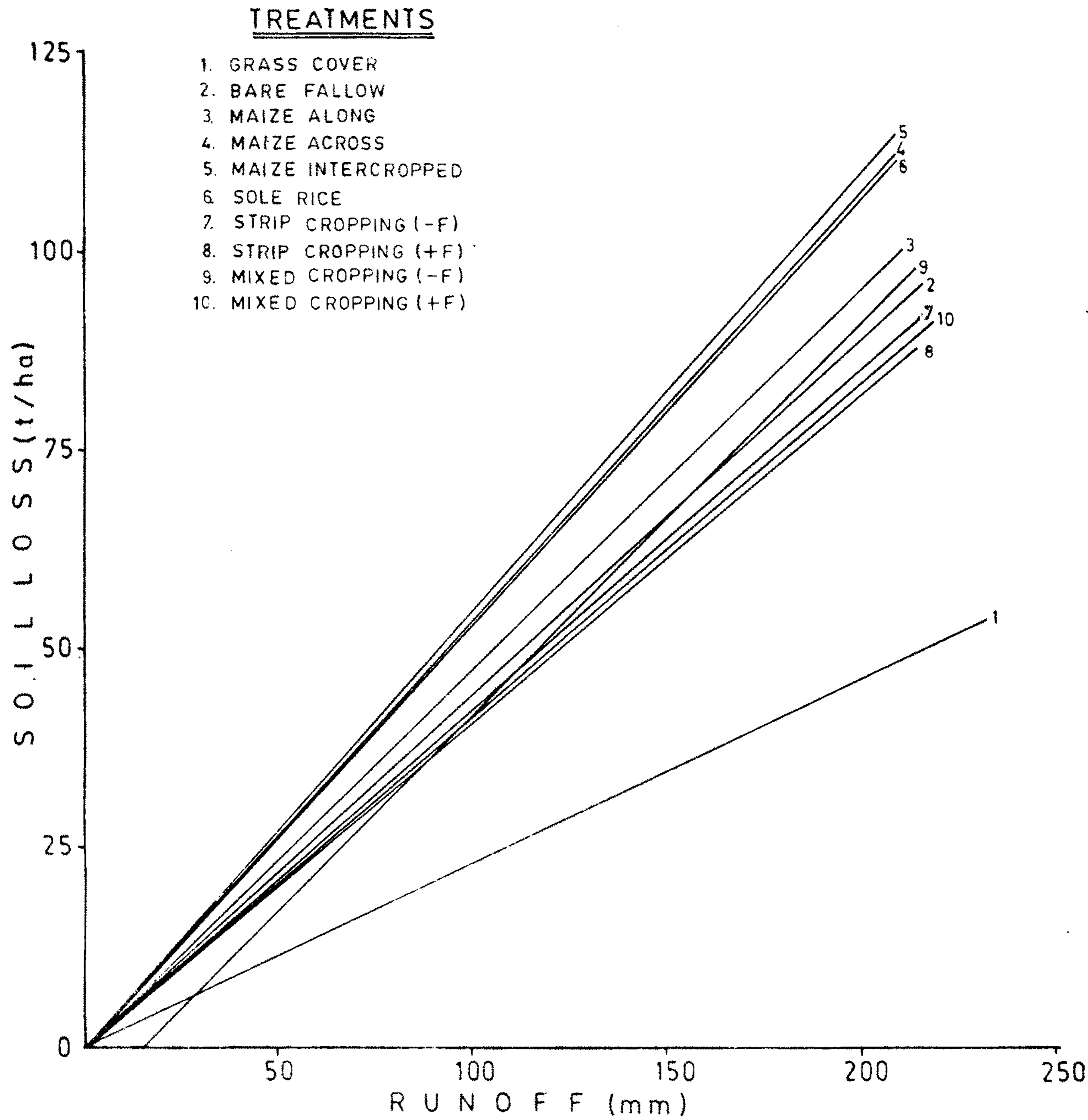


Fig.9 Estimated Relationship Between Monthly Run-off and Soil Loss.

of grasses and sole rice whereas in case of mixed and topo-sequential cropping it may be due to multistorey canopy structure which helped in providing better vegetal cover at different growth stages of crop thereby resulting in better interception of rain water. These results are in conformity with the findings of other research workers like Hudson (1957), Hudson and Jackson (1959) and Tejwani et al., (1975), Elwell and Stocking (1976).

An interesting thing to note here is that although the experiment reported in this work was carried out in a steep slope (65 %) yet the runoff is not as high as has been reported by several workers like Tejwani et al., (1975), Chakraborty (1976), Pratap Narain et al., (1978) whose experiments were carried out at very mild slopes of 3 to 8 per cent. This might be due to the fact that soil of experimental site at Burnihat was more porous and was cultivated with minimum tillage (only dibbling of seeds).

5.3 Relationship between soil loss and runoff

There was highly close and significant relationship between runoff and soil loss under different systems of cropping and management practices (Table 4.21). The daily runoff amount accounted for 27 to 48 per cent variation in soil loss under different treatments. Under each of the cropping systems there was general increase of soil loss with runoff. Striking differences were also observed in the rates at which soil loss increased with runoff (Fig. 4, 5 and 6). The runoff efficiency in initiating soil loss was lowest (0.20) under grass cover and highest (0.42) in bare fallow plot with threshold retention values of 0.25 and 0.03 mm, respectively. The soil loss recorded under bare fallow were 17.8, 28.1 and 205.6 t / ha as against a loss of 8.3, 2.6 and 20.4 t / ha under grass cover during the cropping seasons of 1979, 1980 and 1981, respectively. Amongst arable cropping systems there were not much differences in the values of runoff efficiency which ranged from 0.44 to 0.47 except in case of topo-sequential cropping with fertilizer application and that of maize across the slope which showed loer values of 0.30 and 0.40, respectively when compared with the value of 0.42 for bare fallow treatment and it was even more (0.51) in case of sole cropping of rice.

5.4 Relationship between soil loss, rainfall and runoff

There was highly significant positive relationship between soil loss and rainfall as well as runoff (Table 4.21). The rainfall accounted for 13 to 21 per cent variation in soil loss whereas runoff accounted for 27 to 48 per cent variation implying that runoff was better predictor of soil loss than rainfall for different systems of cropping and management practices. The runoff efficiency (as indicated by regression co-efficient value) in initiating soil loss was lowest (0.195) under grass cover with threshold retention value of 0.25 mm and highest (0.42) in bare fallow plot with threshold retention value of 0.03 mm. Lower rainfall efficiency and higher threshold retention value in case of grass cover indicated better retension and water infiltration capacity of grass cover and thereby it resulted in very low amount of soil loss (2.58 to 20.35 t / ha). In case of bare fallow plot, very high value of runoff efficiency and very low value of threshold retention indicated that almost all the runoff values resulted in soil loss and; maximum soil loss (17.8 to 205.6 t / ha) was recorded in bare fallow plots in all the three years of experimentation. Among arable cropping systems, rate of increase in soil loss for each mm of runoff was found to be minimum under topo-sequential system of cropping without fertilizer application. This is reflected by low runoff efficiency value of 0.30 followed by maize along the slope (0.41) as compared to higher runoff efficiency of other cropping systems which ranged from 0.44 to 0.48 thereby indicating not much differences amongst themselves. Interestingly runoff efficiency in initiating soil loss was low (0.42) for bare fallow plot as compared with sole cropping of rice (0.51). The reasons for this discrepancy is not clear. Langbein and Schuman (1958) and Douglas (1967) have, however, indicated that sediment yield increases with effective rainfall upto a point where improved vegetative ground cover leads to less erosion.

5.5 Cropping systems and nutrient losses

The results of the experiment showed profound influence of cropping systems in reducing nutrient losses.

Organic carbon : The total loss of organic carbon was found to be maximum under bare fallow plot (247, 496 and 2611 kg / ha) and the least under grass cover (118, 45 and 244 kg / ha) during the three successive seasons of cropping (Table 4.23). Grass cover reduced the loss of organic carbon by 52, 91 and 91 per cent in 1st, 2nd and 3rd year of cropping and thus resulted in a saving of 147, 45 and 2367 kg / ha of organic carbon in respective years. The enrichment ratios for organic carbon under bare fallow treatment were 1.47, 1.36 and 1.09 as compared to enrichment ratios of 1.20, 1.23 and 0.93 under grass cover during the three cropping seasons, respectively (Table 4.22). Amongst arable cropping sole cropping of rice followed by topo-sequential and mixed cropping system were found to be very effective in reducing the loss of organic carbon by 40 to 50 per cent.

Considering the steepness of slope (65 %) the loss of organic carbon in the first two years of cropping is not so much as compared to the loss recorded in the third year, which is extremely high. The value of enrichment ratio indicated that percent composition of organic carbon in runoff sediment was much higher in the first year but in subsequent years it was reduced. This is attributed due to the high content of organic carbon initially in the soil. Knoblaugh et al., (1942) reported an annual loss of 1287 kg / ha of organic matter from fallow plot as against a loss of 377 kg / ha under cover crop applied with manure. Bhatt et al., (1971) obtained a loss of 2168 kg / ha of organic carbon under cultivated fallow condition. Debyle and Packer (1972) reported a loss of 387 kg / ha of organic matter. Neal (1944) reported as high as 4.0 to 4.7 enrichment ratio for organic matter. Massey et al., (1953) reported an enrichment ratio of 1.34 for organic carbon. Goel and Khanna (1969) in Uttar Pradesh reported a loss of 246 kg / ha of organic carbon under cultivated fallow on plots with 8.5 per cent slope. Borthakur et al., (1978) reported a loss of 85 and 1321 kg / ha of organic carbon from the first and second year of Jhum cultivation, respectively.

Total phosphorus : The losses of total phosphorus under bare fallow plot were 8.2, 8.1 and 25.9 kg / ha with enrichment ratios of 3.65, 2.41 and 0.95 as compared to a total loss of 3.1, 0.75 and 2.31 kg / ha under grass cover in three successive years (Table 4.24). With regard to the effect of various cropping systems on the loss of phosphorus trend of variation was observed to be similar to those recorded in case of organic carbon. The magnitude of loss of total phosphorus was much less as compared to other nutrients primarily because it is one of the least mobile nutrients and secondly this might be due to the fact that on account of high content of iron and aluminium in the soil it gets fixed up and therefore becomes less vulnerable to losses due to erosion. Similar result has been reported by Gupta and Singh (1967). Lal (1976) reported that loss of phosphorus in tropical region may be as low as 0 to 2 kg / ha per season. Borthakur et al., (1978) reported a loss of 80 and 211 kg P_2O_5 / ha from first and second year of Jhum cultivation, respectively. Jayaram et al., (1982) obtained enrichment ratios of 2.09 and 2.43 for total phosphorus in clay soil planted to sorghum and safflower, respectively.

Total Calcium, potassium and magnesium : The losses of total potassium under bare fallow were 52, 189 and 1227 kg / ha with corresponding enrichment ratios of 1.61, 2.45 and 2.24 as compared to losses of 24, 17 and 114 kg / ha under grasses with enrichment ratios of 1.31, 1.92 and 1.85 during the cropping seasons of 1979, 1980 and 1981, respectively (Table 4.25 to 4.27). With regard to other cropping systems similar trend of variations was observed as has been earlier discussed in case of organic carbon. The losses of total calcium under these systems ranged between 32.6 and 72.9 kg / ha in the first year to as high as 856 and 1688 kg / ha in third year of cropping. Knoblangh et al., (1942) reported losses of total potassium as high as 477 kg / ha from fallow plot which was reduced to 110 kg / ha under a manured crop cover. Hays et al., (1948) reported losses of 957 kg / ha of total potassium when soil was put to oats and only 29 kg / ha from plots planted with corn. It is interesting to note that enrichment ratio of total potassium was lower in the first year but in subsequent years it was relatively high. It may be attributed to less runoff in first year and high runoff in subsequent years as observed by

Turvey (1973) in a study on water quality from a forested catchment area in Papua New Guinea.

The losses of total calcium were 157, 171 and 161 kg / ha with corresponding enrichment ratios of 6.21, 2.87 and 3.60 in bare fallow plots as against losses of 51.4, 11.2 and 164.1 kg / ha with enrichment ratios of 3.63, 2.33 and 3.13 in grassed plots in 1979, 1980 and 1981, respectively. With respect to other cropping systems the losses ranged from 63 to 168 kg / ha in the first year, and 728 to 1765 kg / ha in the third year of cropping.

The losses of total magnesium under bare fallow were 36.6, 73.2 and 1111.4 kg / ha with corresponding enrichment ratios of 0.78, 0.69 and 1.34 in three successive years as compared to the losses of 17, 7 and 92 kg / ha with enrichment ratios of 0.69, 0.64 and 1.40 under grass cover; under other cropping systems losses ranged between 20 and 49 in the first year and between 590 and 123 kg / ha in the third year of cropping.

Suarez de Castro and Rodrigues (1955, 1958) reported losses of as high 238 and 152 kg / ha of total calcium and magnesium, respectively from bare soil at 22 per cent slope. Goel and Khanna (1969) reported a loss of 119 kg / ha of CaO and 82 kg / ha of MgO from uncultivated fallow.

Exchangeable calcium, magnesium and potassium : The losses of exchangeable calcium, magnesium and potassium ranged between 30 to 24 kg / ha, 2 to 45 Kg/ha and 14 to 79 Kg/ha. respectively under bare fallow plot as against losses of 13 to 22 kg / ha, 0.6 to 4.0 kg / ha and 4 to 5 kg / ha in three successive years under grass coveer, respectively (Table 4.28 to 4.30). The enrichment ratios for potassium were 4.84, 10.30 and

1.36 in three successive years, under bare fallow plot as against 2.74, 6.01 and 0.81 under grass cover. The values of enrichment ratio for exchangeable magnesium were 0.94, 1.11 and 1.39 in three successive years in bare fallow as against the values of 0.74, 0.99 and 0.89 under grass cover. The enrichment ratios for exchangeable calcium were 4.19, 2.43, and 1.75 under bare fallow plot as against 3.92, 2.07 and 1.64 under grass cover during the three seasons of cropping of 1979, 1980 and 1981, respectively. Jayaram et al., (1982) reported enrichment ratios of 2.24, 2.69 and 2.15 for exchangeable potassium, calcium and magnesium from the area planted to sorghum whereas from areas planted to safflower, the ratios obtained for these nutrients were 2.38, 2.99 and 2.34, respectively.

Losses of micro-nutrients : The loss of total zinc ranged from 3 to 45 kg / ha, total copper 2 to 22 kg / ha, total manganese 6 to 12 kg / ha, total iron 495 to 1093 kg / ha under bare fallow plot. These losses were reduced to 2 to 6 kg / ha for total zinc, 1.4 to 2.3 kg / ha for total copper, 3 to 12 kg / ha for total manganese and 270 to 1093 kg / ha for total iron under grass cover (Table 4.31 to 4.34).

The results further showed significant positive correlation between water losses through runoff and organic carbon, total potassium, total and exchangeable magnesium, total manganese and total iron in the sediment but the relationshipe between soil loss and the concentration of nutrients was not close and significant except in case of total magnesium and total iron. Bedell et al., (1946) found that the amount of nitrogen lost in runoff was more closely related to total runoff than with total soil loss. Martin (1941) observed that loss of organic matter depended upon soil loss, but percentage of humus in the eroded material decreased as the erosion increased. Thomas <u>et al</u>., (1969) found that losses of available phosphorus, potassium and calcium in runoff were about 0.03, 0.13 and 1.5 times the soil loss, respectively, in tonnes / acre / month. Massey <u>et al</u>., (1953) and Stoltenberg and White (1953) demonstrated an inverse relationship between rate of erosion and concentration of nutrients lost.

Generalising the tremendous losses of nutrients from third year and the over all view of nutrient losses through runoff and soil losses it can be inferred that from third year onward it would be most desirable to include grass cover and legume mixture to effectively arrest the erosion losses because arable cropping was not found to be so effective in checking the erosion losses.

5.6 Universal soil loss parameters

<u>Rainfall erosivity factor (EI_{30})</u> : Average erosion index value based on seven years rainfall data suggests June, July and August are the most erosive months. July appears to be more erosive than all other months except in 1980 when June was the most erosive month because of high rainfall receipt in June. Further, erosion index value from worked out from three years data for the experimental site was 1160. The erosion index values reported by Raghunath <u>et al</u>., (1982) for Shillong and Gauhati were 1041 and 704, respectively. Thus, these findings confirm that the experimental area had more erosion hazards and risk because of heavy and more agressive rainfall concentrated mainly during monsoon months.

<u>Soil erodibility factor 'K'</u> : The soil erodibility factor 'K' reported by Tejwani <u>et al</u>., (1975) and other workers were as

high as 300. The results emanating from this experiment are at variance with the earlier workers. In the current experiment, the erodibility factor was only 5 kg / ha / erosion index on the basis of standard slope of 9 % and 22.13 m. The apparent variation may be due to high infiltration rate of soils. Secondly unlike other areas here the values have been calculated from bare soil, resembling zero tillage as is prevalent in shifting cultivation practice. Thirdly the value is estimated on the basis of only 3 years data but the 'K' value determination needs at least five years data (Roose 1978). These may be the possible reasons for its underestimation. However, from this it can be inferred that rainfall erosivity factor is more severe in causing erosion losses than the soil erodibility factor in the experimental site area. Roose (1975) on the basis of 17 years of experimentation with runoff plots in Ivory Coast has demonstrated that ferrallitic soil are resistant to erosion (K = 0.10) but rainfall is particularly severe (R = 500 to 1400). Therefore he emphasised the importance of covering the soil during critical rainy periods.

5.7 <u>Crop management factor 'C'</u> : The results showed that grass cover gave maximum protection with a very low value of 'C' (0.133). For mixed, sole cropping of rice and topo-sequential cropping the 'C' values ranged from 0.568 to 0.644. For widely spaced crop of maize the C value ranged from 0.857 to 1.0 under different management practices. Similar results have been reported by Pratap Narain <u>et al</u>., (1982).

5.8 Future scope of further worker

The present investigation was based on only one replication in view of the cost involved in constructing the big runoff plots on difficult terrain. To be more meaningful, various systems of cropping and management practices should be tried on watershed approach basis with adequate number of replications.

Since early rainfall is more aggressive to initiate erosion it will be desirable to provide effective cover before the aggressive rain starts. This can be achieved by trying some spreading types of legumes, or combination of legumes and grasses or through live mulch or by leaving the residue of the preceding crop. In future work, such soil restorative treatments may be included.

Arable cropping alone, although provided some protection against erosion losses, was not so effective as grass cover. There appears to be a great need to integrate crop with grass, legumes, horticultural crops, trees or combinations of all the three. These studies may be conducted to evaluate the performance of crops under Agro-forestry, Agro-horticultural or Agro-hortipastural systems on runoff, soil and nutrients losses as well as for sustained productivity.

Agronomic management practices, with particular reference to those mentioned above, will involve studies on compatibility of different crops, its proper plant density and arrangement, adjustment in sowing time, proper crop combination and their ratios.

Soil management system should involve treatments on the maintenance of organic matter, which is drastically reduced causing great damage to soil health, in the system.

Considering the steepness of the slope, it may be desirable to integrate cheap mechanical measures like contour bunding along with different types of restorative farmings.

6. SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

Considering the magnitude of the problems of shifting agriculture on resource degradation in North-Eastern Hill Region of India, and lack of basic data on quantitative and qualitative aspect of erosion losses under the exhisting system, runoff plot studies were conducted at the I.C.A.R. Research Complex Experimental Farm at Burnihat (26°N, 91.5°E; slope 65 %; 100 m altitude) Shillong, Meghalaya (India) under sandy loam soil with a pH of ~~6.5~~ 5.8 for three consecutive years from 1979 to 1981 to evaluate the performance of ten cropping systems (grass cover, bare fallow, maize along the slope, maize across the slope, intercropped maize, sole rice, topo-sequential and mixed cropping with and without fertilizer application, crops established under minimal cultivation method (slashing, burning and dibbling) and management practices) on production potential, runoff, soil and nutrient losses as well as to estimate some of the parameters of soil loss equation with the ultimate objective of developing better technology for improvement and conservation of physical environment of crops for sustained production, land utilisation and maintenance of soil health. Based on the results of three years data, the following summary and conclusion can be made.

1. An analysis of rainfall distribution revealed that rainfall was more severe and agressive (EI_{30} = 1160) than erodibility of soil (K = 0.005) based on almost zero tillage as adopted under the system. The estimated threshold retension value of rainfall to initiate runoff was 2.65 mm per day. The rainfall amount greater than 25 mm per day constituted 67 to 73 % of the total erosive rainfall and caused maximum runoff and soil loss.

2. Burning of soil caused substantial increase in almost all the major and micro-nutrients but these nutrients tended to decrease after three successive years of cropping. As a result of burning cation exchange capacity increased by 27 per cent but again decreased by 17 per cent after three years of cropping. Total phosphorus, potash, calcium and magnesium increased by 24, 14, 52 and 9 per cent, respectively due to burning. Among the exchangeable cations there was maximum increase (185 %) in magnesium followed by increases of 88 and 40 % in potassium and calcium, respectively.

3. Under uncultivated bare fallow there was maximum water runoff to the extents of 95.2, 288.5 and 211.9 mm with corresponding runoff co-efficient values of 7.9, 20.0 and 20.2 per cent during the cropping seasons of 1979, 1980 and 1981, respectively. The grass cover recorded minimum runoff to the extents of 57.6 (4.8 %), 24.1 (1.7 %), 25.2 (2.4 %) mm. Under arable cropping systems the values were within these extremes. Among arable croppings, sole cropping of rice followed by mixed and topo-sequential cropping with and without fertilizer application proved to be more effective systems in reducing runoff, as judged from their lower rainfall efficiency values which ranged from 0.12 to 0.16 with threshold retension values of 4.02 to 4.70 mm.

4. The maximum soil loss occurred under bare fallow (17.8, 28.0 and 205.6 t / ha) and the minimum under grass cover (8.3, 2.6 and 20.4 t / ha) in the respective seasons of cropping. Among arable croppings, sole cropping of rice followed by mixed and topo-sequential cropping proved more effective in reducing runoff and soil losses.

5. The maximum loss of nutrients occurred under bare fallow and minimum under grass cover. The losses of nutrients under bare fallow ranged between 247 and 2611 kg / ha of organic carbon, between 8 and 26 kg / ha of total phosphorus, between 52 and 1227 kg / ha of total potassium, between 157 and 1619 kg / ha of total calcium, between 37 and 1111 kg / ha of magnesium, between 30 and 238 kg / ha of ex-calcium, between 2 to 45 kg / ha of ex-magnesium, between 3 and 45 kg / ha of total zinc, between 2 and 22 kg / ha of copper, between 6 and 103 kg / ha of manganese, between 495 and 10925 kg / ha of iron. The enrichment ratios for these nutrients ranged between 1.09 to 1.47 for organic carbon, 0.95 to 3.65 for total phosphorus, 1.61 to 2.45 for total potassium, 2.87 to 6.21 for total calcium, 0.69 to 1.34 for total magnesium, 1.36 to 10.29 for exchangeable potassium, 1.75 to 4.19 for exchangeable calcium, 0.94 to 1.39 for exchangeable magnesium, 3.04 to 3.36 for total zinc, 4.61 to 11.53 for total copper, 0.98 to 1.04 for total manganese and 0.98 to 1.30 for total iron. Amongst arable cropping systems, sole cropping of rice followed by topo-sequential cropping system were found to be efficient in reducing the loss of nutrients; loss of organic carbon was reduced to 40 - 50 % due to arable cropping as compared to bare fallow.

6. The cropping management factor 'C' was minimum under grass cover (0.133) followed by mixed and topo-sequential cropping with and without fertilizer application and ranged between 0.568 to 0.664.

7. Mixed cropping resulted in maximum biomass production of 37.7 and 27.2 q / ha with and without fertilizer applications followed by an average production of 32.5 and 22.2 q / ha with and without fertilizer application in case of topo-sequential

croppings as against the average production 12.9 q / ha in case of sole rice.

8. The productivity of crops showed gradual fall with passage of time, irrespective of the differences in cropping systems and fertilizer management. The yield decline in maize in second and third years of cropping were 30 and 37 % when planted along the slope, 40 and 37 % when intercropped and 55 and 16 % under topo-sequential cropping with fertiliser application, respectively. The yield decline in case of rice was no so high in second year but it was extremely high (67 to 82 %) in the third year and it failed even to produce any grain under mixed cropping system. In fox tail millet the yield decline in the second and third year were 46 and 26 % when grown under mixed cropping, respectively. Cassava performed well under mixed cropping situation where the tuber yields increased by 11 and 24 % in second year with and without fertiliser but in the third year yield decreased by 5 and 54 % (with and without fertiliser applications).

9. Through fertilizer applications only, the fall in yields with passage of time could not be arrested, under such steep slopes.

10. In terms of monetary value of the total produce mixed cropping was found to be slightly superior to topo-sequential cropping under both fertilized and unfertilized condition.

It was, thus, concluded that at 65 % steep slope arable cropping for three successive years, under minimal cultivation (slashing, burning and dibbling mixed crops), accelerated soil and nutrient losses resulting in fast deterioration in productivity. The reduction in crop yield was less under mixed culture. Reductions in the productivity of different crops in descending order were cassava, maize, fox tail millet and rice.) Further works need to be done on developing better conservation farming methods like alternate husbandry, agro-forestry or silvi-pastoral systems to exploit the available natural resources to the maximum.

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